Chancellor’s Welcome

Welcome to the Air Force Institute of Technology -- AFIT. Whether you are a U.S. or international military member, a government employee or a non-federal civilian, AFIT’s Graduate School of Engineering and Management offers you a wide range of exciting education and cutting-edge research opportunities.

AFIT develops world-class technologists, game-changing technologies, and defense leaders who are capable of using these technologies in support of national security, now and in the future. We are able to accomplish this because of our strong partnerships with other DOD agencies, federal departments, Defense Industry companies and many other research universities.

Regardless of the academic program you choose, your AFIT graduate-school experience will prepare you to think more critically, logically, systematically and objectively, as you tackle some of our most demanding and important national-security challenges and opportunities. You will have the opportunity to learn – by doing – the value of inspiration, innovation, teamwork, effective communication and, yes, hard work!

For almost 100 years – since 1919, AFIT has educated the air, space and cyberspace Airmen who have led the Air Force. Among our distinguished alumni are numerous Air Force pioneers, including Generals Kenney, Doolittle, Fairchild, Bradley, Chidlaw, and Schriever and former Secretary of the Air Force Wynne. Fifteen astronauts are alumni of AFIT’s Graduate School of Engineering and Management including Gus Grissom and Gordon Cooper – members of the Mercury Seven; and Guy Bluford – the first African American in space. It is very likely that some students starting their academic program this fall could join these ranks of distinguished alumni.

Students enrolled in the Graduate School of Engineering and Management soon realize AFIT provides rigorous, respected, and relevant graduate-education, research, and consultation opportunities, to push the frontiers of air, space, and cyberspace power. However, this is just part of AFIT’s mission. Through our School of Systems and Logistics, the Civil Engineer School, and the School of Strategic Force Studies, AFIT also provides world-class professional continuing education for the civil engineer, acquisition, logistics, cyber, nuclear and space communities. In fact, most of our graduate-school alumni have also taken courses from these schools, to continue their professional development; many more will take additional courses in the future.

My goal is to develop in all of our graduates a passion for lifelong learning and for AFIT to be an important partner in that continuing, professional-development journey.

Again, welcome to the AFIT team. We look forward to working with you, as you prepare to help create the Air Force of the future.

TODD I. STEWART, Ph.D., Major General (Ret.), USAF
Director and Chancellor
Graduate School Leadership

Todd I. Stewart, PhD, Major General (Ret.), USAF
Director and Chancellor

Vacant
Deputy Director & Vice Chancellor (Provost)

Colonel Paul Cotellesso, PhD
AU DET 1 Commander/Director of Staff

Adedeji B. Badiru, PhD
Dean, Graduate School of Engineering and Management
Professor of Systems Engineering

Colonel James R. Fee, PhD
Associate Dean, Graduate School of Engineering and Management

Colonel John M. McQuade, PhD
Dean of Students

Heidi R. Ries, PhD
Dean for Research
Professor of Physics

Paul J. Wolf, PhD
Associate Dean for Academic Affairs

Alice E. Grimes, PhD
Director of Faculty Development
Catalog Statement of Understanding

The Graduate Catalog represents the offerings, programs, and requirements in effect at the time of publication, but there is no guarantee that they will not be changed or revoked. The course offerings and requirements of the institution are continually under examination and revision. However, adequate and reasonable notice will be given to students affected by any change. This catalog is not intended to state contractual terms and should not be regarded as a contract between the student and the institution. The institution reserves the right to change any provision, offering, or requirement to be effective when determined by the institution. These changes will govern current and readmitted students. Enrollment of all students is subject to these conditions.

Graduate students must assume full responsibility for knowledge of rules and regulations of the Graduate School of Engineering and Management and the departmental requirements for their chosen degree program. Any exceptions to Graduate School policy stated in this catalog must be approved by the Dean of the Graduate School of Engineering and Management. Individual departments may have requirements beyond the minimum established by the Graduate School. Students are referred to the academic departments for the most current requirements of a program.

This catalog is nondirective and should not be used for quoting AFIT, Air Force, or Department of Defense policy. It is intended as a compilation of AFIT academic information. Cleared for public release, distribution unlimited.
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Mission

**Education and Research**

The mission of the AFIT Graduate School of Engineering and Management is to produce outstanding technical leaders in the Department of Defense by providing superior graduate education built on defense-focused research. The vision of the AFIT Graduate School of Engineering and Management is to be internationally recognized as the school of choice in engineering and applied science for defense-focused and research-based graduate education.

The Graduate School of Engineering and Management provides scientific, technological, and management education applicable to Air Force, Department of Defense, and civilian research and development environments. The Graduate School not only enhances the intellectual growth of its students by offering a broad range of high-quality graduate programs, but also prepares them for successful careers in engineering, applied science, and management. In the preparation of its curricula and in its operation, the Graduate School is continually cognizant of its unique responsibility—the technical and management education of Air Force officers so they can fulfill their roles in serving their country to the greatest degree possible. The Graduate School and AFIT are recognized as a doctoral/research institution by the Carnegie Foundation for the Advancement of Teaching, the only DoD academic institution with such a designation.

**Organization**

The Graduate School of Engineering and Management offers graduate programs leading to Master of Science and Doctor of Philosophy degrees in engineering, applied science, and management disciplines. The Graduate School also offers graduate certificate programs.

The Graduate School is responsible for:

- All academic and admission policies as developed and approved by the Faculty Council
- Delivering high quality, research-based, academic programs
- Maintaining the appropriate standards for graduate-level programs

**Administration**

The Dean of the Graduate School is the chief executive officer. The administrative leadership team includes the Associate Dean, the Dean of Students, the Dean for Research, and the Associate Dean for Academic Affairs.

**Academic Departments**

Six academic departments deliver the academic programs. These departments are Aeronautics and Astronautics, Electrical and Computer Engineering, Engineering Physics, Mathematics and Statistics, Operational Sciences, and Systems Engineering and Management. Each department is responsible for the development and operation of its laboratories at all levels of activity; for the content and teaching of its academic courses; and the conduct of research programs. The chief administrative officer of each department is the Department Head, who reports directly to the Dean of the Graduate School of Engineering and Management.
History of the Air Force Institute of Technology

With War Department approval, the Air School of Application was established on 10 November 1919 at McCook Field in Dayton, Ohio, the home of Orville and Wilbur Wright. There were seven officers enrolled. Colonel Thurman Bane served as the Commandant and Lieutenant Edwin Aldrin, astronaut Buzz Aldrin’s father, served as the Assistant Commandant and only military instructor.

When Congress authorized creation of the Air Corps in 1926, the School was renamed the Air Corps Engineering School and moved, along with all the operations at McCook Field, to Wright Field in 1927. Originally designed to provide technical education for senior officers holding command positions, the school’s mission expanded to include the requirement of preparing younger officers to fill positions in research and design.

When the Air Corps Engineering School was forced to suspend classes shortly after Pearl Harbor, it had graduated more than 200 officers. Among these were many of the Nation’s foremost leaders in military aviation and space. A few of those, such as General Jimmy Doolittle, General George Kenney and General Bernard Schriever would go on to become heroes of the war and fathers of today’s modern Air Force. The School remained inactive until 1944 when, due to an emergency need for expert engineering officers, it reopened as the Army Air Forces Engineering School. In 1946, following the end of the war, the school was officially re-opened as the Army Air Forces Institute of Technology.

When the Air Force became an independent service in 1947, the Institute was renamed the Air Force Institute of Technology and formally received the mission of conducting “educational courses primarily in the field of engineering sciences and industrial administration. At this time, most of the new students already had undergraduate degrees which began a period of planning to raise the School to a graduate school. Over the next three years its name changed again to the United States Air Force Institute of Technology, and its command jurisdiction switched from Air Materiel Command to Air University.

In 1954, President Eisenhower signed Senate Bill 3712, giving the U.S. Air Force Institute of Technology authority to grant degrees. Two years later the Institute granted its first undergraduate engineering degrees. The Institute became a graduate school in 1960 when it was granted accreditation at the master’s level, and in 1965 AFIT’s accreditation was extended to the PhD level.

In other areas of the Institute, the Air Installations Special Staff School was established in 1947 to cover all aspects of air base construction, operation, and maintenance. Since then, the school has gone through eight different name changes, finally taking on its current name of The Civil Engineer School. Students from Sister Services came to AFIT in the 1950s. To date, more than 1,100 officers and enlisted service members from the Army, Navy, Marines, Coast Guard, and Air National Guard have earned degrees from AFIT.

Meanwhile, in response to the growing need for trained senior officers qualified to deal effectively with Air Force worldwide logistics problems, an experimental six-month Advanced Logistics Course was started by the Institute in 1955. The experiment was a renowned success, and a new school of logistics was established, becoming the current School of Systems and Logistics in 1963.

AFIT began accepting international students in 1961. Since then, more than 750 officers from over 30 countries have earned a master’s degree from AFIT.

The Institute discontinued its undergraduate program in 1985 after awarding a total of 920 bachelor’s degrees, deciding instead to focus on graduate and doctoral programs. AFIT also implemented a personnel procedure for civilian faculty based on the traditional four academic ranks – Instructor, Associate, Assistant, and Professor.
History of the Air Force Institute of Technology

AFIT continued restructuring throughout the 1990’s by removing all graduate programs from the School of Systems and Logistics to establish a new school, the Graduate School of Logistics and Acquisition Management and later merging the two resident graduate schools into the Graduate School of Engineering and Management in 1999.

In 2004, under the initiative of the Secretary of the Air Force, James Roche, AFIT’s first enlisted students — eight Air Force and six Marine Corps senior noncommissioned officers – were awarded master’s degrees. More than 100 have graduated since then, including one doctorate degree, emphasizing the importance of the enlisted force to military advancements in science and technology.

General Paula Thornhill became AFIT’s first female Commandant in 2006. Four years later, AFIT celebrated 50 years of continuous accreditation with the Higher Learning Commission of the North Central Association of Colleges and Schools. In another first for AFIT, in 2012, Major General Todd Stewart, PhD, USAF, Retired, became the first civilian Director and Chancellor of AFIT.

In 2016, the AFIT mission expanded, with establishment of its newest school, the School of Strategic Force Studies. This new school was established through a realignment of two existing Air University units. The National Security Space Institute, located at Peterson AFB in Colorado Springs, CO, offers professional continuing education (PCE) courses for space operators. The Air Force Nuclear College, located at Kirtland AFB in Albuquerque, NM, offers PCE courses for Airmen in the Nuclear Enterprise. With the establishment of this new school, AFIT became the home for both graduate degree education and PCE related to nuclear, space and cyber operations.

As the Air Force takes on the challenges of multi-domain operations in a complex, dynamic and uncertain national security environment, AFIT’s innovative education, research, and outreach programs are even more important and relevant today. Now in its 100th year of operation, AFIT’s continues to shape the ever changing world of air, space, and cyberspace technology. While the future promises to be even more challenging than the past, AFIT is prepared to deliver world-class defense-focused, and research-enabled graduate education, professional continuing education, and consultation to sustain the technological supremacy of the United States Air Force.
Consortia

Dayton Area Graduate Studies Institute (DAGSI)

The Air Force Institute of Technology is a member institution of the Dayton Area Graduate Studies Institute (DAGSI), along with the University of Dayton and Wright State University. Although scholarships are currently on hold, please contact DAGSI at www.DAGSI.org for general and detailed information concerning academic offerings and program availability at member institutions.

Southwestern Ohio Council for Higher Education (SOCHE)

SOCHE is a consortium of 20 colleges and universities, one foundation, and two corporations (see http://www.SOCHE.org). One of its goals is to promote inter-institutional cooperation and one of its programs, the cross-registration program, can be used as a vehicle for AFIT students to obtain courses not otherwise available at AFIT. This program is intended for the few students who need additional courses and not for any significant numbers of students who have the need or desire to take courses elsewhere. Students can attend courses at consortium institutions with no charge of tuition. Enrollment is based on the availability of space in the class and courses must be part of an approved program of study leading to a degree. Specifics can be found at https://www.soche.org/students.
Accreditation

The Air Force Institute of Technology is regionally accredited by The Higher Learning Commission (HLC).

HLC Contact Information:
The Higher Learning Commission
230 South LaSalle Street, Suite 7-500
Chicago, Illinois 60604-1413
Phone: (800) 621-7440
www.hlcommission.org

In addition to institutional accreditation, the Engineering Accreditation Commission of ABET accredits the following Master’s degree programs in the Graduate School of Engineering and Management: Aeronautical Engineering, Astronautical Engineering, Computer Engineering, Electrical Engineering, Engineering Management, Environmental Engineering and Science, Nuclear Engineering, and Systems Engineering. The Applied Science Accreditation Commission of ABET accredits the Industrial Hygiene program.

ABET Contact Information:
ABET
415 North Charles St.
Baltimore, MD 21202
Phone: (410) 347-7700
www.abet.org

AFIT holds general membership in the Council of Graduate Schools (CGS), the Midwestern Association of Graduate Schools (MAGS), and the American Society for Engineering Education (ASEE)
Board of Visitors

The Air University Board of Visitors includes an Air Force Institute of Technology Subcommittee that is comprised of a select group of eminent educators from prominent US colleges and universities and senior executives from major industries. The Subcommittee serves in an advisory capacity and meets annually. Its purpose is to review and evaluate AFIT policies related to accreditation, admission requirements, curricula, instructional methodology, facilities, management, and other aspects of AFIT.

The Subcommittee presents its findings and recommendations in a written report to the AFIT Director and Chancellor. The report is included in the annual report submitted by the Air University Board of Visitors to the Commander, Air University and is reviewed by Headquarters United States Air Force.

Chairman:  
Lt Col (Dr.) Stephen E. Cross, USAF, Retired  
Executive Vice President for Research, Georgia Institute of Technology, Atlanta, GA.

Members:  
Lt Gen Robert J. Elder, USAF, Retired  
Research Professor and Independent Consultant, Shreveport, LA.

Col (Dr.) Michael L. Heil, USAF, Retired  
Former President & CEO Ohio Space Institute, Cleveland, OH.

Dr. Jacqueline R. Henningsen  
Retired SES & Independent Consultant, Arlington, VA.

Dr. Lani Kass  
Senior VP and Corporate Strategic Advisor, CACI International, Inc., Arlington, VA.

Ex Officio Member:  
VADM Ronald A. Route, USN, Retired  
President, Naval Postgraduate School (NPS), Monterey, CA.
Academic Programs and Degrees Offered

The degrees currently available through the faculty of the Graduate School of Engineering and Management are: the Master of Science (M.S.) degree, Master of Science in (the appropriate discipline) degree programs, and the Doctor of Philosophy (PhD.) degree. With the exception of the M.S. and PhD. degree programs in Aeronautical and Astronautical Engineering within the Department of Aeronautics & Astronautics, students desiring to pursue ABET-accredited graduate degrees at AFIT must have earned an ABET-accredited undergraduate degree.

<table>
<thead>
<tr>
<th>Program</th>
<th>Degree</th>
<th>Department</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aeronautical Engineering*</td>
<td>M.S., PhD.</td>
<td>Aeronautical and Astronautical Engineering</td>
</tr>
<tr>
<td>Applied Mathematics</td>
<td>M.S., PhD.</td>
<td>Mathematics and Statistics</td>
</tr>
<tr>
<td>Applied Physics</td>
<td>M.S., PhD.</td>
<td>Engineering Physics</td>
</tr>
<tr>
<td>Applied Systems Engineering</td>
<td>M.E.</td>
<td>Systems Engineering and Management</td>
</tr>
<tr>
<td>Astronautical Engineering*</td>
<td>M.S., PhD.</td>
<td>Aeronautical and Astronautical Engineering</td>
</tr>
<tr>
<td>Atmospheric Science</td>
<td>M.S.</td>
<td>Engineering Physics</td>
</tr>
<tr>
<td>Computer Engineering*</td>
<td>M.S., PhD.</td>
<td>Electrical and Computer Engineering</td>
</tr>
<tr>
<td>Computer Science</td>
<td>M.S., PhD.</td>
<td>Electrical and Computer Engineering</td>
</tr>
<tr>
<td>Cost Analysis</td>
<td>M.S.</td>
<td>Systems Engineering and Management</td>
</tr>
<tr>
<td>Cyber Operations@</td>
<td>M.S.</td>
<td>Electrical and Computer Engineering</td>
</tr>
<tr>
<td>Electrical Engineering*</td>
<td>M.S., PhD.</td>
<td>Electrical and Computer Engineering</td>
</tr>
<tr>
<td>Engineering Management*</td>
<td>M.S.</td>
<td>Systems Engineering and Management</td>
</tr>
<tr>
<td>Environmental Engineering and Science*</td>
<td>M.S.</td>
<td>Systems Engineering and Management</td>
</tr>
<tr>
<td>Industrial Hygiene*</td>
<td>M.S.</td>
<td>Systems Engineering and Management</td>
</tr>
<tr>
<td>Logistics</td>
<td>PhD.</td>
<td>Operational Sciences</td>
</tr>
<tr>
<td>Logistics (DL)</td>
<td>M.S.</td>
<td>Operational Sciences</td>
</tr>
<tr>
<td>Logistics and Supply Chain Management</td>
<td>M.S.</td>
<td>Operational Sciences</td>
</tr>
<tr>
<td>Materials Science</td>
<td>M.S., PhD.</td>
<td>Aeronautical and Astronautical Engineering</td>
</tr>
<tr>
<td>Nuclear Engineering*</td>
<td>M.S., PhD.</td>
<td>Engineering Physics</td>
</tr>
<tr>
<td>Operations Management</td>
<td>M.S.</td>
<td>Operational Sciences</td>
</tr>
<tr>
<td>Operations Research</td>
<td>M.S., PhD.</td>
<td>Operational Sciences</td>
</tr>
<tr>
<td>Optical Science and Engineering</td>
<td>M.S., PhD.</td>
<td>Engineering Physics</td>
</tr>
<tr>
<td>Space Systems#</td>
<td>M.S., PhD.</td>
<td>Aeronautical and Astronautical Engineering</td>
</tr>
<tr>
<td>Systems Engineering*</td>
<td>M.S., PhD.</td>
<td>Systems Engineering and Management</td>
</tr>
</tbody>
</table>
Academic Programs and Degrees Offered

@ The Ph.D. in Computer Science or Computer Engineering allows students to specialize in Cyber Operations (or Information Assurance).

* ABET-accredited master's degree programs.

# A Ph.D. is available that allows students to take the core Space Systems coursework and then specialize in an approved Ph.D. program such as Aeronautical, Astronautical, Electrical, Materials Science, or Systems Engineering. Students will start their program in the Department of Aeronautical and Astronautical Engineering, complete the Space Systems coursework, and then finish their studies in the department of their specialization.
Graduate Certificate Programs

AFIT graduate certificate programs generally consist of four to six graduate courses focusing on a particular technical area. Students who complete these programs attain a demonstrated, well-defined proficiency in some body of knowledge related to military and/or aerospace technologies. Students can also apply the credits earned from these certificate programs toward advanced degrees in the future--either at AFIT, or at a participating civilian university, making the certificate programs even more valuable for military officers and DoD civilians. The academic requirements for each certificate are listed in each academic department's section.

<table>
<thead>
<tr>
<th>Program</th>
<th>Department</th>
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<tbody>
<tr>
<td>Autonomy</td>
<td>Electrical and Computer Engineering</td>
</tr>
<tr>
<td>Cost Capability Analysis</td>
<td>Operational Sciences</td>
</tr>
<tr>
<td>Data Science</td>
<td>Operational Sciences</td>
</tr>
<tr>
<td>Human Systems</td>
<td>Systems Engineering and Management</td>
</tr>
<tr>
<td>Nuclear Weapons Effects, Policy, and Prolifer</td>
<td>Engineering Physics</td>
</tr>
<tr>
<td>Space Systems</td>
<td>Aeronautics and Astronautics</td>
</tr>
<tr>
<td>Supply Chain Management</td>
<td>Operational Sciences</td>
</tr>
<tr>
<td>Systems Engineering</td>
<td>Systems Engineering and Management</td>
</tr>
<tr>
<td>Test and Evaluation</td>
<td>Operational Sciences</td>
</tr>
</tbody>
</table>

In addition to earning certificates, students can also apply the credits earned from their AFIT certificate programs toward advanced degrees in the future either at AFIT or at a participating civilian university located near a military base, making the program even more valuable for military officers and DoD civilians. AFIT currently has signed agreements with the University of New Mexico and Loyola Marymount University to facilitate this possibility.

Intermediate Development Education (IDE)

The AFIT Graduate School offers the Advanced Studies of Air Mobility (ASAM) program under the auspices of Intermediate Development Education (IDE). Applicants interested in applying for this program should apply for an academic assessment at http://www.afit.edu/ADMISSIONS/. Selected officers will earn the Master of Science (MS) degree in Logistics (Air Mobility). This is a non-thesis Masters degree program, taught by the Department of Operational Sciences that begins in June each year.
# 2019-2020 Academic Calendar

## Fall Orientation/Review Session 2019
- Technical Refresher Courses Begin: **Tue 3-Sep-19**
- Technical Refresher Courses End: **Fri 27-Sep-19**

## Fall Quarter 2019
- Fall Quarter Classes Begin: **Tue 1-Oct-19**
- Fall Quarter Registration Closes: **Fri 4-Oct-19**
- Last Day to Drop Without Record: **Fri 11-Oct-19**
- Columbus Day - No Classes / Offices Closed: **Mon 14-Oct-19**
- Book Lists for Winter Quarter Due: **Fri 25-Oct-19**
- Winter Quarter Registration Opens: **Mon 4-Nov-19**
- Veteran's Day - No Classes / Offices Closed: **Mon 11-Nov-19**
- Graduation Applications due to Registrar's Office: **Fri 15-Nov-19**
- Master's Thesis Defense Deadline: **Fri 22-Nov-19**
- Last Day to Withdraw Without a Grade: **Fri 22-Nov-19**
- Thanksgiving Day - No Classes / Offices Closed: **Thu 28-Nov-19**
- Final Thesis Documents Due to Department: **Fri 29-Nov-19**
- AETC Family Day (Classes Held): **Fri 29-Nov-19**
- Final Dissertation Documents Due to Department: **Mon 2-Dec-19**
- Fall Quarter Classes End: **Mon 9-Dec-19**
- Final Examinations Begin: **Tue 10-Dec-19**
- Final Examinations End: **Fri 13-Dec-19**
- Final Grades Due NLT 1200: **Mon 16-Dec-19**
- Fall Graduation (Degree Conferral-No Ceremony): **Thu 19-Dec-19**

## Winter Quarter 2020
- Winter Quarter Classes Begin: **Mon 6-Jan-20**
- Winter Quarter Registration Closes: **Fri 10-Jan-20**
- Last Day to Drop Without Record: **Fri 17-Jan-20**
- Martin Luther King Day - No Classes / Offices Closed: **Mon 20-Jan-20**
- Book Lists for Spring Quarter Due: **Fri 31-Jan-20**
- Spring Quarter Registration Opens: **Mon 10-Feb-20**
- President's Day - No Classes / Offices Closed: **Mon 17-Feb-20**
- Graduation Applications due to Registrar's Office: **Fri 21-Feb-20**
2019-2020 Academic Calendar

TPC Begins Accepting Completed Thesis/Dissertation Documents  Mon 24-Feb-20
Last Day to Withdraw Without a Grade  Fri  28-Feb-20
Master’s Thesis Defense Deadline  Fri  28-Feb-20
Final Thesis Documents Due to Department  Fri  6-Mar-20
Final Dissertation Documents Due to Department  Mon  9-Mar-20
Winter Quarter Classes End  Fri  13-Mar-20
Final Examinations Begin  Mon  16-Mar-20
Final Examinations End  Thu  19-Mar-20
Final Grades Due NLT 1200  Fri  22-Mar-20
Commencement Ceremony  Thu  26-Mar-20

Spring Quarter 2020

Spring Quarter Classes Begin  Mon  30-Mar-20
Spring Quarter Registration Closes  Fri  3-Apr-20
Last Day to Drop Without Record  Fri  10-Apr-20
Book Lists for Summer Quarter Due  Fri  24-Apr-20
Summer Quarter Registration Opens  Mon  4-May-20
Graduation Applications due to Registrar’s Office  Fri  15-May-20
TPC Begins Accepting Completed Thesis/Dissertation Documents  Mon  18-May-20
Last Day to Withdraw Without a Grade  Fri  22-May-20
AETC Family Day  Fri  22-May-20
Master’s Thesis Defense Deadline  Fri  22-May-20
Memorial Day - No Classes / Offices Closed  Mon  25-May-20
Final Thesis Documents due to Department  Fri  29-May-20
Final Dissertation Documents due to Department  Mon  1-Jun-20
Spring Quarter Classes End  Fri  5-Jun-20
Final Examinations Begin  Mon  8-Jun-20
Final Examinations End  Thu  11-Jun-20
Final Grades Due NLT 1200  Mon  15-Jun-20
Spring Graduation (Degree Conferral-No Ceremony)  Thu  18-Jun-20
Operations Management Commencement (Ft Dix Location)  Fri  19-Jun-20
# 2019-2020 Academic Calendar

## Summer Quarter 2020

<table>
<thead>
<tr>
<th>Event</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summer Quarter Classes Begin</td>
<td>Mon 29-Jun-20</td>
</tr>
<tr>
<td>Summer Quarter Registration Closes</td>
<td>Fri 3-Jul-20</td>
</tr>
<tr>
<td>Independence Day Observed - No Classes / Offices Closed</td>
<td>Fri 3-Jul-20</td>
</tr>
<tr>
<td>AETC Family Day - No Classes</td>
<td>Mon 6-Jul-20</td>
</tr>
<tr>
<td>Last Day to Drop Without Record</td>
<td>Fri 10-Jul-20</td>
</tr>
<tr>
<td>Book Lists for Fall Quarter Due</td>
<td>Fri 24-Jul-20</td>
</tr>
<tr>
<td>Fall Quarter Registration Opens</td>
<td>Mon 3-Aug-20</td>
</tr>
<tr>
<td>Graduation Applications due to Registrar's Office</td>
<td>Fri 14-Aug-20</td>
</tr>
<tr>
<td>TPC Begins Accepting Completed Thesis/Dissertation Documents</td>
<td>Mon 17-Aug-20</td>
</tr>
<tr>
<td>Last Day to Withdraw Without a Grade</td>
<td>Fri 21-Aug-20</td>
</tr>
<tr>
<td>Master’s Thesis Defense Deadline</td>
<td>Fri 21-Aug-20</td>
</tr>
<tr>
<td>Final Thesis Documents due to Department</td>
<td>Fri 28-Aug-20</td>
</tr>
<tr>
<td>Final Dissertation Documents due to Department</td>
<td>Mon 31-Aug-20</td>
</tr>
<tr>
<td>Summer Quarter Classes End</td>
<td>Thu 3-Sep-20</td>
</tr>
<tr>
<td>AETC Family Day - No Classes</td>
<td>Fri 4-Sep-20</td>
</tr>
<tr>
<td>Labor Day - No Classes / Offices closed</td>
<td>Mon 7-Sep-20</td>
</tr>
<tr>
<td>Final Examinations Begin</td>
<td>Tue 8-Sep-20</td>
</tr>
<tr>
<td>Final Examinations End</td>
<td>Fri 11-Sep-20</td>
</tr>
<tr>
<td>Final Grades Due NLT 1200</td>
<td>Mon 14-Sep-20</td>
</tr>
<tr>
<td>Summer Graduation (Degree Conferral-No Ceremony)</td>
<td>Thu 17-Sep-20</td>
</tr>
</tbody>
</table>
Academic Policies

Associate Dean for Academic Affairs: Paul J. Wolf, Ph.D.
2950 Hobson Way, Building 641, Room 217
Wright-Patterson AFB OH 45433-7765
Phone: (937) 255-3636 x4560
Fax: (937) 255-5989
Email: academicaffairs@afit.edu

Academic Advisor
Each student is assigned a faculty member as an academic advisor who assists the student with academic planning. The faculty advisor is appointed by the Department Head on the basis of familiarity with Institute programs, the student's programs, and the student's individual background. While advisors are available for advice and consultation, students are responsible for understanding and complying with the Graduate School's academic policies and completing all graduation requirements. The Dean, faculty and staff are available for consultation with individual students as well as with sections of students.

Academic Year
The academic year is divided into four 11-week quarters (fall, winter, spring, and summer), each of which includes a week for final exams. Full-time military students assigned to AFIT attend a 4-week technical review session ("short term") commencing in June and September, following Student Orientation. The Graduate School academic calendar can be found in the AFIT Graduate School Catalog, the Student Handbook, or online at www.afit.edu/ENER/calendars.cfm. The academic calendar shows holidays and break periods, as well as the beginning and end of each quarter. Published calendars are subject to change with the approval of the Dean.

Appeal of Grades
A student who feels that an assigned grade is other than the grade earned must first discuss the matter with the course instructor to determine if the discrepancy is caused by error or misunderstanding. If the complaint is not satisfactorily answered by the instructor, and the student feels that an error has not been corrected or that the assigned grade was unfairly determined, the student may appeal the decision to the head of the department in which the course is offered. The procedures are contained in ENOI 36-138, Student Academic Performance Appeals and Complaint Resolution.

Auditing
Students wishing to audit a course need only obtain permission from the instructor teaching that course and register according to prescribed procedures. Audited courses do appear on the student's transcript, but have no bearing on GPA. Audited courses are billed as graded courses and can also be retaken for credit in the future.

Change of Address
Students, who have a change in their permanent or local address while attending AFIT, should make changes through Web Advisor or submit the change in writing to the Registrar’s Office or Student Operations Office.
## Academic Policies

### Classification of Students

The Graduate School recognizes 12 quarter hours as a minimum course load to be considered as a full-time student. A student registered in courses totaling fewer than 12-quarter hours is considered part-time, unless stated otherwise in a student's approved curriculum plan. Part-time students are limited to courses totaling no more than eight quarter hours in a single quarter. Once admitted, part time students are subject to the academic rules and regulations that apply to full-time students.

### Confidentiality of Academic Records

The Family Education and Privacy Act of 1974, as amended, is a federal law that grants to students the right to inspect, obtain copies, challenge, and to a degree control the release of information contained in his/her records. Guidelines and a full text of the law can be obtained from the Registrar's Office. Students who are assigned to AFIT by the Air Force, service member or civilian, are subject to release of transcript to the Air Force.

### Course Changes (Drop/Add)

Courses may be added through the end of the first week of the quarter. Courses may be dropped without record during the first two (2) weeks of the quarter, subject to approval of the student's faculty advisor. Students may withdraw from a course during the third week and through the eighth week with a record. No courses may be added after week 1 and no courses may be dropped after week 8 of the quarter. All course changes after the first week are made using the AFIT Registration Form and require approval of the instructor, academic advisor, and Department Head. The completed Registration Form must be delivered to the Office of the Registrar.

### Course Listings and Schedules

Projected course listings for an academic year are typically published on the Graduate School’s website (www.afit.edu/ENER/classschedule/index.cfm). Final class schedules are available in the term prior to being offered. The Institution reserves the right to cancel courses for administrative purposes.

### Education Plan

All degree-seeking students are responsible for developing, reviewing, and maintaining his/her specific plan of study called an Education Plan. The Education Plan is developed and reviewed with the assistance of the student's academic advisor, and approved by an official of the department prior to the start of the first quarter of study. Both the student and the faculty advisor shall review the Education Plan quarterly prior to course registration. Once the Education Plan is approved, it becomes the curriculum for that individual student, and deviations are permitted only if the student obtains formal approval for the change from the faculty advisor.

### Enrollment

All students in a degree program are required to maintain continuous enrollment in every term from matriculation to the award of the degree.

### Grading System

Academic achievement is indicated by the following letter grades and grade points used in calculating the grade point averages:
# Academic Policies

<table>
<thead>
<tr>
<th>Grade</th>
<th>Ranking</th>
<th>Grade Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Excellent</td>
<td>4</td>
</tr>
<tr>
<td>A-</td>
<td></td>
<td>3.7</td>
</tr>
<tr>
<td>B+</td>
<td></td>
<td>3.3</td>
</tr>
<tr>
<td>B</td>
<td>Good</td>
<td>3</td>
</tr>
<tr>
<td>B-</td>
<td></td>
<td>2.7</td>
</tr>
<tr>
<td>C+</td>
<td></td>
<td>2.3</td>
</tr>
<tr>
<td>C</td>
<td>Fair</td>
<td>2</td>
</tr>
<tr>
<td>C-</td>
<td></td>
<td>1.7</td>
</tr>
<tr>
<td>D</td>
<td>Poor</td>
<td>1</td>
</tr>
<tr>
<td>F</td>
<td>Failure</td>
<td>0</td>
</tr>
<tr>
<td>I</td>
<td>Incomplete (notes 1, 2)</td>
<td></td>
</tr>
<tr>
<td>S</td>
<td>Satisfactory (note 1)</td>
<td></td>
</tr>
<tr>
<td>U</td>
<td>Unsatisfactory (note 1)</td>
<td></td>
</tr>
<tr>
<td>W</td>
<td>Withdrawn (note 3)</td>
<td></td>
</tr>
<tr>
<td>NG</td>
<td>No Grade Posted (note 4)</td>
<td></td>
</tr>
<tr>
<td>AU</td>
<td>Audit (note 5)</td>
<td></td>
</tr>
</tbody>
</table>

**Grading System Clarifications**

1. “S” and “U” grades are assigned to master’s degree and Ph.D. research courses and master’s degree project courses as well as pass/fail courses. "S" grades count only toward earned hours and do not affect the grade point average (GPA).

2. The instructor or the academic advisor, in coordination with the Dean, will determine the resolution deadline.

3. “W” grades will be given when a student withdraws or is withdrawn from any course after the acceptable drop date.

4. Please see your instructor as soon as possible.

5. An “AU” grade will be assigned to students who have registered for a course as an auditing student.

**Graduation Requirements**

Students are governed by the degree requirements in place when they matriculate at AFIT, that is, when they enter as a degree seeking student. This point in time is known as the “catalog year”.

**Incompletes**

Incomplete grades are given for failure to complete the required work on a course or thesis. A grade of "I" is subject to approval by the Dean. A student cannot graduate with a grade of "I". The student must resolve the "I" with a letter grade within a reasonable time period as determined by the instructor or the thesis advisor.
# Academic Policies

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Registration</strong></td>
<td>Students must be admitted into the Graduate School of Engineering and Management in order to register and earn credit for coursework. The responsibility for being properly registered for course rests with the student. Registration is required for each term for all students. Registration instructions and guidelines can be obtained from the Registrar's Office, and the registration dates are published on the academic calendar located on the AFIT website (<a href="http://www.afit.edu/ENER/calendars.cfm">www.afit.edu/ENER/calendars.cfm</a>).</td>
</tr>
<tr>
<td><strong>Repeated Courses</strong></td>
<td>With proper approval, a student may repeat once for credit any course for which a grade of &quot;D,&quot; &quot;F,&quot; or &quot;U&quot; was received. Only the repeat course grade will be used in computing the GPA. Once a course has been repeated, the resulting grade may not be replaced by course substitutions.</td>
</tr>
<tr>
<td><strong>Transcripts</strong></td>
<td>Upon receipt of a written, signed request, the Registrar's Office will issue a transcript of work completed at the Institution, provided all obligations to the school have been met, including all financial accounts with AFIT where applicable. A transcript is official only when it bears the signature of the Registrar and the seal of the Institution. Transcripts mailed directly to the student will be stamped &quot;Issued to Student&quot; and normally are not accepted as official copies. Transcripts are free of charge. Allow five business days for verification and processing. Transcripts, copies of transcripts, test scores, or information for admission purposes will not be released by this Institution and must be obtained by the student from the institution holding the original record.</td>
</tr>
<tr>
<td><strong>Transfer Credit</strong></td>
<td>Students may transfer up to 12 quarter hours of graduate credit from other regionally-accredited institutions. The faculty advisor, the head of the appropriate department, and the Academic Standards Committee must approve transfer credits. All courses transferred for credit must carry a grade of &quot;B&quot; or better. Neither the grades nor the credit hours pertaining to the transferred courses will be used in grade point average calculations except to remedy academic deficiencies. The Graduate School does not accept transfer credit for Ph.D. programs.</td>
</tr>
</tbody>
</table>
Academic Standards

Academic Integrity

Students are expected to adhere to the highest standards of academic integrity, in accordance with ENOI 36–107, Academic Integrity. Individuals who violate this instruction are subject to adverse administrative actions including enrollment termination. Military students may be discharged from the service or face disciplinary action including punishment under Articles of the Uniform Code of Military Justice or comparable discipline for non-military students. Incidents of academic dishonesty are subject to release during employment investigations for any position which requires a release of records.

Attendance Policy

Prompt and regular attendance is considered necessary for satisfactory work. Therefore, students are expected to attend classes, and absences should be explained to the instructor. The student should provide advance notice, if possible. This is especially important in the case of full-time military assigned to AFIT, since they attend AFIT as an official duty assignment. Therefore, class attendance is mandatory unless the student is formally on leave or in another non-duty status. A satisfactory explanation of absence may secure students from disciplinary action, but does not in any case relieve them from responsibility for the work during their absence. A student who misses an announced test, examination, or laboratory period in a regular course of study, and has the permission of the instructor, may be given the opportunity to make up the work at the instructor's convenience. The instructor determines in all instances the extent to which absences and tardiness affect each student's grade. Students may be dropped at any time by a course instructor or the Dean for non-attendance or tardiness with a grade of "W".

Probation and Dismissal

Failure to meet established minimum acceptable standards of academic or disciplinary performance could result in probation or dismissal. The academic advisor will counsel students failing to maintain the minimum GPA of 3.0, and the advisor will develop a plan to help the student remedy the deficiency. At this point, the student is considered on academic probation. A student on probation is considered in "good standing" for certification purposes and is eligible to register for courses. No entry is made on the student's permanent record. Failure to meet the minimum academic standard after the probationary period could result in the student meeting an academic review board.

The purpose of the academic review board is to recommend to the Dean whether the student should be eliminated from or be allowed to continue with his/her academic program. A faculty board should be convened for any student who receives a letter grade of "F" or "U" in any course, any student at the request of his faculty advisor, any student by his own request, and any doctoral student at the request of the academic department. A faculty board will also be conducted for any graduate student with a cumulative GPA less than 2.6 by the end of the second quarter, less than 2.8 by the end of the third quarter, less than 3.0 by the end of the fourth or subsequent quarters, and any graduate student with a cumulative or quarterly GPA less than 2.50.

Dismissal is a permanent and involuntary separation of the student from AFIT. The student is not eligible for readmission and is not in good standing in the Graduate School of Engineering and Management. "Academic dismissal" is recorded on the student's permanent record.

Academic Good Standing

To remain in good academic standing, all students must maintain a cumulative GPA of 3.0.
Academic Standards

Academic Honors (Awards)

Several awards are presented to students by the various departments, professional associations, and the Institute. AFIT's academic honors include the Commandant's Award, the Mervin E. Gross Award, and the designation of students as "Distinguished Graduates".

The Commandant's Award is presented to the student with the most outstanding thesis in the graduating class, which is selected from single entries from each department. The department nominees also receive the Dean's Award to recognize the most exceptional thesis in each department.

The Mervin E. Gross Award is given to the graduating student who has demonstrated the most exceptional academic achievement and high qualities of character, initiative, and leadership while pursuing a master's degree in the Graduate School of Engineering and Management.

The Air Force Institute of Technology rewards excellent academic performance during graduation by designating certain students as "Distinguished Graduates." The number of distinguished graduates is limited to no more than 10% of the graduating class.
Master's Degree Programs

Degree Elements

All master's degree programs typically consist of five elements:

- Core courses that provide the breadth of content in a particular field. These courses are identified by the department as those in which each student must demonstrate competence in order to meet the academic requirements of the particular field
- A specialization area* which provides in-depth knowledge in a chosen field
- Electives* that are used to round the student's experience or provide additional background material.
- A mathematics requirement
- An independent research project, which carries a 12-credit-hour load

*Students choose their electives and specialization courses based on their academic interest and the requirements of the Air Force for those military officers enrolled in AF sponsored programs.

General Degree Requirements

The Master's degree is awarded for the successful completion of a curriculum that has the approval of the faculty as meriting the award of that degree. To satisfy the specific requirements for the master's degree the student must:

- Complete at least 48 quarter hours of required graduate courses and approved graduate electives
- Complete an independent investigation of a problem approved by the major department, the results of which have been presented as a formal thesis (or research paper for non-thesis programs, if required). This thesis must be acceptable as partial fulfillment of the required quarter hours of credit. In certain programs, approved in advance by the Faculty Council, group design studies may replace the independent study
- Attain a grade point average of at least "B" (3.00) for all graded courses included in the student's approved program. Courses for which the student received the grade "D" or lower will not be accepted as a part of the 48 quarter hours required for the degree
- Complete all degree requirements within six calendar years after beginning the first course in an approved program.
- Be recommended for the degree by the Faculty Council of the Graduate School of Engineering and Management
- The degree title is "Master of Science," "Master of Science in (designated area) Engineering," or "Master's in (subject area)." Although the graduate programs for engineering students pursuing either degree are normally the same, the designated degree in criteria of the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology (ABET) is awarded only to students whose total preparation, undergraduate and graduate, satisfies the appropriate accreditation.

Academic Standards

The Graduate School expects its students to meet fully the rigorous demands of its programs. For many students, this means a weekly investment averaging at least three hours per quarter hour of graduate registration. Students are expected to maintain a 3.00 grade point average for all of their courses. In cases of serious academic deficiencies, students must consult their faculty academic advisors regarding an appropriate study load to remedy their deficiencies.
Master's Degree Programs

Thesis Requirement

A student seeking certain master's degrees are required to pursue an independent study and submit a thesis in partial fulfillment of their degree requirements. The student is required to present the thesis at a formal defense to a faculty committee chaired by the research advisor. Upon successful completion of the defense, the student will submit a final document that contains a thesis approval page signed by the thesis examination committee. The administrative requirements for the thesis document are fully described in Style Guide for AFIT Theses and Dissertations.
Doctor of Philosophy Programs

The AFIT doctoral program is based on the following statement by the Council of Graduate Schools in the United States (from The Doctor of Philosophy Degree: A Policy Statement, Oct 1977):

The Doctor of Philosophy degree is awarded by universities in many parts of the world as the mark of highest achievement in preparation for active scholarship and research. The doctoral program is designed to prepare a student for a lifetime of intellectual inquiry that manifests itself in creative scholarship and research. The program emphasizes freedom of inquiry and expression and development of the student's capacity to make significant contributions to knowledge. An essential element is the development of the ability to understand and evaluate critically the literature of the field and to apply appropriate principles and procedures to the recognition, evaluation, interpretation, and understanding of issues and problems at the frontiers of knowledge. All of this is most effectively accomplished in close association with those experienced in research and teaching.

A central purpose of doctoral programs is the extension of knowledge, but this cannot be accomplished on all fronts simultaneously. Students must choose an area in which to specialize or a professor with whom to work. Individualized programs of study are then developed and committee members are selected cooperatively as course work is completed and research undertaken. When all courses have been taken, the research finished, the dissertation written, and all examinations passed, the student will have acquired the knowledge and skills expected of a scholar and will have extended knowledge in the field. Details of requirements and policies are documented in AFIT instructions, Graduate School of Engineering and Management instructions, and Doctoral Council policy letters. These are available at AFIT.

General Degree Requirements

The Doctor of Philosophy degree is awarded for the successful completion of a curriculum that has the approval of the faculty as meriting the degree. The PhD degree includes the following general requirements:

- Complete an approved program of study
- Meet the residency requirement
- Pass specialty examination
- Be admitted into candidacy
- Submit a dissertation
- Successfully defend the dissertation

These requirements and the policies and procedures that implement the program are specified in the Doctoral Council Policy Letters, and are summarized in the following sections.
**Doctor of Philosophy Programs**

**Advising**

Upon admission of each student into the program, a pro-tem faculty advisor is appointed by the Department Head to guide the student through the initial phases of the coursework, and suggest potential specialization areas. The pro-tem advisor is responsible for providing the student with advice on an appropriate plan of study and helping the student identify a research area and research advisor. A pro-tem advisor serves until the research advisor is selected and approved.

Upon selecting a field of specialization (research area), the student chooses a regularly appointed faculty member in that area to act as his/her research advisor and research committee chairperson. In many cases, the pro-tem advisor becomes the research advisor. The research advisor supervises the specialty examination and advises the student throughout the remainder of the program concerning the prospectus, the research project, writing of the dissertation, and any other matters pertaining to the program. The research advisor also chairs the research committee, which shall consist of no fewer than three faculty members, representing at least two academic departments from within the Graduate School of Engineering and Management. (A department of the engineering school of The Dayton Area Graduate Studies Institute (DAGSI) partner schools may be represented in lieu of one of the AFIT departments.) The membership of the research committee, and any subsequent changes, must be approved by the Department Head of the admitting department.

**Course Requirements**

The student must complete at least 36 quarter hours of course work, of which at least 24 quarter hours must be successfully completed in the specialty area and at least 8 quarter hours must be successfully completed in the mathematics area.

Any additional hours are used for required courses and electives. The minimum 24 hours of specialty area courses may consist of courses from more than one department as long as these courses form an integrated program designed to make the student an expert in the chosen area of research. Individual departments approve the specific courses that will constitute the specialty area of study.

The residency requirement is met when the student completes three quarters of full-time study in residence during a single contiguous four-quarter period. The student must also attain an average grade of at least B (3.00) for all courses attempted after admission to the program. For the PhD program, qualifying examinations and the dissertation are paramount, and course requirements are identified to facilitate the student’s education towards the qualifying examination.

Waivers may be granted to the 36 quarter-hour requirement. Such a waiver requires documentation that the student has previously successfully completed courses normally included in the AFIT PhD program of his or her chosen discipline, and that the program, including the waived courses, contains a well-integrated specialty sequence of at least 24 quarter-hours. No more than 12 credit hours may be waived under this provision, and none of the waived hours can be used in meeting the mathematics requirement.
# Doctor of Philosophy Programs

**Academic Load**

Students assigned to AFIT for full-time Ph.D. study are expected to carry a full academic load of 12 credit hours per quarter. Other Ph.D. students generally have monetary or other support that entails its own requirements for full-time study, such as 8 quarter hours of courses plus 20 hours per week as a research assistant. Except in unusual circumstances, no student should carry more than 12 credit hours per quarter. The head of the admitting department may grant an exception to this guideline. This 12 credit hour limitation is based upon the following considerations:

- The PhD courses are of such advanced nature that a student needs time to understand and assimilate the material contained therein
- The limitation allows time to interact with other PhD students and with the faculty
- It allows time to explore areas that may intrigue him or her in the pursuit of the coursework

Generally, a full-time PhD student will complete the course requirements during the first four or five quarters. During the succeeding quarters, the student's full load involves completing the examination requirements and working on his or her dissertation research.

**Standards of Work**

Each student is expected to perform at a high academic level and maintain a grade point average of at least "B" (3.00) on the course work. In addition, he/she must pass the examinations and be admitted to candidacy on a timely basis. A course grade less than "B" constitutes a deficiency. Failure of the specialty exam constitutes a deficiency. An academic board is usually convened if a student has two deficiencies. The board reviews the situation and may dictate corrective action or may take action to remove the student from the program.

**Qualifying Examinations**

The PhD qualifying examination is the "specialty exam". This written and oral examination in the specialty area is required for each PhD student. The oral part may be included in the prospectus examination or it may be part of the specialty examination or both. The specialty examination has two objectives: to measure the student's mastery of the specialty area and to measure his or her readiness to define a dissertation research area.

**Prospectus Examination**

The Research Committee will examine the student on the prospectus that the student has submitted. Normally this examination will be an oral examination conducted after the committee has had an opportunity to study the prospectus. The prospectus examination will be graded as "pass" or as "not yet ready". Therefore, it can be viewed as an ongoing process, in which the "defense" can be adjourned and reconvened (as necessary) until the committee accepts the prospectus.
# Doctor of Philosophy Programs

## Admission to Candidacy

The graduate student does not formally become a candidate for the PhD degree until the application for candidacy is approved. Admission to candidacy requires the approval of the student's supervisory committee, the Department Head, the Academic Standards Committee of the Faculty Council, and the Dean of the Graduate School. The approval is based upon:

- Passing the qualifying examination
- An academic record of the student that meets the program and grade point average requirements
- Approval of the student's prospectus for the dissertation project
- Completion of the residency requirement or approval of a specific plan for meeting

The formal application for candidacy should be submitted as soon as these requirements are met and at least one year prior to receipt of the degree.

## Dissertation Requirement

The most clearly distinguishing characteristic of a program leading to the PhD degree is the requirement that the candidate write a dissertation embodying the results of a significant and original investigation. The dissertation must make a real contribution to the engineering or applied science discipline chosen by the student, and it is expected to be a mature and competent piece of writing. With the exception of such progress reports as may be required by the sponsoring agency, no publication of the results of dissertation research will be made prior to acceptance of the dissertation without the approval of the student's Research Committee.

While research in a classified area is acceptable, the dissertation document must be unclassified, stand alone, and be releasable for unlimited distribution. In compelling circumstances (quite rare), a classified dissertation may be accepted. Details regarding administrative requirements and style suggestions are provided by the Style Guide for AFIT Theses and Dissertations.

## Defense of the Dissertation

The oral defense of the dissertation constitutes the final examination of the student's work. This examination must enable the research committee to satisfy itself that the dissertation is an original piece of work that has been carried out in keeping with the highest standards of investigation and reporting, and that it makes a contribution to knowledge that is of value to the engineering profession or scientific community. The written dissertation and the results of this defense will be judged satisfactory if they have the approval of a three-fourths majority (including the Advisor) of the evaluation committee. The committee may approve the defense subject to still further revisions in the written dissertation. This has been the rule rather than the exception. Therefore, the candidate should retain all materials, files, etc. that would be needed to make those revisions until the Dean has approved the dissertation and all necessary copies have been produced and accepted.
Doctor of Philosophy Programs

| Time Limit | All requirements for the PhD degree must be satisfied not later than eight years from the beginning of the first course in the approved program and not later than four years from admission to candidacy. The time limit may be waived by the faculty council when appropriate, such as when the research has been vigorously pursued but is delayed by circumstances beyond the control of the student. |
Registrar and Student Operations

Registrar and Director of Student Operations, Kathleen K. Burden
AFIT/ENE
2950 Hobson Way, Building 641
Wright-Patterson AFB, OH 45433-7765
Phone: (937) 255-6234 x3125 (DSN 785-6234 x3125)
FAX (937) 255-2791 (DSN 785-2791)

The Student Operations Division consists of Admissions, Registrar, Student Support, and International Military Student Office (IMSO)

Office of Admissions
Phone: (937) 255-6234 x3184 (DSN 785-6234 x3184)
Toll Free: 800-211-5097 x3184
FAX (937) 255-2791 (DSN 785-2791)
Email: ENERAdmissions@afit.edu
Web: https://www.afit.edu/ADMISSIONS/index.cfm

ADMISSION TO THE AFIT GRADUATE SCHOOL

Who May Apply

Programs offered by the Graduate School of Engineering and Management are available to officers and enlisted members of all branches of the United States Armed Services, U.S. government civilian employees, civilians employed by certain defense industry contractors, and military officers from select foreign countries. The Office of Admissions will assist all interested parties with their admission and application questions. Please contact Admissions or apply online at https://www.afit.edu/ADMISSIONS/index.cfm. Applicants who happen to be on veterans, or otherwise eligible, may qualify for the education benefits offered through the Veterans Administration, see "Financial Assistance."
### Registrar and Student Operations

#### Admissions Standards

The faculty determines the admissions standards for the Graduate School of Engineering and Management. The standards maintained by the Graduate School and individual departments and programs are applied to ensure that applicants admitted to the Graduate School have adequate undergraduate and graduate preparation in their proposed field of study and possess a reasonable expectation of successfully completing a graduate program.

Prospective cadets applying for quota assignment may apply for admission to the Graduate School of Engineering and Management during or after their final year of undergraduate study, but must furnish proof of graduation before the end of their first quarter of enrollment. Prospective students applying for admission to a graduate degree program in a field of specialization in which they already hold that same degree or its equivalent may do so only if the previous degree program was of substantially different character or was not regionally accredited.

Applicants who apply for admission to the Graduate School are evaluated on the individual merits of their academic achievements and scholarly potential to complete graduate-level coursework and curriculum requirements. Admission is granted only upon the recommendation of the department and approval of the Dean. The decision to admit an applicant to a program is based primarily on a combination of the following criteria and according to the academic requirements of the specific graduate program.

#### Academic Eligibility Criteria Master's Degree

Applicants, applying for master's programs, who meet the criteria below are generally considered fully-qualified and can immediately enter a master's degree program, and have a greater potential to successfully complete a master's degree program in the nominal time of 18 months.

1. Hold an appropriate bachelor's degree in an area relevant to the master's program of interest from a regionally accredited college or university in the United States, or the equivalent of this degree in from another country.
2. Meet or exceed grade point average of 3.00 based on a 4.00 scale, and
3. Submit satisfactory scores on standardized examinations like the Graduate Record Examination (GRE) or, depending on the program, the Graduate Management Admissions Test (GMAT). The recommended GRE scores are 153 verbal and 148 quantitative (or 500 verbal and 600 quantitative for GREs taken prior to 1 Aug 2011). The recommended GMAT score is 550 or higher.
Registrar and Student Operations

Academic Eligibility Criteria for
Doctoral Degree

Admission to Ph.D. programs is open to qualified individuals who:

- Hold a bachelor's degree from a regionally accredited college or university in the United States, or the equivalent of this degree in another country, with grades averaging at least a 3.00 on a 4.00 scale.
- Hold a master's degree from a regionally accredited college or university in the United States, or the equivalent of this degree in another country, with grades averaging at least a 3.50 in an area relevant to the doctoral program of interest, and
- GRE scores of at least 156 verbal and 151 quantitative (or 550 verbal and 650 quantitative for GREs taken prior to 1 August 2011) or, depending on the program, a GMAT score of 650 or higher.

A baccalaureate-to-doctoral admission may also be granted in some circumstances to applicants who are entering directly from an undergraduate program without a master's degree. The requirement to hold a master's degree will be met during the student's PhD program. Endorsements by the student's undergraduate faculty may be required. Note: This admission option is not available to active duty Air Force members selected for an advanced academic degree (AAD) assignment unless specifically coordinated and approved by HQ AFPC and the functional area manager at the Air Staff.

The entry requirements for certificate programs and non-degree seeking status are the same as those stated above for master's degree programs, with the exception that a standardized test (GRE, GMAT) is not required. Students enrolled in a certificate program are limited to the classes required for the certificate program, therefore, taking additional classes requires department approval, or a change of enrollment to another certificate program or to a degree program. A maximum of 12 quarter hours of graduate credit, earned in a non-degree status and/or transferred from another regionally-accredited institution may be permitted for application toward an advanced degree, once the student obtains acceptance into a degree program. See the "Change of Enrollment" sub-section under the "Changes after Admission" section of this catalog.

Non-degree seeking students may enroll in graduate level courses as their qualifications and performance permit, and they must contact the department(s) offering the courses to ensure that courses are available to non-degree students. Admission in a non-degree-seeking status is reserved for those interested in course enrollment for professional development, intellectual enrichment, or exploring the possibility of applying later for a graduate degree program or certificate program. Non-degree students may earn a maximum of 12 quarter hours, either in non-degree status and/or transferred from another regionally-accredited institution. In addition, non-degree students may only register for up to 12 quarter hours of coursework. If the non-degree seeking student desires to take more classes, they must complete a "Change of Enrollment" form and choose non-degree-seeking status under a different academic focus, or move to a certificate or degree program. See the "Change of Enrollment" sub-section under the "Changes after Admission" section of this catalog.
### Registrar and Student Operations

| General Application Process | Each applicant must submit an application to be considered for admission to the Graduate School of Engineering and Management. The application is completed online and submitted to the Office of Admissions. The application form and instructions are found online at https://www.afit.edu/ADMISSIONS/, look for "APPLY ONLINE" on the side menu. Applicants must submit their application packages so they are received, processed, and the applicant admitted to the Graduate School, no later than the last day of the first week of the first term the applicant plans to attend. General inquiries for admission should be addressed to: Office of Admissions Graduate School of Engineering and Management AFIT/ENER, Bldg 641, Room 102 2950 Hobson Way Wright-Patterson Air Force Base, OH 45433-7765 1-800-211-5097 x3184 https://www.afit.edu/ADMISSIONS/index.cfm Note: Officers, enlisted personnel, and federal civil servants applying for full-time graduate study who are interested in attending the Graduate School of Engineering and Management under the sponsorship of their respective military service or government agency must seek selection through a process defined by their respective service. All sponsored selection processes include establishing academic acceptance by the Graduate School's Admissions Office. |

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| 19-20 Graduate School of Engineering and Management Catalog | 19-20 Graduate School of Engineering and Management Catalog |
### Registrar and Student Operations

Each applicant must submit the following items, constituting a complete application package, to the Admissions Office:

- A completed online application form.
- One complete set of official transcripts from each school attended reflecting all undergraduate and graduate work completed or in progress. Each transcript must bear the signature of the registrar, the institution's official seal, years of attendance, courses taken, grades received, and if applicable, the degree, certificate or diploma received.
- For doctoral programs only, if you did not receive a master's degree from the AFIT Graduate School of Engineering and Management, please submit two letters of academic recommendation, preferably from faculty involved in or aware of your Master's thesis.
- The Graduate School of Engineering and Management graduate degree programs require applicants to submit standardized test scores applicable to the program requested. The Graduate Record Examination (GRE) is acceptable for all master's and doctoral degree programs. The GMAT is accepted by several master's and doctoral degree programs. Please contact Admissions if you cannot determine which standardized test are accepted under the academic department's web pages. Examination scores should be sent directly to the Admissions Office by the appropriate testing agency. AFIT's institutional code for the GRE and GMAT is 1827, and we are listed in the GRE/GMAT booklets under the State of Ohio.
- AFIT exists within the framework of the United States Air Force; therefore, with the exception of international military officers sponsored by their governments, all U.S. government civilian employees and civilians employed by certain defense industry contractors, must provide proof of U.S. citizenship prior to being admitted to the AFIT Graduate School.

For more information about these tests, you may visit the GRE/GMAT websites (www.gre.org or www.gmat.org)
## Registrar and Student Operations

<table>
<thead>
<tr>
<th>Required Documentation for Certificate Programs and Non-Degree Seeking Applicants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Each applicant must submit the following items, constituting a complete application package, to the Admissions Office:</td>
</tr>
<tr>
<td>• A completed online application form.</td>
</tr>
<tr>
<td>• An official transcript from the institution which granted the highest degree. In the event that the applicant holds equivalent level higher degrees, the most recently awarded degree transcript is required.</td>
</tr>
<tr>
<td>• AFIT exists within the framework of the United States Air Force; therefore, with the exception of international military officers sponsored by their governments, all U.S. government civilian employees and civilians employed by certain defense industry contractors, must provide proof of U.S. citizenship prior to being admitted to the AFIT Graduate School.</td>
</tr>
<tr>
<td>• For certificate and non-degree-seeking applications some programs have specific prerequisite course(s) that are required for admission. If the prerequisite courses do not appear on the highest degree granting transcript, the applicant must also provide official transcripts from the school(s) where the prerequisite courses were completed.</td>
</tr>
<tr>
<td>• Admissions tests (GRE/GMAT) are not required for certificate programs and non-degree-seeking applicants.</td>
</tr>
</tbody>
</table>

## International Military Officers

The International Military Student Office at AFIT assists international military officers and international government civilian employees with the procedures of applying for admission to the AFIT Graduate School of Engineering and Management. Prospective international military students and international government civilian employees must apply for admission to the AFIT Graduate School of Engineering and Management through the United States Security Assistance Office (SAO) at the United States (US) Embassy in their home country.
Registrar and Student Operations

Application Process for International Military Officers

Application packages for admission eligibility should arrive at the AFIT Graduate School's International Student Military Office no later than 31 March of each year, in preparation for entrance to the AFIT Graduate School the following September. The international military officer seeking admission to the AFIT Graduate School must have the following documents submitted:

1. Official academic transcripts, either in English or accompanied by an English translation, from every academic institution attended. The AFIT Graduate School strongly recommends that all official academic transcripts be accompanied by a foreign course-by-course credential evaluation by an independent evaluation service that is a member of the National Association of Credential Evaluation Services (NACES) in order for courses to be considered for credit at the AFIT Graduate School. In order for it to be considered official, the course-by-course evaluation must be sent directly from the NACES-affiliated evaluation service to the AFIT Graduate School or to the United States Security Assistance Office (SAO) at the United States Embassy in the international military officer's home country. A full list of NACES members is available online at http://www.naces.org/members.htm. NACES members charge a fee for their services and applicants are responsible for the payment of that fee.

2. The Test of English as a Foreign Language (TOEFL) is required for all international military officers except as noted below. Two TOEFL's are acceptable, the Internet-Based Testing with a minimum TOEFL score of 76, or under Computer-Based Test, a minimum score of 207 is required for admission to the AFIT Graduate School. A satisfactory command of the English language is required for admission to the AFIT Graduate School. Therefore, international military officers from non-English speaking countries are required to validate their fluency in English through the Test of English as a Foreign Language (TOEFL). The Defense Security Assistance Agency (DSSA) publishes an exemption list annually and these countries are exempted from the TOEFL requirement: Antigua, Australia, Bahamas, Barbados, Belize, Brunei, Canada, Dominica, Grenada, Guyana, India, Ireland, Jamaica, Malta, Mauritius, Netherlands, New Zealand, Norway, Singapore, St. Kitts, St. Lucia, St. Vincent, Trinidad, and the United Kingdom. Students from Pakistan and Kenya scheduled for senior Professional Military Education courses are also exempt from the TOEFL requirement.

3. An official score report from the Graduate Record Examination (GRE) or, if applicable to the particular program, the Graduate Management Aptitude Test (GMAT). The recommended GRE scores for a master's program are 153 verbal and 148 quantitative (or 500 verbal and 600 quantitative if taken prior to 1 Aug 2011). The recommended GMAT score is 550.

4. For doctoral programs, GRE scores of at least 156 verbal and 151 quantitative (or 550 verbal and 650 quantitative if taken prior to 1 August 2011) or a GMAT score of 650 or higher. The Educational Testing Service will be updating the GRE percentile ranks, and possibly the test scores, after 1 July 2012, thus our GRE scores may change. The GMAT is only accepted in certain programs or not at all. Thus, taking the GRE is highly recommended, as it is accepted by all departments.
Registrar and Student Operations

Send all score reports (GRE, GMAT, TOEFL) to this school identification code; 1827.

Applications for any master’s degree program will be considered by the Graduate School of Engineering and Management if GRE/GMAT scores are less than the scores published above, or not available, however the applicant’s academic record and TOEFL scores must be exceptionally strong. In addition, the academic departments reserve the right to ask for either test (GRE/GMAT) prior to making an admission decision. Thus, if the applicant chooses to submit an application without a GRE or GMAT it should be submitted no later than 1 March in the year of the desired program start date.

Doctoral program applicants must include all of the above documents. For required doctoral program test scores, see the Eligibility Criteria – Doctoral Degree section above. In addition, doctoral applicants must provide a clear and concise statement describing the area in which the student intends to concentrate his or her studies. Doctoral and IDE students cannot be admitted without a GRE (or GMAT if applicable to program).

Waivers to the above admission standards may be granted on an individual basis at the discretion of our faculty. Therefore, individuals whose academic credentials fall below any of the above entry criteria are encouraged to apply for a graduate program. Applicants who do not meet these criteria may be conditionally admitted and/or the department may grant individual waivers to the entrance requirements.

Applicants, such as military personnel, international military officers, and civilians who apply for full-time graduate study under the sponsorship (full pay and allowances) of a military service or government organization, but fall short of the admission standards mentioned above may be admitted after a department review. Applicants who are accepted under these circumstances may be entered into a program that is longer than the nominal 18-month program length. The longer programs will include courses designed to remedy academic deficiencies and/or provide additional background preparation.

Other applicants who do not meet the standard admission criteria or receive a waiver may be able to enroll on a conditional basis. Full admission as a degree-seeking student is granted upon successful completion of the conditions set forth in the applicant’s admission letter.

The GRE (or GMAT, if applicable) is required for admission unless waived by the academic department. The Graduate School of Engineering and Management may evaluate applications for admission to master’s degree programs for active duty service members who have not taken the GRE (or GMAT, if applicable), provided the request to do so is made by their personnel agency based upon official agency needs.
Registar and Student Operations

Full Admission

Students admitted to full (or unconditional) degree-seeking status must have submitted official transcripts from each college or university attended, and at least one of those official transcripts must indicate conferral or award of a baccalaureate or master's degree from a regionally accredited institution. Submission of GRE, or GMAT scores as appropriate to the program requested, and be judged qualified for the degree program requested by the applicable academic department and the Graduate School of Engineering and Management.

For applicants seeking admission as non-degree-seeking students or into certificate programs, GRE/GMAT scores are not required. Also, see the "Required Documents" section regarding transcript submission requirements for these categories of applicants. In all cases (degree-seeking, certificate program, and non-degree-seeking), the student has met all the general requirements of the Institute and the specific program requirements of the department in which the student plans to pursue study.
Conditional Admission

Students may be admitted to conditional status because:

The applicant has not graduated from their undergraduate or master's program, yet is expected to do so within 9 months.

The applicant has not provided all official documents required by the graduate program or the Graduate School. For example, the applicant has completed the baccalaureate degree and/or the master's degree, but has yet to submit official verification of the last term's work and/or receipt of the degree. All official documents must be submitted prior to the completion of the first term of study; otherwise, the student will not be allowed to enroll in further coursework.

The applicant has majored in another field with a creditable record but has not yet clearly demonstrated abilities in the proposed new field.

The prerequisite coursework in the chosen field is insufficient.

The previous academic record is borderline (e.g. low cumulative GPA, low GRE/GMAT scores, etc.).

A student, while in conditional degree or conditional non-degree status due to academic issues, must meet the conditions set forth by the faculty in a predetermined time-frame prior to being fully accepted into a degree program. A student who fails to meet the academic conditions will not be allowed to continue studies in an advanced degree program. In the case of missing information, the student must submit all required official documentation (undergraduate and/or graduate degree transcripts and/or test scores) by the end of the first term of study. Otherwise, the student will not be allowed to register for courses in subsequent quarters and, depending on the situation, grades for completed classes will not be released.

Air Force personnel seeking an Advanced Academic Degree assignment are not offered conditional admission. The AFPC needs to know whether or not the service member will mostly likely succeed in their studies and graduate prior to selection for assignment. The Graduate School does, on a case-by-case situation, offer AF personnel extended length options.
Registrar and Student Operations

Change of Enrollment Status
Non-degree or certificate-seeking Graduate School of Engineering and Management students who wish to become degree-seeking students must submit an application for the new program through the Admissions Office (https://www.afit.edu/Admissions/AFITApplicationProcess/). Students requesting such a change must also meet the program entry requirements and provide all required documents, to include test scores, as necessary for full acceptance into a degree or certificate program. The academic department will determine the number of Graduate School course hours, or classes, of prior coursework it will accept based upon admission to the new program. The student will coordinate this with his/her academic advisor and the department. The department will notify the registrar of its decision.

Termination
Admission status will terminate for students (excluding service sponsored military personnel) who are admitted either conditionally or unconditionally, that do not enroll in any course within one year of the term for which admission was requested. For all students, both degree and non-degree seeking, who have taken at least one course, continuation in their enrollment status is at the discretion of the academic department, the chair of the graduate program, and the Dean of the Graduate School, consistent with the policies and practices of the Graduate School and the graduate program. Also see "Probation and Dismissal" under the Academic Information section of this catalog.
# AFIT Student Association

The AFIT Student Association (ASA) is a student-run, private, non-profit organization established to provide advocacy and services to AFIT graduate program students.

## Membership
All AFIT students in graduate programs (resident or nonresident, full-time or part-time, master's or doctoral) are members of the ASA.

## Purpose
To serve students by providing information on programs and events directly related to morale and services.

## Point of Contact
afit.asa@afit.edu

## More Information
The student association web page contains information on student events and a means to contact the current leadership with questions and/or ideas.  
https://www.facebook.com/AFITStudentAssociation/info
AFIT's School of Engineering and Management offers a growing number of graduate-level distance learning (DL) programs to U.S. Government customers, who can benefit from the institution's educational opportunities and expert faculty without having to enroll in a resident campus program. Generally speaking, AFIT DL programs use streamable and downloadable course lectures, accessible via the Internet. Most courses also have weekly webinars or teleconferences to augment these lectures. Hence, save for a couple of hours per week, all the coursework can be completed as scheduled by the student; the only hardware requirements are a telephone, webcam, and internet-capable computer with a high-speed connection. (Because many courses rely heavily on recorded videos, you may need something larger than a smart phone to successfully complete these programs.)

The Graduate School’s Office of E-Learning Support provides administrative support for distance learning programs offered by the Graduate School. For more information about these educational opportunities, you may:

• Visit the office's webpage at http://www.afit.edu/DL/
• Send an email to en.dl@afit.edu or
• Contact the Office of E-Learning Support by phone at (937) 255-3636 x7422 (DSN 785-3636)

Currently, the Graduate School offers five master’s degree programs and four graduate certificate programs via DL. These programs are listed below.

### Certificate Programs (4)
- Human Systems Engineering
- Systems Engineering
- Test and Evaluation
- Nuclear Weapons Effects, Policy, and Proliferation (NWEPP)

### Master's Degree Programs (5)
- Applied Systems Engineering
- Electrical Engineering - Guidance, Navigation & Control
- Engineering Management
- Logistics
- Systems Engineering

### Application and Enrollment Information
Admission to some programs requires department approval in addition to meeting the admissions criteria. See our website for more details.
More information about the programs, including application process, can be found at AFIT's E-Learning Support website:
http://www.afit.edu/DL/
## Library Services

**Dr. Ellis Beteck, Director**  
AFIT/ENWL  
2950 Hobson Way, Bldg. 642, Room 1400B  
Wright-Patterson AFB, OH 45433-7765  
Phone: (937) 255-3005 (DSN: 785- 6565 x4216)  
Fax: (937) 656-7746  
Website: http://www.afit.edu/library/

<table>
<thead>
<tr>
<th>Mission Statement</th>
<th>The primary mission of The D’Azzo Research Library is to support the educational, research and consulting programs of AFIT and AFRL.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>The D’Azzo Research Library is housed in a centrally located, 40,000 sq. ft. facility. The library also maintains a 6,000 sq. ft. annex facility that stores retrospective journal titles. A reserve room contains materials selected by faculty for students to use in conjunction with their courses. The facility features 12 student seminar rooms, two conference rooms, and a computer classroom with 20 public workstations. An additional 26 public workstations are located throughout the library, and 24 networked computers are on the second floor for student and faculty use.</td>
</tr>
</tbody>
</table>
| Over a Million Items | In the aggregate, the library collection numbers more than a million items.  
- The book collection primarily has print titles and a growing collection of ebooks that support the curricular subject areas of aeronautics and astronautics, electrical and computer engineering, physics, mathematics and statistics, operational sciences, and systems engineering and management.  
- The library holds or has access to paper and electronic foreign and domestic journal subscription titles covering the social, basic, and applied sciences.  
- A comprehensive collection of conference reports, proceedings, and transactions is available to library users. These reports are available in paper, electronic and multiple micro-formats.  
- The library manages the AFIT Scholar repository, a collection of digital content generated by AFIT students, faculty and staff. AFIT theses, dissertations and publications are included.  
- A small collection of non-print media is available including CDs, DVDs and audio materials.  
- The Reference collection contains standard and specialized reference works that support the AFIT curriculum. |
## Library Services

- Various materials relating to AFIT history, including annual histories, accreditation reports, inspection reports and other special reports dating back to 1919, are held in the AFIT archival collection in the library.

### Access to resources

AFIT maintains subscription and license agreements for databases and journals that support AFIT curricular and research requirements.


A complete list of databases and journals is available at: http://afit.libguides.com/az.php

Students, faculty and staff may use the library's interlibrary loan service to request materials that are not owned by The D'Azio Research Library. Registration for an interlibrary loan account is available on the library homepage.

### Library instructional classes provided

Orientation programs and instructional classes on the use of library resources are provided to students and faculty throughout the year. Library liaisons are appointed to each major school and graduate department to ensure that students and faculty have a personal contact who can direct them to library resources required for their research.

### Consortia Memberships

The D'Azio Research library is a member of the On-Line Computer Library Center (OCLC), an on-line bibliographic and interlibrary loan provider that enables the identification and retrieval of library and research materials on an international basis. The library also has a representative on the Library Council for SOCHE (Southwest Ohio Council for Higher Education), a consortium of more than 22 colleges in southwest Ohio that collaborate on the education, employment and engagement of students and faculty in the area. Wright State University and the University of Dayton, the area's largest academic libraries, provide Institute faculty members and graduate students with borrowing privileges.
Financial Assistance

Ms. Amber L. Richey, Director, Financial Management

AFIT/FM
2950 Hobson Way, Building 643, Room 209
Wright-Patterson AFB, OH 45433-7765
Phone: (937) 255-8400 x3611 (DSN 785-8400 x3611)
Fax: (937) 656-4775 (DSN) 986-4775
E-mail address: amber.richey@us.af.mil

Students assigned to the Graduate School of Engineering and Management by the U.S. Air Force and other military organizations through the Air Force Education Requirements Board (AFERB) to pursue degrees full time incur no financial liability with regards to tuition.

Effective 1 October 2014, AFIT will allow Air Force military and civilian personnel, whose education is not sponsored by the Air Force, the opportunity to enroll tuition free on a space-available basis. Students are required to submit the Bursar Form located on the website. As per the 88th FSS/FSDE Installation Training Guide, Section 7.11, even when no tuition costs are involved the SF 182 is required for all training requests of eight hours or more of class time (not credit hours). Please check with your Unit Training Manager or Base Education Office for details.

Please forward a copy of your Registration Form and Approved Funding Documentation (i.e. SF 182, SMART Acceptance letter) to the AFIT Bursar before the beginning of classes.

AFIT/FMA
ATTN: Bursar
Bldg 643, Room 209
2950 Hobson Way
Wright-Patterson AFB OH 45433-7765
937-255-8400 x3623 DSN 785-8400 x3623
marzena.kluska-maier@afit.edu or Bursar@afit.edu

Tuition Rates
All rates are subject to change. Contact the Bursar for current rates.

Refund Policy
Tuition refunds will be handled by DFAS. Once AFIT receives word that a student has withdrawn from class, we will notify DFAS and a refund will be processed. Tuition refunds for Residential Students will otherwise be limited according to the following schedule:

- Prior to and during the first week of classes 100%
- During the second and third weeks of classes 70%
- After completion of the third week of classes 0%
## Financial Assistance

<table>
<thead>
<tr>
<th>Financial Assistance</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Research Assistantships (RA)</td>
<td>The Air Force Institute of Technology engages the services of Research Assistants who are pursuing a degree at other academic institutions through a contract with the Southwestern Ohio Council for Higher Education (SOCHE). Civilian students must be US citizens. To request additional information contact Ms. Maggie Varga, (937)258-8890 or e-mail <a href="mailto:Maggie.Varga@soche.org">Maggie.Varga@soche.org</a></td>
</tr>
<tr>
<td>Tuition Assistance</td>
<td>AFIT will no longer accept Tuition Assistance.</td>
</tr>
<tr>
<td>VA Education Benefits</td>
<td>Students can use their VA Education Benefits. Contact the Admission’s office for more details.</td>
</tr>
</tbody>
</table>
Computer Support

Darold Froemming, Maj, USAF, Director, Communications and Information

AFIT/SC
2950 Hobson Way, Building 642, Room 220
Wright-Patterson AFB, OH 45433-7765
Phone: (937) 255-6565 x4228 (DSN 785-6565 x 4228)
Fax: (937) 656-7080 (DSN 986-7080)
E-mail address: afit.sc@afit.edu
Website: http://www.afit.edu/help.cfm

Mission Statement
Air Force Institute of Technology's (AFIT) Directorate of Communications and Information (SC) provides a broad range of information resources and services to the students, faculty and staff of AFIT. Services provided by SC include network and voice communications, central and end-user computing support, information systems planning and support, Campus Help Desk, applications development, visual information support and information management. Additional information can be found at: http://www.afit.edu/help.cfm.

Student, Staff and Faculty Support
SC establishes computer accounts for every enrolled student, faculty and staff member following their verified security training. These accounts enables users access to electronic mail (e-mail), software applications, information and database storage and retrieval, network access and similar functions necessary for the conduct of classes and other mission needs. Accounts are to be used for AFIT related and official government business only by the person assigned the account. Most students will automatically be assigned a computer account upon arrival through SC's coordination with the Directorate of Admissions/Registrar. If you have not been automatically assigned a computer account, you'll need to submit a request to the AFIT Help Desk, through your faculty advisor.

Scientific workstations and computer programs available
AFIT’s computing capabilities include a variety of mathematical, statistical, simulation and modeling applications available on various Unix-, Linux- and Intel-based platforms. There is also a wide array of programming languages for use while completing class projects, assignments, theses and research projects. Over 300 dual/dual core - processor workstations throughout AFIT provide access to these applications and programming languages.

Help for computer concerns
In addition to the scientific workstations, AFIT also maintains over 2,000 desktop and notebook computer systems for general office automation functions such as e-mail, word processing, spreadsheet, database, and presentation software. Assistance and problem resolutions are available through the Campus Help Desk during normal duty hours. High-speed black-and-white and color laser printers for hard copy output are readily available for coursework and thesis production.
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Computer Support
Internet access

Internet access options are abundant. In addition to global e-mail capability, the
Institute offers Internet and World Wide Web browsing applications, plus Secure Shell
File Transfer Protocol and Secure Shell Telnet capability for research collaboration
and data sharing. Additionally, secure VPN remote access is available for authorized
users requiring access from home or other off-site locations. Also, campus wide
wireless is available for authorized users. Our remote access capabilities permit access
to private data storage areas, e-mail, the Internet and other services. You can also
access your voice mail messages from home or while traveling.

Additional research
computers available

AFIT is a member of the Ohio Higher Education Computing Council (OHECC) and
the Ohio Academic Research Network (OARNET). Authorized students and faculty
also have access to the supercomputing facilities at Wright-Patterson AFB's Major
Shared Resource Center (MSRC)

50


Aeronautics and Astronautics (ENY)

Department Head: Bradley S. Liebst, PhD
2950 Hobson Way Building 640, Room 349
Wright Patterson AFB OH 45433-7765
Phone: (937) 255-3069 (DSN 785-3069)
Fax: (937) 656-7053 (DSN 986-7053)
E-mail address: eny@afit.edu
Website: https://www.afit.edu/ENY

The Department of Aeronautics and Astronautics, Air Force Institute of Technology (AFIT) provides educational expertise (through the doctoral level) in Aeronautical Engineering, Astronautical Engineering, Materials Science, Space Systems, Mechanical Engineering, and Engineering Mechanics. The major departmental effort is devoted to teaching and research in support of programs leading to the Master’s degree in the first four of these program areas and Doctoral studies in any area of departmental activity. The Master of Science programs in Aeronautical Engineering and Astronautical Engineering are accredited by the Accreditation Board for Engineering and Technology (ABET). The North Central Association of Colleges and Universities accredits all other Masters level degree programs.

Facilities

The Department of Aeronautics and Astronautics is equipped with Laboratories for the study of fluid mechanics, solid mechanics, and system dynamics and control. Laboratory facilities specifically support lecture courses, laboratory courses, faculty research, and student thesis research at Master, PhD, and postdoctoral levels.

The laboratory facilities are comprised of general instrumentation and equipment, which are shared by a variety of facilities. These research facilities are dedicated to specific research topics and have unique equipment and instrumentation requirements.

The facilities are housed in two different buildings. Building 640 has 13,000 square feet of general laboratory facilities, including the computational dynamics and design laboratory which is equipped with high-performance Linux workstations and access to local Linux-based computer clusters. Building 644 has 5246 square feet of laboratory space housing a 44” x 31” wind tunnel, 5 kip shaker with digital controller, Simulated Satellite (SIMSAT II), vibration lab, an instrumentation lab, high pressure shock tube facility, 9 inch low velocity wind tunnel, and turbine cascade facility, among other facilities. A new Additive Manufacturing Laboratory was added in early 2017 in Building 644. Additionally, partnerships with base organizations have permitted shared use of space for ballistics research and weapons testing.

Support instrumentation and sensors include: digital data acquisition systems, Schlieren, Moire, shadowgraph, high speed video recording equipment, one- and three-component laser velocimeter, hot wire anemometers with linearizers and signal conditioners, optical equipment, modal analyzers, frequency spectrum analyzers, multi-port pressure measuring systems, material test and characterizations facility, material preparation facility, and a full range of transducers (temperature, force, pressure, acceleration, displacement).

The fixed facilities include air and electrical supplies. A dry oil-free 100 psi (1000 ft3), 250 psi (800 ft3) and 2,500 psi (44 ft3) air supplies are available in Building 640. There are also two overhead electrical buss bar systems that include 440-volt three-phase and 220-volt three-phase.
Aeronautics and Astronautics (ENY)

Programs

Master of Science

• Aeronautical Engineering (M.S.)
• Astronautical Engineering (M.S.)
• Materials Science (M.S.)
• Space Systems (M.S.)

Doctor of Philosophy

• Aeronautical Engineering (Ph.D.)
• Astronautical Engineering (Ph.D.)
• Materials Science (Ph.D.)

Certificate

• Space Systems Certificate

Faculty

Distinguished Professor
Anthony Palazotto structural mechanics

Professor
Paul I. King propulsion and aerodynamics
Bradley S. Liebst dynamics and control
Shankar Mall structures and materials
Marina B. Ruggles-Wrenn structures and materials
William E. Wiesel astrodynamics

Associate Professor
Jonathan Black structural dynamics and control
Richard G. Cobb structural dynamics and control
Robert B. Greendyke fluid dynamics, physical chemistry, air weapons
Donald L. Kunz dynamics and control
Marc D. Polanka heat transfer and propulsion
Mark F. Reeder fluid dynamics

Assistant Professor
Jeremy S. Agte dynamics and control
Bradley J. Ayres dynamics and control
Michael J. Caylor dynamics, systems and control
Frederick Harmon dynamics and control
Carl R. Hartsfield propulsion and air weapons
Kevin J. LaRochelle solid mechanics and structures
David Liu propulsion and air weapons
Christopher L. Martin fluid dynamics and heat transfer
# Aeronautics and Astronautics (ENY)

<table>
<thead>
<tr>
<th>Name</th>
<th>Specialty</th>
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<tr>
<td>Timothy C. Radsick</td>
<td>solid mechanics and structures</td>
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<td>James L. Rutledge</td>
<td>fluid mechanics and heat transfer</td>
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<td>Ronald J. Simmons</td>
<td>propulsion and dynamics</td>
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<td>Eric Swenson</td>
<td>solid mechanics and structures</td>
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<td>Professor Emeritus</td>
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<td>Delmar W. Breuer</td>
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<td>Robert A. Calico</td>
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<td>William C. Elrod</td>
<td>propulsion</td>
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<td>Milton E. Franke</td>
<td>aerodynamics, propulsion, and weapons</td>
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<td>Andrew J. Shine</td>
<td>fluid dynamics</td>
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<td>Peter J. Torvik</td>
<td>dynamics</td>
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Aeronautics and Astronautics (ENY)

Aeronautical Engineering (M.S.)*

Program Description
The Graduate Aeronautical Engineering program is a fully accredited program, leading to a Master of Science degree in Aeronautical Engineering. This program is designed for students from all branches of the U.S. military services as well as students from allied foreign military services, civilians and part-time students. Air Force quota students normally enter as a class in September and are scheduled to graduate in March after 18 months of study. Program entry date and length may vary for other students. See Department Brochure for further details: www.afit.edu/ENY/

Program Educational Objectives (PEOs)
- Our graduates will make direct contributions as practicing engineers in the area of aeronautical engineering
- Our graduates will effectively communicate, evaluate, monitor and administer aeronautical research and development programs
- Our graduates will solve new technological challenges to meet the needs of the Air Force and other DoD organizations

Student Outcomes (SOs)
- GAE graduates will demonstrate the ability to perform independent research, resulting in substantial contributions to the field of aeronautical engineering
- GAE graduates will demonstrate the ability to effectively communicate complex ideas and concepts both orally and in writing
- GAE graduates will be able to perform research that provides substantial and tangible value to the DoD

Program Elements
- Core Aeronautical Engineering
- Mathematics (2)
- Specialty Sequences (2)
- Independent Investigation (i.e., Thesis Research)
- Electives
- 48 graduate quarter hours, minimum

See Department Brochure for further details regarding each of the above program elements.

School and Program Admission Criteria
DEGREE REQUIRED: Aeronautical, Astronautical, Aerospace, Mechanical, Systems Engineering or Engineering Mechanics from USAFA. Must have graduated from an ABET program.

MATHEMATICS REQUIRED: Ordinary Differential Equations

TEST REQUIRED: GRE - 153V/148Q

GPA REQUIRED: OVERALL - 3.0; MATH - 3.0; MAJOR - 3.0

Waivers to the above criteria may be granted on a case by case basis. Therefore, individuals whose academic credentials fall below any of the above criteria are encouraged to apply.
Aeronautics and Astronautics (ENY)

Degree Requirements

This program adheres to the general requirements for the MS degree established by the AFIT Graduate School of Engineering and Management. For more complete information and for the final authority on these requirements, the reader should consult Graduate School of Engineering and Management Operating Instruction (ENOI) 36-135, “Requirements for the Master of Science Degree,” and ENOI 36-135, “Degree Requirements for Two Masters’ Degrees.” Degree requirements are 48 credit hours; however, the 6- quarter in-residence MS program normally includes a minimum of 72 quarter hours (12 hours per quarter is considered full-time status). The requirement for 72 hours may be waived only by approval of the department head and the dean.

Core Aeronautical Engineering

Each student who graduates with a Master of Science in Aeronautical Engineering must have a broad foundation in the theoretical and applied aspects of the fundamental disciplines of aeronautical engineering. This department offers courses in five aeronautics disciplines: 1) aeronautics, 2) aircraft stability and control, 3) air breathing or rocket propulsion, 4) structures and materials, and 5) air weapons. The department requires that each student take at least one department-offered course from three of the five disciplines.

Mathematic Courses

Each student must complete at least two graduate level courses containing a major emphasis in mathematics or statistics. This requirement can be satisfied by taking two courses offered by the Department of Mathematics and Statistics or one course from the same, plus a second course approved by the Department of Aeronautics and Astronautics. The department-approved second course may also be used simultaneously in satisfying other degree requirements.

Specialty Sequences

Each student is required to take two specialty sequences. Each of these three-course sequences form a coherent body of knowledge in a particular area and provide the student with a strong theoretical background for thesis work and post-graduate assignments.

Thesis

Each student is required to complete an independent investigation of a problem of current DoD interest. This investigation is conducted and documented by the student, with supervision of the faculty, then presented orally and in written form as a formal thesis. The thesis carries 12 credit hours, is graded, and contributes to the student's grade point average. See Department Brochure for details regarding thesis policies, procedures and requirements for AFIT and the Department of Aeronautics and Astronautics.

AERO 799 - Independent Study

An in-depth study of a research topic selected from variety of problems of current interest to the Air Force, with the results presented in a formal thesis written under the supervision of a departmental professor.

Instructional Method Thesis
Min Hours 1
Max Hours 12
Aeronautics and Astronautics (ENY)

TENY 799 - Thesis Completion

Thesis Completion course for graduating students to be taken during the last quarter of study. Registration in TENY 799 for 12 non-billable credit hours is required for all Master’s students whose research advisors are in the Department of Aeronautics and Astronautics. The grade assigned to this course is the official thesis grade.

Instructional Method Thesis
Min Hours 12
Terms Offered All

ABET Core

The Accreditation Board for Engineering Technology (ABET) specifies general program outcomes and professional components for Aeronautical Engineering; and the American Institute of Aeronautics and Astronautics (AIAA), acting as the lead society for ABET, specifies required course topics. The general ABET criteria are usually satisfied by any ABET-accredited undergraduate engineering program, while specific topics are usually only satisfied by an aeronautics or aerospace engineering undergraduate program. In order for students to graduate with an ABET-accredited degree, each student's transcript is examined to identify any deficiencies in the general and/or specific core aeronautical engineering areas. Those deficiencies can then be remedied by taking specific courses offered by the department.
Aeronautics and Astronautics (ENY)

Aeronautical Engineering (Ph.D.)*

Program Description

Students are admitted to a study leading toward the PhD degree in Aeronautical Engineering with a concentration in one of the three major divisions of the Department of Aeronautics and Astronautics. A pre-tem advisor will be appointed by the Department to assist each full-time student in program planning. Additionally, each fully-funded officer student has an educational code, the requirements of which are to be met within the appropriate division. See Department Brochure for additional details: www.afit.edu/ENY/.

Typically, a PhD degree program in the Department consists of two phases:

PHASE ONE: Course work and examination period of 6 academic quarters. All requirements for admission to candidacy (course work, examinations, and approval of research prospectus) are met.

PHASE TWO: Dedicated to research. This phase usually lasts 18 - 24 months, and the students devote their full attention to a research problem investigated under the direction of an approved member of the faculty of the Graduate School of Engineering and Management.

School and Program Admission Criteria

DEGREE REQUIRED: Requires Master’s degree in Astronautical, Aeronautical, Mechanical, or Systems Engineering.
GRE REQUIRED: 156V/151Q
GPA REQUIRED: 3.50 (MS); 3.00 (BS)

Additionally, it is desirable for applicants seeking admission to the Department's PhD program to have successfully completed a MS thesis and obtained endorsement by their MS faculty, especially the MS thesis advisor.

Waivers to the above criteria may be granted on a case by case basis. Therefore, individuals whose academic credentials fall below any of the above criteria are encouraged to apply.

Degree Requirements

Major - 24 hours
Mathematics - 12 hours
Dissertation Research - 48 hours
Admission to candidacy - One year before graduation
In-residence study - 3 successive quarters
Present Dissertation at a Public Defense
Aeronautics and Astronautics (ENY)

Astronautical Engineering (M.S.)*

Program Description

The Graduate Astronautical (GA) Engineering program is a fully accredited program, leading to a Master of Science degree in Astronautical Engineering. The discipline of Astronautical engineering is dedicated to the design, testing and development of spacecraft, missiles, launch vehicles and related systems. Air Force quota students normally enter as a class in September and are scheduled to graduate in March after 18 months of study. Program entry date and length may vary for other students. See Department Brochure for further details: http://www.afit.edu/ENY/

Program Educational Objectives (PEOs)

- Make direct contributions to the area of astronautical engineering as a practicing engineer
- Successfully evaluate, monitor, and administer astronautical research and development projects
- Use an AFIT education to approach and solve new technical challenges to meet the needs of the Department of Defense

Student Outcomes (SOs)

Graduates of the GA program will:
- Apply sound engineering principles to solve Air Force and DoD problems
- Communicate technical information, via oral presentations and written documents, to a wide range of audiences, including engineering professionals and senior military officers
- Understand the principles of orbital mechanics. Graduates will be able to describe Keplerian motion, major perturbations to Keplerian motion, and be able to plan orbital maneuvers
- Prepared to describe and discuss significant aspects of the space environment and their effect on Earth-orbiting spacecraft
- Model spacecraft attitude dynamics and synthesize control laws to control spacecraft attitude. Graduates will understand transformations due to coordinate frame translation and rotations
- Have a basic understanding of modern communication principles as they relate to satellite communications. Graduates will recognize methods of modulation, multiplexing, and encoding. Graduates will be able to perform simple link margin analyses needed to establish initial design requirements
- Prepared to describe essential features of rocket propulsion including: performance parameters, propellant types, rocket staging, and fluid mechanics as it pertains to rocket propulsion
- Conduct basic analyses of space structures including deformation from tension, torsion, shear, and bending
- Basic understanding of the remote sensing process, and be able to recognize key concepts relating to optical systems, imaging, spatial and spectral resolution, and atmospheric absorption and scattering

Additional Information

The Graduate Astronautical Engineering program provides the student with a broad education in the scientific and engineering disciplines associated with Astronautical Engineering, as well as in-depth study in selected specialty areas.

The program’s core courses are designed to ensure graduates have a solid foundation in the areas of orbital
Aeronautics and Astronautics (ENY)

mechanics, space environment, attitude determination and control, telecommunications, remote sensing, space structures, and rocket propulsion. Specialty sequences are available in, but not limited to, these important aspects of astronautical engineering.

The program leads to a Master of Science in Astronautical Engineering degree (ABET accredited). Students entering this program should possess an ABET undergraduate degree in a related engineering discipline such as aeronautical, astronautical, aerospace, or mechanical engineering. Students without the appropriate technical background may wish to consider the department’s Graduate Space Systems degree program. A special program in space facilities is offered for officers in the Civil Engineering career field to prepare them for roles in the development and operation of launch facilities and large permanent space facilities.

School and Program Admission Criteria

DEGREE REQUIRED: Aeronautical, Astronautical, Aerospace, Mechanical, Systems Engineering or Engineering Mechanics from USAFA.
MATHEMATICS REQUIRED: Ordinary Differential Equations
TEST REQUIRED: GRE - 153V/148Q
GPA REQUIRED: OVERALL - 3.0; MATH - 3.0; MAJOR - 3.0

Waivers to the above criteria may be granted on a case by case basis. Therefore, individuals whose academic credentials fall below any of the above criteria are encouraged to apply.

Degree Requirements

Core Courses

Each student who receives a Master of Science in Astronautical Engineering must have a foundation in the theoretical and applied aspects of the fundamental areas of astronautical engineering. These areas, and associated program outcomes, are specified by the Accreditation Board for Engineering Technology (ABET). Expected outcomes include competency in orbital mechanics, space environment, spacecraft attitude determination and control, telecommunications, space structures, space-related design, and rocket propulsion. A course in sensor systems is also required for all Air Force students.

Not all Master’s students are required to take courses in each of these areas to complete the GA program. Prior to beginning their program, it is the dual responsibility of the student and faculty advisor to identify areas in which the student’s undergraduate degree does not satisfy ABET core requirements and ensure their graduate program will cover any deficiencies. Faculty advisors will evaluate undergraduate transcripts to determine the applicability of undergrad courses in meeting requirements, and will prepare an ABET degree form to document that each student will meet all ABET requirements upon satisfactory completion of their education plan.

In addition to meeting ABET core requirements, students are required to meet all GA Core requirements listed in the Department Brochure. These classes can be used to simultaneously meet other degree or ABET requirements. Students are strongly encouraged to take as many of the ABET courses as possible even if they have taken undergraduate courses in these areas. The graduate courses often go beyond similar undergraduate courses in these subject areas, and are designed to provide a strong academic foundation for anyone planning a career in a space-related field.
Aeronautics and Astronautics (ENY)

Mathematic Courses

Each student must complete at least two graduate-level mathematics courses. The particular courses each student takes are based upon background and area of specialization.

Nearly all students take math courses that cover the following topics: advanced calculus, complex variables, Fourier series, Laplace transforms, boundary value problems, linear algebra, numerical methods, and probability/statistics. Two courses specifically designed to cover most of these topics are: MATH 511 - Methods of Applied Math I and MATH 513 – Methods of Applied Math II. See Department Brochure for details regarding other courses complementing the GA curriculum.

Specialty Sequences

Each program must contain two specialty sequences. A specialty sequence, three or more courses in length, is an integrated presentation of a specific technical specialty. Air Force quota students are directed to the Department Brochure regarding the specific requirements imposed upon them by their assigned education specialty code.

Thesis

The thesis is an independent investigation of a problem of current DoD interest, conducted and documented by the student, with supervision by the faculty. The student presents the thesis both orally and in written form, and is graded on the outcome.
Aeronautics and Astronautics (ENY)

Astronautical Engineering (Ph.D.)*

Program Description

Students are admitted to a study leading toward the PhD degree in Astronautical Engineering. A pro-tem advisor will be appointed by the Department to assist each full-time student in program planning. Additionally, each fully-funded officer student has an educational code, the requirements of which are to be met within the appropriate division. See Department Brochure for additional details: www.afit.edu/ENY/

Typically, a PhD degree program in the Department consists of two phases:

PHASE ONE: Course work and examination period of 6 academic quarters. All requirements for admission to candidacy (course work, examinations, and approval of research prospectus) are met.

PHASE TWO: Dedicated to research. This phase usually lasts 18 - 24 months, and the students devote their full attention to a research problem investigated under the direction of an approved member of the faculty of the Graduate School of Engineering and Management.

School and Program Admission Criteria

DEGREE REQUIRED: Requires Master’s degree in Astronautical, Aeronautical, Mechanical, or Systems Engineering.
GRE REQUIRED: 156V/151Q
GPA REQUIRED: 3.50 (MS); 3.00 (BS)

Additionally, it is desirable for applicants seeking admission to the Department's PhD program to have successfully completed a MS thesis and obtained endorsement by their MS faculty, especially the MS thesis advisor.

Waivers to the above criteria may be granted on a case by case basis. Therefore, individuals whose academic credentials fall below any of the above criteria are encouraged to apply.

Degree Requirements

Major - 24 hours

Mathematics - 12 hours

Dissertation Research - 48 hours

Admission to candidacy - One year before graduation

In-residence study - 3 successive quarters

Present Dissertation at a Public Defense
Aeronautics and Astronautics (ENY)

Materials Science (M.S.)

Program Description

The Materials Science program is under the joint supervision of the Department of Aeronautics and Astronautics (Structural Materials) and the Department of Engineering Physics (Non-structural Materials) and is carried out in cooperation with the Materials and Manufacturing Directorate of the Air Force Research Laboratory (AFRL). This program is normally six quarters in length. Five quarters are devoted to coursework, and one quarter is devoted to thesis research.

The program provides core preparation in thermodynamics and kinetics of materials; mechanical, electronic, and optical properties of materials; material characterization; material selection and processing; and mathematics. Each student is also required to take an in-depth study and perform research either in structural materials (metallic, composite, polymer, ceramics, etc.) or non-structural materials (electronics, optical, magnetic, dielectric, coating, etc.). Emphasis is placed on the application of fundamental knowledge to the design, development, test, and evaluation of materials for Air Force systems.

The goal of the Materials Science program is to provide a student who has a background in engineering or physical science with the knowledge of materials science and engineering necessary for work in the fields of structural and non-structural materials for aerospace systems. Such positions may range from those requiring very detailed and advanced level work in a specific discipline to those involving broad responsibilities and requiring interaction among many disciplines.

Program Educational Objectives (PEOs)

The specific goals of the Materials Science program are to produce graduates with:

• A solid background in the fundamental areas of materials science and engineering (structural and non-structural materials, thermodynamics and kinetics, materials characterization, and materials selection and processing)
• An in-depth knowledge in one specialty area
• Experience in conducting and documenting an independent investigation, a thesis, or a problem of Air Force interest

Program Outcomes (POs)

The program outcomes of the Materials Science program describe what students will know or be able to perform upon degree completion:

• Apply engineering principles to solve Air Force and DoD problems
• Communicate technical information, via oral presentations and written documents, to a wide range of audiences including engineering professionals and senior military officers
• Demonstrate knowledge of significant aspects of both structural and non-structural materials used in the current and future aerospace and defense systems
Aeronautics and Astronautics (ENY)

School and Program Admission Criteria

DEGREE REQUIRED: Materials Science, Mechanical Engineering, Chemistry, Physics, or any Engineering degree. All degrees must contain the following courses: Introduction to Materials, Physical Chemistry, and Strength of Materials.

MATHEMATICS REQUIRED: Ordinary Differential Equations

TEST REQUIRED: GRE - 153V/148Q

GPA REQUIRED: Overall - 3.0; Mathematics – 3.0; Major - 3.0

USAF EDUCATION CODES: 4FYY, Materials Science and Engineering, General, and 4FBY, Electronic and Optical Materials

Waivers to the above criteria may be granted on a case-by-case basis. Therefore, individuals whose academic credentials fall below any of the above criteria are encouraged to apply.

Please refer to the latest version of the Department Brochure for complete program details: www.afit.edu/ENY

Degree Requirements

Core Courses

Each student who graduates with a Master of Science (Materials Science) must have a foundation in the theoretical and applied aspects of the fundamental areas of materials. This foundation is laid through a core of courses taken by all materials science and engineering students.

Mathematic Courses

Each student must complete at least one graduate level mathematics course. A second course is highly desirable. The particular courses each student takes are based upon background and area of specialization. Nearly all students take mathematics courses that cover the following topics; advanced calculus, complex variables, Fourier series and boundary value problems, linear algebra, numerical methods, and probability/statistics. Two courses specifically designed to cover most of these topics are: MATH 511 - Methods of Applied Math I, and MATH 513 - Methods of Applied Math II. In addition, students should consider courses in Statistics or Numerical Methods such STAT 527 - Introduction to Probability; STAT 537 - Introduction to Statistics; and MATH 508 - Numerical Methods.

Specialty Sequences

Each student is required to take one such sequence with the option of adding a second. These sequences, each composed of at least three courses, together form a coherent body of knowledge in a particular area and provide the student with a strong theoretical background for eventual applications in thesis work and post-graduation assignments. This sequence is normally dedicated to meeting Air Force requirements for specialized education, as indicated by a student’s advanced-level education specialty code (Ed Code).

Students will enter the GMS program with the following Ed Codes:
4FAY Materials Science and Engineering-Structural Materials
4FBY Materials Science and Engineering-Electronic and Optical Materials
4FYY Materials Science and Engineering-General
Aeronautics and Astronautics (ENY)

Thesis

The thesis is an independent investigation of a problem of current DoD interest, conducted and documented by the student, with supervision by the faculty. The student presents the thesis both orally and in written form, and is graded on the outcome.
Aeronautics and Astronautics (ENY)

Materials Science (Ph.D.) - Structural*

Program Description

Students are admitted to a study leading toward the PhD degree in Materials Science. A pro-tem advisor will be appointed by the Department to assist each full-time student in program planning. Additionally, each fully-funded officer student has an educational code, the requirements of which are to be met within the appropriate division. See Department Brochure for additional details: www.afit.edu/ENY/

Typically, a PhD degree program in the Department consists of two phases:
PHASE ONE: Course work and examination period of 6 academic quarters. All requirements for admission to candidacy (course work, examinations, and approval of research prospectus) are met.

PHASE TWO: Dedicated to research. This phase usually lasts 18 - 24 months, and the students devote their full attention to a research problem investigated under the direction of an approved member of the faculty of the Graduate School of Engineering and Management.

School and Program Admission Criteria

DEGREE REQUIRED: Requires masters degree in Astronautical, Aeronautical, Mechanical, or Systems Engineering.
GRE REQUIRED: 156V/151Q
GPA REQUIRED: 3.50 (MS); 3.00 (BS)

Additionally, it is desirable for applicants seeking admission to the Department's PhD program to have successfully completed a MS thesis and obtained endorsement by their MS faculty, especially the MS thesis advisor.

Waivers to the above criteria may be granted on a case by case basis. Therefore, individuals whose academic credentials fall below any of the above criteria are encouraged to apply.

Degree Requirements

Major - 24 hours

Mathematics - 12 hours

Dissertation Research - 48 hours

Admission to candidacy - One year before graduation

In-residence study - 3 successive quarters

Present Dissertation at a Public Defense
Aeronautics and Astronautics (ENY)

Materials (Ph.D.) - Electronic/Photonic

Program Description

The PhD. program in Materials Science (Electronic and Photonic Materials) is typically 36 months in length (beyond the M.S. degree) with a total of 36 to 60 credit hours plus dissertation. The program is under the supervision of the Department of Engineering Physics with specializations available in various aspects of electronic and optical materials or in the chemistry of materials.

A program of study is largely determined by the areas and depth of knowledge required by the student in order to adequately carry out the research in his or her chosen specialization. Program content and length are embodied in the student's "approved program" and reflect departmental guidelines, as well as the school's doctoral degree requirements.

Program Educational Objectives (PEOs)

- This program is designed to produce graduates broadly educated at the highest level who are capable of actively identifying, conducting, directing, and evaluating materials research at the frontiers of knowledge.
- The successful student should be able to perform duties as a research scientist/engineer and scientific manager in order to develop the basic science and technology base required for new Air Force weapons systems.

School and Program Admission Criteria

DEGREE REQUIRED: A Master’s degree in a physical science or engineering
GPA REQUIRED: B.S., 3.0 or higher; M.S., 3.5 or higher
TEST REQUIRED: GRE - 156V/151Q.
USAF EDUCATION CODES: 4FYY, Materials Science and Engineering, General, and 4FBY, Electronic and Optical Materials

Waivers to the above criteria may be granted on a case-by-case basis. Therefore, individuals whose academic credentials fall below any of the above criteria are encouraged to apply.

Please refer to the latest version of the Department Brochure for complete program details (available upon request).

Degree Requirements

The PhD. degree requirements adhere to standards defined by the Graduate School of Engineering and Management faculty. These basic requirements include completion of at least 36 credit hours of courses, including 24 credit hours in a specialty area, 8 credit hours in math, successful completion of an exam in the specialty area, a prospectus examination, and successful completion of a dissertation. Courses that constitute a program of study will be determined by the Research Advisor and must be approved by the Department Head. A typical program of study will consist of an in-depth sequence of courses at the 6XX, 7XX, and 8XX level and will establish a foundation of knowledge suitable for pursuing dissertation research and meeting general academic expectations for the major area of study.
Aeronautics and Astronautics (ENY)

Space Systems (M.S.)

Program Description

The Graduate Space Systems program is designed to provide officers with a broad knowledge of space systems engineering and space science. Education in the fundamentals of these areas will increase military officer’s effectiveness in planning, executing, and evaluating space systems and operations. Each student completes a research thesis on some aspect of space systems (engineering, science, or operations). The Space Systems graduate is ready to participate actively in organizations responsible for the selection, planning, management, operation, and evaluation of space systems for the DoD. Most graduates will receive a Master of Science (Space Systems); however, students with adequate background may pursue an alternate degree as long as the GSS requirements detailed below are satisfied. Full-time quota students enter as a class in September and are scheduled to graduate in March, approximately 18 months later. Program entry date and length may vary for other students; see Department Brochure for further details: http://www.afit.edu/ENY/

Program Educational Objectives (PEOs)

This program provides the student with a broad education in the scientific and engineering disciplines associated with space systems engineering and space science. Our PEOs are to provide graduates who:

• Make direct contributions to the area of space systems engineering and space science as a practicing engineer
• Successfully evaluate, monitor, and administer space systems research and development projects
• Use their AFIT education to approach and solve new technological challenges to meet the needs of the Department of Defense

Program Outcomes (POs)

• Space Programs: Be knowledgeable about current and past US and international space programs. Understand the objectives of these programs and how they fit into military operations. Understand the basic technical means through which these objectives are achieved
• Spaceflight Dynamics: Understand the physics of orbital mechanics and what impact it has on orbital mission operations. Be able to calculate orbital maneuvers and understand the basics of orbit control in the presence of perturbations. Understand the basics of torque-free spacecraft attitude dynamics
• Satellite Communications: Understand modern communication principles with particular emphasis on applications to satellite and space communication systems including modulation, signals, multiplexing, demodulation, multiple access, coding, look angles, satellite hardware, earth station hardware, and link analysis
• Space Environment: Understand the physics of radiation, particles, and general conditions encountered in space. Understand spacecraft thermal equilibrium, orbit decay, spacecraft charging, space-to-ground communications, atmospheric chemistry, Van Allen belts, and solar phenomena
• Remote Sensing: Attain understanding of the remote sensing process with an emphasis on visible light and infrared systems. Understand the physics of interaction of light with matter, atmospheric absorption and scattering, radiometry, optical systems, spectral and spatial resolution and imaging, and electro-optical detectors
• Spacecraft Engineering: Be knowledgeable of the design issues related to complex space systems. Understand the key elements and subsystems of important classes of space systems. Gain experience with the systematic approach necessary to effectively design space systems through a group design process
Aeronautics and Astronautics (ENY)

School and Program Admission Criteria

DEGREE REQUIRED: BS degree in any discipline that includes: calculus-based general physics, statics and dynamics, differential and integral calculus, differential equations and computer programming. (Typically engineering, physics, or mathematics majors, but other degrees may also meet criteria.).

MATHEMATICS REQUIRED: Ordinary Differential Equations

TEST REQUIRED: GRE - 153V/148Q

GPA REQUIRED: OVERALL - 3.0

Waivers to the above criteria may be granted on a case by case basis. Therefore, individuals whose academic credentials fall below any of the above criteria are encouraged to apply.

Degree Requirements

Core Courses

The core program assures that students have a broad background in the engineering and science of space systems and operations. The core program includes courses in orbit and attitude dynamics, sensor systems, telecommunications, space environment, spacecraft engineering, and space programs.

Mathematics Courses

The mathematics courses provide the student with the tools to perform the quantitative analysis of the engineering, physics and operations courses. At least one math course is required. Additional math courses may be needed as prerequisites for other classes.

Specialty Sequences

A three-course specialty sequence is required for each student. This sequence is intended to provide depth in order to support the thesis effort and/or follow-on assignment requirements. The courses comprising particular specialty sequences are specified in the Department Brochure.

Thesis

The thesis is an independent investigation of a space-related problem of current DoD interest, conducted and documented by the student, under supervision of the faculty advisor. Thesis requirements will be determined by the department of the faculty member serving as the thesis advisor.
Program Description

Students are admitted to a study leading toward the PhD degree in Space Systems. A pro-tem advisor will be appointed by the Department to assist each full-time student in program planning. Additionally, each fully-funded officer student has an educational code, the requirements of which are to be met within the appropriate division. See Department Brochure for additional details: http://www.afit.edu/ENY/

Typically, a PhD degree program in the Department consists of two phases:
PHASE ONE: Course work and examination period of 6 academic quarters. All requirements for admission to candidacy (course work, examinations, and approval of research prospectus) are met.

PHASE TWO is dedicated to research. This phase usually lasts 18 - 24 months, and the students devote their full attention to a research problem investigated under the direction of an approved member of the faculty of the Graduate School of Engineering and Management.

School and Program Admission Criteria

DEGREE REQUIRED: Requires masters degree in Astronautical, Aeronautical, Mechanical, or Systems Engineering.
GRE REQUIRED: 156V/151Q
GPA REQUIRED: 3.50 (MS); 3.00 (BS)

Additionally, it is desirable for applicants seeking admission to the Department's PhD program to have successfully completed a MS thesis and obtained endorsement by their MS faculty, especially the MS thesis advisor.

Waivers to the above criteria may be granted on a case by case basis. Therefore, individuals whose academic credentials fall below any of the above criteria are encouraged to apply.

Degree Requirements

Major - 24 hours

Mathematics - 12 hours

Dissertation Research - 48 hours

Admission to candidacy - One year before graduation

In-residence study - 3 successive quarters

Present Dissertation at a Public Defense
Aeronautics and Astronautics (ENY)

Space Systems Certificate

Program Description

For those students not enrolled in the Space Systems Master of Science (MS) degree program, AFIT now offers a Graduate Space Systems Certificate Program. This program consists of four courses, three core and one elective. The core courses cover the areas of spacecraft dynamics, space environment, and spacecraft design. The elective course may be in the area of space communications or remote sensing fundamentals.

Program Educational Objectives (PEOs)

The Graduate Space Systems Certificate Program is designed for students with traditional engineering backgrounds (mechanical, electrical, aerospace, etc.) and produces graduates who can effectively approach and analyze complex space-related problems, design feasible solutions, and select an appropriate solution. Specific objectives are as follows:

• A graduate will have a general understanding of the purpose and requirements for all spacecraft subsystems and how these subsystems relate to the spacecraft payload and mission
• A graduate will have a thorough understanding of orbital mechanics and the space environment and how these might affect the spacecraft mission
• A graduate will have an understanding of a specific application of space vehicles

School and Program Admission Criteria

DEGREE REQUIRED: Any accredited B.S. degree, but courses are designed for students with a science or engineering undergraduate degree. Regardless of undergrad degree, a calculus-based physics course and a course in dynamical systems (circuits or engineering dynamics) is also required.

MATHEMATICS REQUIRED: Ordinary Differential Equations

TEST REQUIRED: None

GPA REQUIRED: OVERALL - 3.0

Waivers to the above criteria may be granted on a case by case basis. Therefore, individuals whose academic credentials fall below any of the above criteria are encouraged to apply.

Certificate Requirements

15 hours: MECH 532, PHYS 519, ASYS 631, and one of the following: OENG 530 or EENG 571
Electrical and Computer Engineering (ENG)

Department Head: Kenneth M. Hopkinson, PhD
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Website: https://www.afit.edu/ENG

The Department of Electrical and Computer Engineering is home to graduate programs in Electrical Engineering, Computer Engineering, Computer Science, and Cyber Operations. The Department has a 50-year record of outstanding academic support to the Air Force, the Department of Defense, and the professional science and engineering community. In recent years, the Department has experienced significant growth in its research programs, as well as the demand for its graduates. The Department will continue to grow by focusing on the following seven academic areas that are of critical importance to the Air Force:

- Artificial Intelligence and Machine Learning
- Cyber, to include computer systems, computer networks, and system information security
- Communications, radar, and signal processing
- Electromagnetics and low observables
- Electro-optics
- Guidance, navigation, and control
- Microelectronics and nanotechnology

Facilities

The Department of Electrical and Computer Engineering operates an extensive complex of laboratory and computing facilities in support of its academic and research programs. The laboratory facilities include the following dedicated areas:

- Advanced Compact Electromagnetic Radar Cross Section (ACER) Laboratory
- Augmented Reality/Virtual Reality Workspace
- Autonomy and Navigation Technology (ANT) Laboratory
- Atmospheric and Adaptive Optics Laboratory
- Center for Cyber Research Laboratory (CCRL)
- Cyber Agents, Networking and Mobile Applications Laboratory (Cyber-ANiMAL)
- Cyber Defense Network (CDN)
- Cyber Physical Systems Research Laboratory
- Global Navigation Satellite System (GNSS) Laboratory
- Graduate Education in Cyber Operations (GECO) Laboratory
- Hardware Reverse Engineering Laboratory
- Human Systems Integration (HIS) Laboratory
- Micro and Nano Devices and Systems Cleanroom
- Microsystems Design and Simulation Laboratory
- Microsystems Test and Characterization Laboratory
- Radar Instrumentation Laboratory (RAIL)
- Radio Frequency Signal Exploitation Laboratory (RFSEL)
Electrical and Computer Engineering (ENG)

The computer facilities available in the Department cover the broad range of capabilities from microprocessors evaluation systems to general purpose computing systems to high-performance supercomputers. A vast number of computing resources, with supporting peripherals and a variety of general purpose software, are available for student and faculty use.

Programs

Master of Science

- Computer Engineering (M.S.)
- Computer Science (M.S.)
- Cyber Operations (M.S.)
- Electrical Engineering (M.S.)

Doctor of Philosophy

- Computer Engineering (Ph.D.)
- Computer Science (Ph.D.)
- Electrical Engineering (Ph.D.)

Certificate

- Graduate Certificate in Autonomy (GCA)

Faculty

Professor Emeritus

Frank M. Brown - Discrete Mathematics, Operations Research
Nathaniel J. Davis IV - Computer networks, computer security, computer architectures, and parallel computing systems, computer modeling
Thomas C. Hartrum - Computer Database Systems, Software Engineering
Constantine H. Houpis - Guidance, Navigation, Control Systems
Peter S. Maybeck - Guidance, Navigation, Control, Stochastic Processes
Vittal P. Pyati - Electromagnetics, Radar, Electronic Warfare
Richard A. Raines - Networks and information security, computer communication networks, satellite and mobile communications, biometrics and pattern recognition

Professor

### Electrical and Computer Engineering (ENG)

<table>
<thead>
<tr>
<th>Name</th>
<th>Research Areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Michael J. Havrilla</td>
<td>Electromagnetism, Guided Waves, Material Characterization, Low Observables</td>
</tr>
<tr>
<td>Gary B. Lamont</td>
<td>Artificial Intelligence, Computer Science, Computer Engineering, Digital Control Systems, Parallel and Distributed Computation, Software Engineering, Network Security, UAVs, Evolutionary Computing</td>
</tr>
<tr>
<td>Gilbert L. Peterson</td>
<td>Uncertainty in Artificial Intelligence, Robotics, Machine Learning, Data Mining</td>
</tr>
<tr>
<td>Associate Professor</td>
<td>Machine Learning, Deep Learning, Human Subject Research, Artificial Intelligence, Opponent Modeling, Agents, Multi-agent Systems, Mechanism Design</td>
</tr>
<tr>
<td>Brett J. Borghetti</td>
<td>Digital Systems, Image Processing, Optics</td>
</tr>
<tr>
<td>Scott R. Graham</td>
<td>Cyber-physical Systems Security, Automotive and Avionics Cyber Vulnerabilities, Data Bus Architectures, Critical Infrastructure Protection</td>
</tr>
<tr>
<td>Douglas D. Hodson</td>
<td>Software Engineering, Modeling and Simulation</td>
</tr>
<tr>
<td>Julie A. Jackson</td>
<td>Radar Signal Processing, Electromagnetics, Automatic Target Recognition, Multi-static Radar, Novel Image Formation Techniques, Sensor Fusion</td>
</tr>
</tbody>
</table>
Electrical and Computer Engineering (ENG)

Assistant Professor


David J. Becker Electro-optics, Image Processing, Space Object Detection


Aaron J. Canciani Magnetic Anomaly Navigation, Non-GPS Navigation, Sensor Integration


Joseph A. Curro Non-GPS Navigation, Sensor Integration, Sensor Fusion, Machine Learning, Artificial Intelligence, Uncertainty in Artificial Intelligence

Mark E. Deyoung Hardware/Software Co-design, Embedded Systems, Cyber Situational Awareness, Computational Statistics, Software Engineering, Reverse Engineering

Tod V. Laurvick NEMS, Microelectronic Thin Films/Surface Effects, Microelectronic Integration, Additive Manufacturing


Scott L. Nykl Computer Graphics, Computational Geometry, GPGPU, Parallel/Concurrent Systems, UAVs, Networking, Computer Vision, Augmented Reality, Sensor Fusion, Software Engineering, Virtual Worlds
### Electrical and Computer Engineering (ENG)

<table>
<thead>
<tr>
<th>Name</th>
<th>Research Interests</th>
</tr>
</thead>
</table>
Electrical and Computer Engineering (ENG)

Computer Engineering (M.S.)*

Program Description

In the Computer Engineering program, the student is provided with the challenging opportunity of pursuing a versatile course of study reflecting the student's desires, background, and future responsibilities. The student selects from a variety of specialties which are covered in depth and probe the frontiers of engineering and scientific knowledge. Special study courses are available to study emerging technology and its application for solving problems. Advanced concepts and applications are emphasized throughout the program and in the thesis research.

Program Educational Objectives (PEOs)

- Breadth. Apply foundational scientific concepts and sound engineering principles to efficiently and effectively advance Air Force and DoD technological capabilities
- Depth. Are well-educated, highly valued, and successful engineers and scientists
- Teamwork. Significantly contribute to technical interdisciplinary team projects
- Professionalism. Professionally communicate technical solutions and results
- Lifelong Learning. Continue to pursue lifelong multidisciplinary learning as professional engineers and scientists

Student Outcomes (SOs)

- Graduates will demonstrate an in-depth understanding of computer engineering
- Graduates will be able to communicate technical information clearly by written and oral means
- Graduates will conduct independent research on topics related to computer engineering, including identifying and scoping a problem, locating and synthesizing relevant published prior work, planning and executing valid research, documenting results, and publishing them
- Graduates will be able to apply the scientific method and use reliable standards of evidence for conclusions reached
- Graduates will independently learn technical details for which they are responsible

School and Program Admission Criteria

DEGREE REQUIRED: BS in Computer Engineering or Electrical Engineering (with concentration in computer engineering).
MATHEMATICS REQUIRED: Discrete mathematics, ordinary differential equations
TEST REQUIRED: GRE - 153V/148Q
GPA REQUIRED: OVERALL - 3.0; MATHEMATICS - 3.0; MAJOR - 3.0

Waivers to the above criteria may be granted on a case-by-case basis. Therefore, individuals whose academic credentials fall below any of the above criteria are encouraged to apply.
Electrical and Computer Engineering (ENG)

Degree Requirements

Core Courses - 16 hours
CSCE 586 - Design and Analysis of Algorithms
CSCE 587 - Microprocessor Design and Synthesis
CSCE 687 - Advanced Microprocessor Design Lab
CSCE 692 - Design Principles of Computer Architecture

Mathematics - 4 hours

Theory - 4 hours

Application Sequence - 12 hours

Thesis - 12 hours (For a detailed discussion of degree requirements, see the Department Student Guide)
Electrical and Computer Engineering (ENG)

Computer Engineering (Ph.D.)

Program Description

The Department of Electrical and Computer Engineering offers doctoral programs in Computer Engineering that lead to the award of a PhD. The Doctor of Philosophy degree is a research degree that recognizes mastery of a field of study, a demonstrated ability to conduct independent research, and the dissemination of significant and original contributions to the body of knowledge in that field. The Graduate School of Engineering and Management specifies the degree requirements for the school’s doctoral program. The doctoral programs offered within the Department are differentiated from one another based on the area of research specialization chosen by each student.

School and Program Admission Criteria

DEGREE REQUIRED: Requires Master’s degree in Astronautical, Aeronautical, Mechanical, or Systems Engineering.
GRE REQUIRED: 156V/151Q
GPA REQUIRED: 3.50 (MS); 3.00 (BS)

Additionally, it is desirable for applicants seeking admission to the Department's PhD program to have successfully completed a MS thesis and obtained endorsement by their MS faculty, especially the MS thesis advisor.

Waivers to the above criteria may be granted on a case by case basis. Therefore, individuals whose academic credentials fall below any of the above criteria are encouraged to apply.

Degree Requirements

The PhD. degree requirements adhere to standards defined by the Graduate School of Engineering and Management faculty. These basic requirements include completion of at least 36 credit hours of courses, including 24 credit hours in a specialty area, 8 credit hours in math, successful completion of an exam in the specialty area, a prospectus examination, and successful completion of a dissertation. Courses that constitute a program of study will be determined by the Research Advisor and must be approved by the Department Head. A typical program of study will consist of an in-depth sequence of courses at the 6XX, 7XX, and 8XX level and will establish a foundation of knowledge suitable for pursuing dissertation research and meeting general academic expectations for the major area of study.
Electrical and Computer Engineering (ENG)

Computer Science (M.S.)

Program Description

In the Computer Science program, the student is provided with the challenging opportunity of pursuing a versatile course of study reflecting the student’s desires, background, and future responsibilities. The student selects from a variety of specialties, which are covered in depth and which probe the frontiers of engineering and scientific knowledge. Special study courses are available to study emerging technology and its application for solving problems. Advanced concepts and applications are emphasized throughout the program and the thesis research.

Program Educational Objectives (PEOs)

- Breadth. Apply foundational scientific concepts and sound engineering principles to efficiently and effectively advance Air Force and DoD technological capabilities
- Depth. Are well-educated, highly valued, and successful engineers and scientists
- Teamwork. Significantly contribute to technical interdisciplinary team projects
- Professionalism. Professionally communicate technical solutions and results
- Lifelong Learning. Continue to pursue lifelong multidisciplinary learning as professional engineers and scientists

Student Outcomes (SOs)

- Graduates will demonstrate an in-depth and comprehensive understanding of computer science
- Graduates will be able to communicate technical information clearly by written and oral means
- Graduates will conduct independent research on topics related to computer science, including identifying and scoping a problem, locating and synthesizing relevant published prior work, planning and executing valid research, documenting results, and publishing them
- Graduates will be able to apply the scientific method and use reliable standards of evidence for conclusions reached
- Graduates will independently learn technical details for which they are responsible

School and Program Admission Criteria

DEGREE REQUIRED: BS in Computer Science, or a BS in an engineering, science or mathematical field with extensive course work (24 semester hours) in computer science
MATHEMATICS REQUIRED: Discrete mathematics, differential and integral calculus
TEST REQUIRED: GRE - 153V/148Q
GPA REQUIRED: OVERALL - 3.0; MATHEMATICS - 3.0; MAJOR - 3.0

Waivers to the above criteria may be granted on a case-by-case basis. Therefore, individuals whose academic credentials fall below any of the above criteria are encouraged to apply.
Electrical and Computer Engineering (ENG)

Degree Requirements

Core Courses - 16 hours
CSCE 586 Design and Analysis of Algorithms
CSCE 593 Introduction to Software Engineering
CSCE 686 Advanced Algorithm Design
CSCE 689 Distributed Software Systems or CSCE 692 Design Principles of Computer Architecture

Mathematics - 4 hours

Theory - 4 hours

Application Sequence - 12 hours

Thesis - 12 hours For a detailed discussion of degree requirements, see the Department Student Guide.
Electrical and Computer Engineering (ENG)

Computer Science (Ph.D.)

Program Description

The Department of Electrical and Computer Engineering offers doctoral programs in Computer Science that lead to the award of a PhD. The Doctor of Philosophy degree is a research degree that recognizes mastery of a field of study, a demonstrated ability to conduct independent research, and the dissemination of significant and original contributions to the body of knowledge in that field. The Graduate School of Engineering and Management specifies the degree requirements for the school’s doctoral program. The doctoral programs offered within the Department are differentiated from one another based on the area of research specialization chosen by each student.

School and Program Admission Criteria

DEGREE REQUIRED: MS in relevant area (or BS in relevant area, if applying directly to the PhD. program after completing a BS degree)
TEST REQUIRED: GRE - 156V/151Q
GPA REQUIRED: 3.50

Waivers to the above criteria may be granted on a case-by-case basis. Therefore, individuals whose academic credentials fall below any of the above criteria are encouraged to apply.

Degree Requirements

Coursework
A minimum of 36 hours (post-MS) consisting of 28 hours of integrated coursework which supports the student’s area of research specialization and 8 hours of mathematics. This coursework will normally be at the 600-level or above. Up to 12 hours of the required 36 hours can be waived based on courses taken since the undergraduate degree.

Dissertation
At least 48 hours of the following courses, Dissertation Research, leading to the successful completion of the PhD. dissertation.
Cyber Operations (CO), which encompasses most of the technological aspects of Information Operations, are those actions taken to affect an adversary's information and information systems, while defending one's own information and information systems. To support CO, professionals must be cognizant of the tools, techniques, and practices required to defend, attack, and exploit these resources. At the technical level, CO encompasses multiple scientific disciplines that ensure the security of critical infrastructures.

Program Educational Objectives (PEOs)

- Breadth. Apply foundational scientific concepts and sound engineering principles to efficiently and effectively advance Air Force and DoD technology capabilities
- Depth. Are well-educated, highly-valued, and successful engineers and scientists
- Teamwork. Significantly contribute to technical interdisciplinary team projects
- Professionalism. Professionally communicate technical solutions and results
- Lifelong Learning. Continue to pursue lifelong multidisciplinary learning as professional engineers and scientists

Student Outcomes (SOs)

- Graduates will demonstrate an in-depth understanding of cyber operations
- Graduates will be able to communicate technical information clearly by written and oral means
- Graduates will conduct independent research on topics related to cyber operations, including identifying and scoping a problem, locating and synthesizing relevant published prior work, planning and executing valid research, documenting results, and publishing them
- Graduates will be able to apply the scientific method and use reliable standards of evidence for conclusions reached
- Graduates will independently learn technical details for which they are responsible

School and Program Admission Criteria

DEGREE REQUIRED: BS in Computer Science or Computer Engineering. Applicants with computer-oriented technical degrees in other fields may be considered. Some applicants may need to complete matriculation requirements to address any weaknesses in their backgrounds. Students must possess the following background knowledge prior to fully engaging in the program: proficiency in software programming and code development; knowledge and application of data structures, computer architecture, and operating systems. Must be a U.S. citizen.

MATHEMATICS REQUIRED: Differential and Integral Calculus
TEST REQUIRED: GRE - 153V/148Q
GPA REQUIRED: OVERALL - 3.0; MATHEMATICS - 3.0; MAJOR - 3.0

Waivers to the above criteria may be granted on a case-by-case basis. Therefore, individuals whose academic credentials fall below any of the above criteria are encouraged to apply.
Electrical and Computer Engineering (ENG)

Degree Requirements

Core Courses - 24 hours
- CSCE 525 Introduction to Information Warfare
- CSCE 526 Secure Software Design and Development
- CSCE 528 Cyber Defense and Exploitation
- CSCE 629 Cyber Attack
- CSCE 660 Mobile, Wireless & SCADA Device Security
- CSCE 725 Reverse Engineering

Mathematics - 4 hours

Cyber Operations Breadth - 8 hours

Thesis - 12 hours
(For a detailed discussion of degree requirements, see the Department Student Guide at:
http://www.afit.edu/en/eng/current_students.cfm?a=studentguide)
Electrical and Computer Engineering (ENG)

Electrical Engineering (M.S.)*

Program Description

In the Electrical Engineering program, the student is provided with the challenging opportunity of pursuing a versatile course of study reflecting the student’s desires, background, and future responsibilities. The student selects from a variety of specialties which are covered in depth and which probe the frontiers of engineering and scientific knowledge. Special-study courses are available to study emerging technology and its application for solving problems.

Program Educational Objectives (PEOs)

After completing the Electrical Engineering program, our graduates will meet the following objectives:
- **Breadth.** Graduates apply foundational scientific concepts and sound engineering principles to efficiently and effectively advance Air Force and DoD technological capabilities
- **Depth.** Graduates are well-educated, highly-valued, and successful engineers and scientists
- **Teamwork.** Graduates significantly contribute to technical interdisciplinary team projects
- **Professionalism.** Graduates professionally communicate technical solutions and results
- **Lifelong Learning.** Graduates continue to pursue lifelong multidisciplinary learning as professional engineers and scientists

Student Outcomes (SOs)

Students will be able to:
- Graduates will demonstrate an in-depth understanding in their specialty area within electrical engineering
- Graduates will be able to communicate technical information clearly by written and oral means
- Graduates will conduct independent research on topics related to electrical engineering, including identifying and scoping a problem, locating and synthesizing relevant published prior work, planning and executing valid research, documenting results, and publishing them
- Graduates will be able to apply the scientific method and use reliable standards of evidence for conclusions reached

School and Program Admission Criteria

**DEGREE REQUIRED:** BS degree in Electrical Engineering or Computer Engineering
**MATHEMATICS REQUIRED:** Ordinary Differential Equations
**TEST REQUIRED:** GRE - 153V/148Q
**GPA REQUIRED:** OVERALL - 3.0; MATHEMATICS - 3.0; MAJOR - 3.0

Waivers to the above criteria may be granted on a case-by-case basis. Therefore, individuals whose academic credentials fall below any of the above criteria are encouraged to apply.
Electrical and Computer Engineering (ENG)

Degree Requirements

Coursework - 28 hours
Specific courses are determined based on the student’s selected area of specialization/emphasis. In general, each area has a defined set of core courses and follow-on elective "emphasis" courses. Typical emphasis areas include the following:
• Electromagnetic Engineering
• Electronic Circuits and Devices
• Software Engineering
• Digital Engineering
• Communications
• Digital Communications Networks
• Radar
• Guidance, Navigation, and Control
• Electro-Optics
• Observables Reduction
• Signal Processing

Mathematics - 8 hours

Thesis - 12 hours (For a detailed discussion of degree requirements, see the Department Student Guide)
Electrical and Computer Engineering (ENG)

Electrical Engineering (Ph.D.)

Program Description

The Department of Electrical and Computer Engineering offers doctoral programs in Electrical Engineering that lead to the award of a PhD. The Doctor of Philosophy degree is a research degree that recognizes mastery of a field of study, a demonstrated ability to conduct independent research, and the dissemination of significant and original contributions to the body of knowledge in that field. The Graduate School of Engineering and Management specifies the degree requirements for the school’s doctoral program. The doctoral programs offered within the Department are differentiated from one another based on the area of research specialization chosen by each student.

School and Program Admission Criteria

DEGREE REQUIRED: MS in relevant area (or BS in relevant area, if applying directly to the PhD. program after completing a BS degree)
TEST REQUIRED: GRE 156V/151Q
GPA REQUIRED: 3.50

Waivers to the above criteria may be granted on a case-by-case basis. Therefore, individuals whose academic credentials fall below any of the above criteria may apply.

Degree Requirements

Coursework
A minimum of 36 hours (post-MS) consisting of 28 hours of integrated coursework which supports the student’s area of research specialization and 8 hours of mathematics. This coursework will normally be at the 600-level or above. Up to 12 hours of the required 36 hours can be waived based on graduate courses taken since the undergraduate degree.

Dissertation
At least 48 hours of the following courses, Dissertation Research, leading to the successful defense of the PhD. dissertation.
Graduate Certificate in Autonomy

Program Description

The Graduate Certificate in Autonomy (GCA) provides a specialization in topics pertinent to the development of autonomous systems. It is intended to provide a broad understanding of the concepts and approaches related to autonomy, as well as provide the student the ability to develop in-depth knowledge in one of the following specialty areas: 1) Artificial Intelligence, 2) Unmanned Aerial Systems (UAS), and 3) Human-Machine Teaming.

Student Outcomes (SOs)

Upon completion of the certificate program, students will be able to:

• Define autonomy and identify systems that require autonomous operation as distinct from automated systems
• Identify the ethical considerations of autonomy
• Analyze the challenges of autonomy in various environments and develop approaches to overcome those challenges
• Develop new approaches for using AI in autonomous systems, using autonomy to improve UAS capabilities, or improve human-machine teaming (depending on the sequence)
• Design and implement an aspect of an autonomous system (artificial intelligence, human-machine teaming, or UAS, depending on sequence)

School and Program Admission Criteria

DEGREE REQUIRED: BS in an engineering or scientific field
GPA REQUIRED: OVERALL - 3.0

Waivers to the above criteria may be granted on a case-by-case basis. Therefore, individuals whose academic credentials fall below any of the above criteria are encouraged to apply

Degree Requirements

The program consists of 1 core course and an elective sequence from 3 areas, each consisting of 3 courses. A student will select one of the three sequences to complete the certificate and not a combination of courses from all three. The final course in each sequence will include an individual or group “capstone” project where students apply the material learned in their particular sequence to a relevant Department of Defense problem.

Core Courses - 2 hours
EENG 550 - Introduction to Autonomy

Elective Sequences - 12 hours
Electrical and Computer Engineering (ENG)

Artificial Intelligence for Autonomy Sequence
CSCE 523 Artificial Intelligence
CSCE 623 Statistical Machine Learning And 1 of the following courses:
CSCE 723 Advanced Topics in Artificial Intelligence
CSCE 823 Artificial Neural Networks

Unmanned Systems Sequence
SENG 550 Small UAS Concept Definition and Preliminary Design
SENG 650 Small UAS Detailed Design
SENG 651 Small UAS Test and Evaluation

Human-Machine Teaming Sequence
HFEN 560 Introduction to Human Factors
HFEN 663 Human Computer Interaction
HFEN 665 Human-Agent Interaction
Engineering Physics (ENP)

Interim Department Head: Kenneth W. Burgi, PhD
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Phone: (937) 255-3636 x4696 (DSN 785-3636 x4696)
Fax: (937) 656-6000 (DSN 986-6000)
E-mail address: enpadministration@afit.edu
Website: https://www.afit.edu/enp

The Department of Engineering Physics provides Department of Defense-focused graduate education and research through Master of Science (M.S.) and Doctor of Philosophy (Ph.D.) programs in Applied Physics, Optical Sciences and Engineering, Nuclear Engineering, and Materials Science. Furthermore, it offers a M.S. degree in Combating Weapons of Mass Destruction (currently unavailable) and certificate programs in Combating Weapons of Mass Destruction (currently unavailable), and Nuclear Weapons Effects, Policy, and Proliferation. The Department of Engineering Physics is the Air Force's primary provider of graduate education in physics and nuclear engineering. Military officers from sister services and civilians may also qualify for admission.

Facilities

The Department of Engineering Physics is one of six engineering departments in the Graduate School of Engineering and Management of the Air Force Institute of Technology (AFIT) located on Wright-Patterson Air Force Base (WPAFB) Ohio. The AFIT campus is comprised primarily of a series of interconnected buildings in Area B of WPAFB. The Department of Engineering Physics is located in Building 640 with residence courses taught primarily in Building 640 and the adjoining Building 646.

In addition to department offices and classrooms, the Department of Engineering Physics utilizes laboratories in Buildings 640, 644, and 470. The laboratories in Building 640 consist primarily of instructional laboratories, as well as research facilities dedicated to semiconductor characterization, photoluminescence excitation and emission, and image-based bi-directional reflectance distribution functions. Building 640 also houses a modeling and simulation facility devoted to research analysis of naturally occurring electrically charged gases (also known as geoplasmas) in the outer reaches of the Earth's atmosphere. Research in this field is of growing concern to military operations. Faculty and students have acquired many of the leading space weather models within the DOD and scientific communities, along with the supporting data and software necessary to pursue publishable research.

Building 644 is a 29,914 gross square foot engineering research laboratory connected to the southeast corner of Building 640. The Department of Engineering Physics operates laboratories within this facility to support faculty and student research at the M.S. and Ph.D. levels in laser spectroscopy, optics, solid state physics, Mossbauer spectrometry, nuclear radiation detection, nuclear effects, and environmental engineering. The instructional laboratories complement courses of study in engineering physics, optical observables, nuclear radiation detection and instrumentation, nuclear and environmental engineering, space weather, optics, and lasers and optical diagnostics. Equipment is continually updated to remain abreast of the state-of-the-art in engineering physics, optical engineering, space weather, and nuclear engineering. There also exists a suite of three environmental science laboratories that provide research in remediation technologies, environmental sampling, remote sensing, and microbiology in support of the department's research in nuclear proliferation and combating weapons of mass destruction.
Engineering Physics (ENP)

Building 644 contains a clean room suite (class 1000) that enables the fabrication of microelectromechanical systems (MEMS) and micro-and opto-electronic devices, and integrated systems. The Clean Room supports basic research on advanced electronic and photonic materials. Coupled with the Clean Room is the Electronic Devices and Materials (Microelectronics) Laboratory, which contains an array of integrated circuit fabrication equipment and cutting edge diagnostic instrumentation. The fabrication facilities encompass complete photolithography, mask printing, thermal oxidation, dopant diffusion, and metallization capabilities. The diagnostic facilities include a sub-micron probe station, scanning electron microscope, atomic force microscope, cathodoluminescence, profilometer, and probe station.

Building 470, located apart from the AFIT complex, houses teaching and research laboratories that support our nuclear engineering program. These laboratories have up to date equipment for detecting and measuring sources of alpha, beta, gamma, and neutron radiation, and these capabilities are updated constantly. Areas of focus include neutron and gamma-ray spectroscopy, gamma imaging, detection of nuclear fuels in trace quantities, and studies of radiation effects on materials and electronics. Data acquisition and analysis are carried out with a network of high-end PCs, complete with multi-channel analyzer software interfaced to computer-controlled nuclear electronics components. This system provides advanced data acquisition and data sharing between measurement stations. A radiochemistry laboratory and radio-nuclide storage facility support these laboratories. In addition, environmental measurement tools for laboratory and field characterization of pollutants are being enhanced, excellent equipment for nuclear analytical measurements is available, and a complete range of semiconductor characterization tools are available for studies of radiation effects on electronics.

Programs

Master of Science

- Applied Physics
- Atmospheric Science
- Materials Science
- Nuclear Engineering
- Optical Science and Engineering

Doctor of Philosophy

- Applied Physics
- Materials Science
- Nuclear Engineering
- Optical Sciences and Engineering

Certificate

- Nuclear Weapons Effects, Policy, and Proliferation (DL)
# Engineering Physics (ENP)

## Faculty

<table>
<thead>
<tr>
<th>Title</th>
<th>Name</th>
<th>Research Interests</th>
</tr>
</thead>
<tbody>
<tr>
<td>Professor</td>
<td>Larry W. Burggraf</td>
<td>computational and materials chemistry, optical/nuclear spectroscopy, exotic particles</td>
</tr>
<tr>
<td></td>
<td>Steven T. Fiorino</td>
<td>atmospheric physics, microwave remote sensing; Director of CDE</td>
</tr>
<tr>
<td></td>
<td>Nancy C. Giles</td>
<td>experimental solid state physics, photoluminescence, absorption, Raman, and magnetic resonance (EPR) spectroscopy</td>
</tr>
<tr>
<td></td>
<td>Michael A. Marciniak</td>
<td>optical/infrared signatures, electro-optics</td>
</tr>
<tr>
<td></td>
<td>Glen P. Perram</td>
<td>laser physics, chemical kinetics, molecular spectroscopy</td>
</tr>
<tr>
<td></td>
<td>James C. Petrosky</td>
<td>nuclear engineering, radiation, Director of NEAT CSR</td>
</tr>
<tr>
<td></td>
<td>Heidi R. Ries</td>
<td>nonlinear optical materials, electron paramagnetic resonance imaging spectroscopy, laser processing of materials, Dean for Research</td>
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<tr>
<td></td>
<td>David E. Weeks</td>
<td>computational chemical physics</td>
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<tr>
<td></td>
<td>Paul J. Wolf</td>
<td>atomic, molecular and optical physics, Associate Dean for Academic Affairs</td>
</tr>
<tr>
<td>Associate Professor</td>
<td>John W. McClory</td>
<td>nuclear engineering; Director of NWEPP</td>
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<tr>
<td></td>
<td>Anil K. Patnaik</td>
<td>combustion spectroscopy, laser-based sensing</td>
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<tr>
<td></td>
<td>Ronald F. Tuttle</td>
<td>measurement and signature intelligence; NWEPP course instruction</td>
</tr>
<tr>
<td>Assistant Professor</td>
<td>James E. Bevins</td>
<td>optimization, neutron spectroscopy, nuclear effects, post-detonation forensics, radiation detector development and nuclear policy</td>
</tr>
<tr>
<td></td>
<td>Abigail A. Bickley</td>
<td>research faculty; nuclear chemistry, nuclear engineering, nuclear forensics</td>
</tr>
<tr>
<td></td>
<td>Santasri Bose-Pillai</td>
<td>research faculty; laser beam propagation and imaging through atmosphere, partially coherent sources, laser communications</td>
</tr>
<tr>
<td></td>
<td>Kenneth W. Burgi</td>
<td>Fourier optics, statistical optics; Interim Department Head</td>
</tr>
<tr>
<td></td>
<td>Samuel D. Butler</td>
<td>optical physics</td>
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<tr>
<td></td>
<td>Michael J. Caylor</td>
<td>research faculty; space systems</td>
</tr>
<tr>
<td></td>
<td>Justin A. Clinton</td>
<td>nuclear engineering; NWEPP course instruction</td>
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<tr>
<td></td>
<td>Michael L. Dexter</td>
<td>nuclear weapon effects, Interim Director of CTISR</td>
</tr>
<tr>
<td></td>
<td>Daniel J Emmons II</td>
<td>plasma physics, space physics</td>
</tr>
<tr>
<td></td>
<td>Manuel R. Ferdinandus</td>
<td>optics, fast-pulse lasers, non-linear optics</td>
</tr>
<tr>
<td></td>
<td>Anthony L. Franz</td>
<td>optics, laser dynamics, space weather</td>
</tr>
<tr>
<td></td>
<td>Michael R. Hawks</td>
<td>research faculty; optics, remote sensing</td>
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<tr>
<td>Name</td>
<td>Research Focus</td>
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<tr>
<td>Nicholas C. Herr</td>
<td>laser/materials interactions; materials</td>
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<tr>
<td>Edward L. Hobbs</td>
<td>radiation transport; Deputy Director of NEAT CSR</td>
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<tr>
<td>Darren E. Holland</td>
<td>research faculty; nuclear engineering</td>
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<tr>
<td>Royce W. James</td>
<td>plasma physics, emphasis in fusion, energy, space, and environmental applications</td>
<td></td>
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<tr>
<td>Christopher A. Lenyk</td>
<td>material physics, nuclear weapon effects, wide-band gap oxides, laser materials, point effect characterization</td>
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<tr>
<td>Robert D. Loper</td>
<td>quantum scattering, computational physics</td>
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<tr>
<td>Jesse J. Lutz</td>
<td>research faculty; quantum chemistry, quantum physics, modeling solid state defects</td>
<td></td>
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<tr>
<td>Jack E. McCrae</td>
<td>research faculty; directed energy weapons systems</td>
<td></td>
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<tr>
<td>Omar A. Nava</td>
<td>atmospheric science</td>
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<tr>
<td>Michael V. Pak</td>
<td>research faculty; quantum computing and quantum information systems</td>
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<tr>
<td>Christopher A. Rice</td>
<td>research faculty; image processing, laser development, remote sensing, rare-gas lasers</td>
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<tr>
<td>Adib J. Samin</td>
<td>nuclear engineering, nuclear materials</td>
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<tr>
<td>Michael B. Shattan</td>
<td>nuclear engineering</td>
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<tr>
<td>Bryan J. Steward</td>
<td>EO/IR, remote sensing, OPIR, data exploitation, physical modeling</td>
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<tr>
<td>Robert C. Tournay</td>
<td>atmospheric science, land surface interaction, ML/AI forecasting</td>
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<tr>
<td>H. Rose Tseng</td>
<td>atmospheric science</td>
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<tr>
<td>Gaiven Varshney</td>
<td>research faculty; nuclear engineering</td>
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<tr>
<td>William F. Bailey</td>
<td>plasma physics, space physics</td>
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<tr>
<td>Robert L. Hengehold</td>
<td>experimental solid state physics, electrical and optical characterization of semiconductors, electro-optics</td>
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<tr>
<td>Kirk A. Mathews</td>
<td>computational nuclear engineering, nuclear weapons</td>
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<tr>
<td>Professor Emeritus</td>
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<tr>
<td>John R. Bruzzese</td>
<td>lasers, photonics</td>
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<tr>
<td>Xiaofeng Frank Duan</td>
<td>computational chemistry and materials science</td>
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<tr>
<td>Michael T. Eismann</td>
<td>hyperspectral imaging</td>
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<tr>
<td>Kevin C. Gross</td>
<td>molecular spectroscopy; remote sensing</td>
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<tr>
<td>F. Kenneth Hopkins</td>
<td>directed energy, photonics devices</td>
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<tr>
<td>Gary S. Kedziora</td>
<td>computational chemistry and materials science</td>
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<tr>
<td>Tony D. Kelly</td>
<td>nuclear engineering</td>
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<tr>
<td>C. David Lewis II</td>
<td>computational physics</td>
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<tr>
<td>Joseph Meola</td>
<td>hyperspectral imaging</td>
<td></td>
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<tr>
<td>COL Buckley E. O’Day</td>
<td>nuclear engineering; radiation health physics</td>
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<tr>
<td>Adjunct Faculty</td>
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<tr>
<td>COL Buckley E. O’Day</td>
<td>nuclear engineering; radiation health physics</td>
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## Engineering Physics (ENP)

<table>
<thead>
<tr>
<th>Name</th>
<th>Research Areas</th>
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</thead>
<tbody>
<tr>
<td>Gregory A. Pitz</td>
<td>diode pumped alkali laser, hollow core gas filled-</td>
</tr>
<tr>
<td></td>
<td>fiber lasers, laser spectroscopy</td>
</tr>
<tr>
<td>Mark Spencer</td>
<td>Adaptive optics, directed energy</td>
</tr>
<tr>
<td>Augustine M. Urbas</td>
<td>metamaterials</td>
</tr>
</tbody>
</table>
Engineering Physics (ENP)

Applied Physics (M.S.)

Program Description

The Applied Physics program provides each student with a broad graduate-level foundation in applied physics with degree requirements in the areas of mathematics, foundational physics, applications, laboratory work, and capstone courses. Analytic and numerical mathematics are important, and students often take courses in both. Additionally, computational methods are used in many courses. Courses in electrodynamics, quantum mechanics, and thermal/statistical physics, provide foundational physics as well as other courses and provide breadth to the curriculum. Air Force organizations that employ our graduates consistently value the ability of the graduate to apply their knowledge to problems of interest to the organization. These problems change as the graduate moves to new Air Force organizations, so they value graduates with breadth. One application course will typically be the start of the specialized study in preparation for the student’s thesis research, and two other application courses provide this breadth. Also, a graduate laboratory course is required. Rather than follow specific prescribed steps, graduate labs have students make decisions about what to measure to reach a goal, design the experiment, collect and analyze data, assess the results, and communicate results through papers and talks. Finally, students take a capstone course that integrates material from other courses in the program and is focused on a specific Air Force mission, problem area, or relevant technology.

The research experience is the culmination of graduate education. All students are required to complete and defend a thesis. Many students take other coursework to increase depth and prepare them for thesis research.

Students will take one of two tracks: engineering or space physics. Both tracks begin with the same foundation, but the curriculum diverges with applications courses and beyond. The Engineering Physics track requires three applications courses designed to achieve an educational breadth. For example: plasma physics, solid state physics, and laser physics. The Space Physics track provides breadth across the ionosphere, magnetosphere, and solar atmosphere.

Flexibility in the program is maintained to take full advantage of the varied backgrounds and abilities of the students. The specific courses in the curriculum vary depending on the specialization pursued and, in the case of an Air Force officer, the requirements associated with the officer’s Air Force academic specialty code or follow-on assignment. Also, for students who need more preparation, we offer pre-requisite courses.

Concentration in the two tracks is described below:

- Engineering Physics: A broad range of applied physics topics, including the areas of laser physics, infrared systems, remote sensing, solid state physics, and plasma physics. Emphasis is placed on the application of basic physics to a variety of engineering areas, such as directed energy weapons, remote sensing, molecular dynamics, photonics surveillance and countermeasures.
- Space Physics: Encompasses the variations in the Earth’s magnetosphere, ionosphere, and subsequent effects of the space environment on the propagation of electromagnetic waves, communication, space operations, and manned space flight. An understanding of solar effects on the near-earth environment and ramifications on military operation is achieved.

In both tracks, emphasis is placed on applying basic physical principles together with current state-of-the-art computational and experimental techniques to address Air Force and DOD problems.
Engineering Physics (ENP)

Program Educational Objectives (PEOs)

The PEOs of the Applied Physics identify desired capabilities and anticipated activities of our graduates three years after graduation:

• Direct or perform basic research; conduct and evaluate design and analysis; and communicate their work clearly, working independently and in groups, with a focus on applications of interest to the commands to which they are assigned after graduation.
• Learn program details and technologies in their new areas of responsibility and apply the skills and tools learned at the Air Force Institute of Technology.
• Apply knowledge and skills to solve problems that arise in the technical work they conduct or supervise.
• Study an issue, identify and evaluate alternative actions, propose appropriate courses of action, and identify optimal choices.
• Develop and implement programs, working within their organizations, to implement the chosen solutions.
• Write, edit, and/or supervise the preparation by contractors or subordinates of written reports, journal articles, military briefings, and professional presentations that clearly communicate their work and support the needs of decision makers; present their ideas effectively and defend them appropriately.
• Develop and implement, or sustain and improve, programs that entail multidisciplinary research, simulation, modeling, engineering design, production, and/or fielding of engineered systems.

Program Outcomes (POs)

The POs of the Applied Physics program identify desired capabilities and anticipated activities of our graduates upon degree completion:

• Apply advanced concepts in mathematics and physics, including analytic and computational methods, electrodynamics, quantum mechanics, and statistical physics, to applications in the areas of laser/optics technology, materials physics, plasma physics, space physics, nuclear physics, and atmospheric science which support AF and DOD mission requirements.
• Perform research, design, and analysis, working independently and in groups, with a focus on applications of interest to the Commands for which they are assigned after graduation.
• Understand and critically evaluate technical communications in the form of journal articles, research proposals, and conference presentations and contribute and communicate their results and understanding in these same forums.

School and Program Admission Criteria

DEGREE REQUIRED: An undergraduate degree in physics or a major with at least 24 semester hours of physics. US Air Force Academy graduates with Engineering Mechanics or Engineering Science are also eligible. Undergraduate majors in Engineering, Meteorology, Astronomy, or Chemistry may be approved by department review.
MATHMATICS REQUIRED: Ordinary Differential Equations
TEST REQUIRED: GRE - 153V/148Q
GPA REQUIRED: Overall - 3.0; Mathematics - 3.0; Major - 3.0
Engineering Physics (ENP)

USAF EDUCATION CODES:
4KDY, Engineering Physics; 8FDD, Ionospheric Environment (21 mo); 8FDY, Solar and Space Sciences (21 month); 8HCX, Atomic and Molecular Physics; 8HCY, Atomic and Molecular Physics; 8HEY, Electromagnetism; 8HFC, Physics, Semiconductor Devices; 8HFU, Physics, Electronics, Other; 8HFY, Electronics; 8HHY, Engineering Physics; 8HKY, Nuclear Effects Physics; 8HLB, Nuclear Physics, Detectors; 8HLC, Nuclear Physics, Neutrons; 8HLH, Radioactive Material and Isotopes; 8HLY, Nuclear Physics; 8HMA, Atmosphere and Space Optics; 8HMH, Infrared Phenomena; 8HMJ, Lasers; 8HMY, Optics; 8HNH, Incompressible Fluid Dynamics; 8HNJ, Plasma Physics; 8HOS, Semiconductors; 8HOX, Solid State Physics, Other; 8HOY, Solid State Physics; 8HOZ, Space Physics; 8HYY, Physics, General.

Waivers to the above criteria may be granted on a case-by-case basis. Therefore, individuals whose academic credentials fall below any of the above criteria are encouraged to apply and allow the department to perform an academic evaluation.
Engineering Physics (ENP)

Applied Physics (Ph.D.)

Program Description

The PhD. program in Applied Physics, initiated in 1965, is typically 36 months in length (beyond the M.S. degree) with a total of 36 to 60 credit hours plus dissertation. The program is under the supervision of the Department of Engineering Physics with specializations available in lasers, optics and optical systems, optical processing, remote sensing and signature analysis, semiconductor physics and devices, photonics, plasma physics and processing, and chemical physics.

A program of study is largely determined by the areas and depth of knowledge required by the student in order to adequately carry out the research in his or her chosen specialization. Program content and length are embodied in the student's "approved program" and reflect departmental guidelines, as well as the school's doctoral degree requirements.

School and Program Admission Criteria

DEGREE REQUIRED: A Master’s degree in a physical science or engineering
GPA REQUIRED: B.S., 3.0; M.S., 3.5
TEST REQUIRED: GRE - 156V/151Q
USAF EDUCATION CODES: 8HYY, Physics, General; 8HCY, Atomic and Molecular Physics; 8HEY, Electromagnetism; 8HFY, Electronics; 8HHY, Engineering Physics; 8HKY, Nuclear Effects Physics; 8HLY, Nuclear Physics; 8HMY, Optics; 8HMJ, Lasers; 8HN, Physics of Fluids (Plasmas); 8HOY, Solid State Physics; 8HFG, Physics, Semiconductor Devices; 8HMA, Physics, Atmosphere and Space Optics; 8HMH, Physics, Infrared, Incompressible Fluid Dynamics; 8HNJ, Plasma Physics; 8FDA, Aeronomy; 8FDD, Ionospheric Environment

Waivers to the above criteria may be granted on a case-by-case basis. Therefore, individuals whose academic credentials fall below any of the above criteria are encouraged to apply.

Please refer to the latest version of the Department Brochure for complete program details (available upon request).

Degree Requirements

The PhD. degree requirements adhere to standards defined by the Graduate School of Engineering and Management faculty. These basic requirements include completion of at least 36 credit hours of courses, including 24 credit hours in a specialty area, 8 credit hours in math, successful completion of an exam in the specialty area, a prospectus examination, and successful completion of a dissertation. Courses that constitute a program of study will be determined by the Research Advisor and must be approved by the Department Head. A typical program of study will consist of an in-depth sequence of courses at the 6XX, 7XX, and 8XX level and will establish a foundation of knowledge suitable for pursuing dissertation research and meeting general academic expectations for the major area of study.
Engineering Physics (ENP)

Atmospheric Science (M.S.)

Program Description

This program provides a broad foundation in Atmospheric Science (Atm Sci) at the graduate level with an emphasis in atmospheric dynamics, physics and remote sensing, as well as numerical weather prediction (NWP) techniques. The program is designed to provide the graduate student with critical thinking and technical capabilities in order to develop a scientifically sound course of action to solve a problem plaguing operational units.

The program length is six quarters for full-time students, although an additional quarter of mathematics review may be added to the curriculum, when necessary. The first two quarters usually stress foundational atmospheric physics/dynamics and mathematics. During the remaining quarters, the student concentrates on applied and specialized courses and pursues research in an area of specialization.

Each student must complete an independent study/thesis and a number of courses in the area of specialization. Flexibility in the program is maintained to take full advantage of the varied backgrounds and abilities of the students. The specific courses in the curriculum vary depending on the specialization pursued and the requirements associated with the student’s assigned Air Force education code.

Emphasis is placed on applying basic physical principles together with current state-of-the-art computational and experimental techniques to address Air Force and DoD problems.

Program Educational Objectives (PEOs)

The PEOs of the Atmospheric Science program identify desired capabilities and anticipated activities of our graduates three years after graduation:

- Direct or perform basic research; conduct and evaluate design and analysis; and communicate their work clearly, working independently and in groups, with a focus on applications of interest to the commands to which they are assigned after graduation.
- Learn program details and technologies in their new areas of responsibility and apply the skills and tools learned at the Air Force Institute of Technology.
- Apply knowledge and skills to solve problems that arise in the technical work they conduct or supervise.
- Study an Air Force weather operational issue, identify and evaluate alternative actions, propose appropriate courses of action, and identify optimal choices.
- Develop and implement programs, working within their organizations, to implement the chosen solution.
- Develop and implement, or sustain and improve, programs that entail multidisciplinary research, simulation, modeling, engineering design, production, and/or fielding of engineered systems.
- Write, edit and/or supervise the preparation of reports, journal articles, military briefings, and professional presentations that clearly communicate their work and support the needs of decision makers; present their ideas effectively and defend them appropriately.
Engineering Physics (ENP)

Program Outcomes (POs)

The Pos of the Atmospheric Science program identify desired capabilities and anticipated activities of our graduates upon degree completion:

• Apply advanced concepts in mathematics atmospheric dynamics and physics, including analytic, computational and statistical methods to applications in the areas of atmospheric science which support AF and DoD mission requirements.

• Perform research, design, and analysis, working independently and in groups, with a focus on applications of interest to the commands for which they are assigned after graduation.

• Understand and critically evaluate technical communications in the form of journal articles, research proposals, and conference presentations. Be able to contribute and communicate their results and understanding in these same forums.

School and Program Admission Criteria

DEGREE REQUIRED: An undergraduate degree in Atmospheric Science or Meteorology

MATHEMATICS REQUIRED: Ordinary differential equations is required for all department M.S. degree programs.

TEST REQUIRED: (General exam only; subject test not required). GRE - 153V/148Q or 500V/600Q for GRE exams taken prior to 1 August 2012.

GPA REQUIRED: OVERALL - 3.0; MATHEMATICS - 3.0; MAJOR - 3.0

USAF EDUCATION CODES: 8FAC, Numerical Weather Prediction; 8FAY, Atmospheric Dynamics; 8FBY, Climatology; 8FEA, Synoptic Meteorology; 8FEG, Radar Meteorology; 8FEH, Satellite Meteorology; 8FEI, Tropical Meteorology; 8FEY, Analysis and Forecasting; 8FFA, Atmospheric Electricity; 8FFD, Cloud/Precipitation Physics; 8FFE, Radiative Transfer; 8FFY, Physical Meteorology; 8FAS, General Meteorology

Waivers to the above criteria may be granted on a case-by-case basis. Therefore, individuals whose academic credentials fall below any of the above criteria are encouraged to apply and allow the department to perform an academic evaluation.
Engineering Physics (ENP)

Nuclear Engineering (M.S.)

Program Description

This program provides each student with a broad foundation in nuclear technology and engineering at the graduate level. The unique combination of coursework and laboratory practice provides the student with experience working in the fields of proliferation of nuclear weapons, nuclear detection, nuclear weapon effects, the nuclear fuel cycle, and nuclear power.

This program is normally six quarters in length. Five quarters are devoted to coursework, and one quarter is devoted to thesis research. The research is normally conducted at the Air Force Institute of Technology (AFIT). The first quarter is focused on neutron transport, fuels, and reactors, to provide a strong foundational basis for the subsequent core and applications courses. The following two quarters build on the first, providing deeper meaning and practice to the concepts. The fourth quarter includes advanced labs, designed to establish the skills needed to conduct research. The fifth quarter is devoted to independent thesis research. In the final quarter, the thesis is defended and revised, as necessary, while final coursework expands the program elements into present day analyses of problems students may face after graduation.

The program satisfies the Air Force education codes 4QYY (Nuclear Engineering) with subspecialties, 4QCY (Nuclear Radiation Effects), 4QDY (Nuclear Weapons of Mass Destruction) as well as 8HKY (Nuclear Effects Physics) and 8HLY (nuclear Physics). The Commission on Institutions of Higher Education of the North Central Association of Colleges and Schools accredits the Air Force Institute of Technology through the doctoral degree level. The Engineering Accreditation Commission of the Accreditation Board for Engineering and technology (ABET) also accredits certain engineering programs. The nuclear engineering program is ABET accredited at the MS level. ABET accreditation demonstrates our continuing commitment to the quality of our program— both now and in the future.

Program Educational Objectives (PEOs)

Our graduates, in their first (and subsequent) assignments within the military nuclear science and engineering career field, will be called upon to perform some or all the following tasks.

- Develop Technical Skills: Understand mathematics, computational modeling, science, and engineering and apply them to problems of interest to the Air Force and (DOD)
- Perform Analysis: Conduct measurements and experiments; evaluate data, and interpret results
- Communicate: Communicate technical subjects orally and in writing with peers and to supervisors
- Behave Ethically: Act ethically in all aspects of science and engineering

At graduation students will have demonstrated:

- A high level of understanding of mathematics, science, and engineering as it applies to nuclear weapons and effects
- An ability to design, develop, and conduct nuclear science and engineering related research to meet a specified object or goal
- An ability to measure, analyze, and report results of nuclear and radiation processes and measurements
Engineering Physics (ENP)

- An ability to apply their education to research, and analyze a technical problem related to the needs of the defense of the nation

School and Program Admission Criteria

DEGREE REQUIRED: An undergraduate degree in Nuclear, Mechanical, Electrical, or Chemical Engineering or Physics. Some other Engineering and Math majors may also be approved by departmental review. Our master’s degree program in Nuclear Engineering is accredited by the Engineering Accreditation Commission of ABET. ABET accreditation is assurance that a college or university program meets the quality standards established by the profession for which it prepares its students. Thus, our accredited nuclear engineering program meets the quality standards set by the nuclear engineering profession. Therefore, while the AFIT graduate nuclear engineering program is unique, the program maintains a level of quality consistent with the broader nuclear engineering profession. ABET accreditation is a significant achievement, and we have worked hard to ensure that our program meets the quality standards set by the profession. Furthermore, because accreditation requires comprehensive, periodic evaluations, ABET accreditation demonstrates our continuing commitment to the quality of our program – both now and in the future. In addition to the academic criteria, this program also requires the ability to obtain a SECRET security clearance and appropriate certification to need to know. Interested civilian students should contact the Department of Engineering Physics for details.

MATHEMATICS REQUIRED: Ordinary Differential Equations

TEST REQUIRED: GRE - 153V/148Q.

GPA REQUIRED: Overall - 3.0; Mathematics - 3.0; Major - 3.0

USAF EDUCATION CODES: 4QYY, Nuclear Engineering, General; 4QCY, Nuclear and Radiation Effects; 4QDY, Nuclear Weapons of Mass Destruction; 8HKY, Nuclear Effect Physics; 8HLY, Nuclear Physics

Waivers to the above criteria may be granted on a case-by-case basis. Therefore, individuals whose academic credentials fall below any of the above criteria are encouraged to apply and allow the department to perform an academic evaluation. Please refer to the latest version of the Department Brochure for complete program details (available upon request).
Engineering Physics (ENP)

Nuclear Engineering (Ph.D.)

Program Description

The PhD. program in Nuclear Engineering, initiated in 1965, is typically 36 months in length (beyond the M.S. degree) with a total of 36 to 60 credit hours plus dissertation. The program is under the supervision of the Department of Engineering Physics with specializations available in nuclear weapons effects, counter proliferation, radiation detection, radiation effects on electronics, and neutral particle transport.

A program of study is largely determined by the areas and depth of knowledge required by the student in order to adequately carry out the research in his or her chosen specialization. Program content and length are embodied in the student’s "approved program" and reflect departmental guidelines, as well as the school’s doctoral degree requirements.

Program Educational Objectives (PEOs)

- The program is designed to produce graduates broadly educated at the highest level who are capable of actively identifying, conducting, directing, and evaluating nuclear weapons and effects research at the frontiers of knowledge.
- The successful student should be able to perform duties as a research scientist/engineer and scientific manager in order to develop the basic science and technology base required for new Air Force weapons systems.

School and Program Admission Criteria

DEGREE REQUIRED: A Master’s degree in Nuclear Engineering, Mechanical Engineering, Chemical Engineering, or Physics. Note: In addition to the academic criteria, this program also requires a SECRET security clearance and appropriate certification to need to know. Interested students should contact the Department of Engineering Physics for details.

GPA REQUIRED: B.S., 3.0 or higher; M.S., 3.5 or higher

TEST REQUIRED: GRE - 156V/151Q.

USAF EDUCATION CODES: 4QYY, Nuclear Engineering, General; 4QCY, Nuclear and Radiation Effects; 4QDY, Nuclear Weapons of Mass Destruction; 68HKY, Nuclear Effect Physics; 8HLY, Nuclear Physics

Waivers to the above criteria may be granted on a case-by-case basis. Therefore, individuals whose academic credentials fall below any of the above criteria are encouraged to apply. Please refer to the latest version of the Department Brochure for complete program details (available upon request).

Degree Requirements

The PhD degree requirements adhere to standards defined by the Graduate School of Engineering and Management faculty. These basic requirements include completion of at least 36 credit hours of courses, including 24 credit hours in a specialty area, 8 credit hours in math, successful completion of an exam in the specialty area, a prospectus examination, and successful completion of a dissertation. Courses that constitute a
Engineering Physics (ENP)

program of study will be determined by the Research Advisor and must be approved by the Department Head. A typical program of study will consist of an in-depth sequence of courses at the 6XX, 7XX, and 8XX level and will establish a foundation of knowledge suitable for pursuing dissertation research and meeting general academic expectations for the major area of study.
The Nuclear Weapons Effects, Policy, and Proliferation (NWEPP) graduate certificate program is a series of three courses educating students in a broad range of nuclear weapon topics at the graduate level. This program is targeted for captains and majors assigned to positions in the Air Force Nuclear Enterprise conducting nuclear operations, maintenance, security and logistics. NWEPP graduates will understand the basic technical aspects of nuclear weapons operations and employment and develop the skills necessary to advise and develop nuclear strategy and policy. The program consists of three, 4-credit hour courses. Focus topics included will be: the historic and current state of the US nuclear policy and strategy, the elements and technology involved in building nuclear weapons capabilities, and the unique effects of nuclear weapon detonations. All students successfully completing and maintaining a GPA of at least 3.0 in the NWEPP program (12 credit hours) will receive a certificate and have the completed certificate noted on their AFIT graduate transcript.

Program Educational Objectives (PEOs)

• Apply knowledge and skills to solve problems that arise in the technical work they conduct or supervise.
• Understand the science, phenomenology, and technology involved in nuclear weapons effects, nuclear weapons proliferation, and nuclear policy.
• Communicate technical subjects orally and in writing, perform analysis, and interpret results.
• Apply their knowledge to meet the defense needs of their organization and the nation.
• Understand the international political environment as it applies to the interplay among technology, national objectives, and adversary postures that shape nuclear policy.

Student Outcomes (SOs)

• Understand the science, phenomenology, and technology involved in the areas of nuclear weapons effects, nuclear policy, and nuclear proliferation.
• Apply advanced concepts in the areas of nuclear weapons effects, nuclear policy, and nuclear proliferation.
• Perform analysis on data, working independently and in groups, with a focus on applications to nuclear weapons effects, nuclear policy, and nuclear proliferation.
• Demonstrate the ability to quantify and estimate various nuclear effects in a scenario.
• Demonstrate the ability to analyze nuclear policy decisions and ramifications.
• Demonstrate the ability to identify and analyze nuclear proliferation areas of concern.
Engineering Physics (ENP)

Program Prerequisites

• A Bachelor degree is required and candidates must have taken a course in college-level algebra. Certificate is available to US citizens only.
• A completed application form and submission of transcripts is required at least 6 weeks prior to start of entering quarter. Academic eligibility does not guarantee admission. Candidates will be nominated to the program by AETC/A10 in consultation with Air Force Global Strike Command (AFGSC) and AETC/A10.

Program Requirements

The Nuclear Weapons Effects, Policy, & Proliferation Graduate Certificate requires the following three courses with options, some are offered via distance learning only as noted:

• NENG 596 Nuclear Weapon Effects (Distance Learning only) or NENG 631 Prompt Effects of Nuclear Weapons
• NENG 591 Nuclear Proliferation (Distance Learning only) or NENG 791 Proliferation of Weapons of Mass Destruction or CWMD 791 Combating Weapons of Mass Destruction (currently unavailable)
• NENG 500 Nuclear Weapons Strategy and Policy (Distance Learning only)
Engineering Physics (ENP)

Optical Science and Engineering (M.S.)

Program Description

The Optical Science and Engineering program is a multi-disciplinary study designed to provide a student who has a background in engineering or physical sciences with the knowledge of optics and laser technology necessary for work in the field of optical science and engineering.

The coursework in this program is in the areas of optical physics and engineering with emphasis on the application of fundamental knowledge in the design, development, test, and evaluation of Air Force systems.

This program is normally six quarters in length for a full-time Air Force student. Each student must complete an independent study, i.e., thesis, in an area related to optical science and engineering and selected from topics proposed by Air Force Institute of Technology (AFIT) faculty and solicited from Air Force research and development organizations. Research toward the Master’s thesis is typically conducted at AFIT, but may also be conducted under a cooperative research program at one of the Air Force laboratories. Flexibility in the program is maintained to take full advantage of the varied backgrounds and abilities of individual students.

Program Educational Objectives (PEOs)

The PEOs of the Optical Science and Engineering program ensure that graduates are prepared to perform the following tasks successfully:

• Primarily within, but not limited to, the field of optical sciences and engineering, direct or perform basic or applied research, conduct and/or evaluate design and analyses, and work independently and in groups.
• Communicate their work clearly, both orally and in writing (This includes writing, editing, and/or supervising the preparation of subordinates' or contractors' written reports, journal articles, briefings, and professional presentations to communicate their work clearly).
• Effectively interpret/translate between optical physicists and engineers who may not always understand each other's technologies and jargon.
• Understand the details of technologies and programs in their area of responsibility.
• Study an issue, identify and evaluate alternative actions, propose appropriate courses of action, and develop programs to implement optimal solutions.
• Develop and implement, or sustain and improve, programs that entail multidisciplinary research, simulation, modeling, engineering design, production, and/or fielding of engineered optical systems.

Program Outcomes (POs)

The POs of the Optical Science and Engineering program describe what students will know or be able to perform upon degree completion:

• Apply advanced concepts in mathematics and optical physics and engineering, including analytic, experimental, and computational methods, to a particular application in the field of optical science and engineering.
• Perform optical sciences and engineering research, design, and analysis, working independently or in groups, limited to a particular problem or problems of interest with which they have experience during their Air Force Institute of Technology experience.
Engineering Physics (ENP)

- Communicate optical sciences and engineering research, design, and analysis effectively, working independently or in groups, limited to a particular problem or problems of interest with which they have experience during their Air Force Institute of Technology experience.
- Understand and critically evaluate technical communications in the form of journal articles, research proposals, and conference presentations and contribute and communicate their results and understanding in these same forums.

School and Program Admission Criteria

DEGREE REQUIRED: An undergraduate degree in Physics, or degree in Engineering or Physical Science with approval from department.
MATHEMATICS REQUIRED: Ordinary Differential Equations
TEST REQUIRED: GRE - 153V/148Q.
GPA REQUIRED: Overall - 3.0; Mathematics - 3.0; Major - 3.0

Waivers to the above criteria may be granted on a case-by-case basis. Therefore, individuals whose academic credentials fall below any of the above criteria are encouraged to apply and allow the department to perform an academic evaluation. Please refer to the latest version of the Department Brochure for complete program details (available upon request).
Program Description

The PhD program in Optical Science and Engineering is typically 36 months in length (beyond the M.S. degree) with a total of 36 to 60 credit hours plus dissertation. The program is under the supervision of the Department of Engineering Physics.

Specialization in the area of optical science and engineering, formally known as electro-optics, was added in the mid-1970s with emphasis on the areas of lasers, optics and optical systems, optical processing, remote sensing and signature analysis, laser beam propagation and control, and photonics.

A program of study is largely determined by the areas and depth of knowledge required by the student in order to adequately carry out the research in his or her chosen specialization. Program content and length are embodied in the student's "approved program" and reflect departmental guidelines, as well as the school's doctoral degree requirements.

Program Educational Objectives (PEOs)

The program is designed to produce graduates broadly educated at the highest level who are capable of actively identifying, conducting, directing, and evaluating research in electro-optics and photonics at the frontiers of knowledge. The successful student should be able to perform duties as a research scientist/engineer and scientific manager in order to develop the basic science and technology base required for new Air Force weapons systems.

School and Program Admission Criteria

DEGREE REQUIRED: A Master’s degree in a physical science or engineering
GPA REQUIRED: B.S., 3.0 or higher; M.S., 3.5 or higher
TEST REQUIRED: GRE - 156V/151Q

Waivers to the above criteria may be granted on a case-by-case basis. Therefore, individuals whose academic credentials fall below any of the above criteria are encouraged to apply. Please refer to the latest version of the Department Brochure for complete program details (available upon request).

Degree Requirements

The PhD degree requirements adhere to standards defined by the Graduate School of Engineering and Management faculty. These basic requirements include completion of at least 36 credit hours of courses, including 24 credit hours in a specialty area, 8 credit hours in math, successful completion of an exam in the specialty area, a prospectus examination, and successful completion of a dissertation. Courses that constitute a program of study will be determined by the Research Advisor and must be approved by the Department Head. A typical program of study will consist of an in-depth sequence of courses at the 6XX, 7XX, and 8XX level and will establish a foundation of knowledge suitable for pursuing dissertation research and meeting general academic expectations for the major area of study.
Engineering Physics (ENP)

Doctoral Program

The doctoral program is designed to produce graduates broadly educated at the highest level who are capable of actively identifying, conducting, directing, and evaluating research at the frontiers of knowledge. The successful student should be able to perform duties as a research scientist/engineer and scientific manager in order to develop the basic science and technology base required for new Air Force weapons systems.

The Ph.D. program in the Department of Engineering Physics offers specialization in lasers, optics and optical systems, optical processing, remote sensing and signature analysis, semiconductor physics and devices, photonics, chemical physics, transport theory, and nuclear engineering. Program length (for full-time AF students) is 3 yrs. The program content is largely determined by the areas and depth of knowledge required by the student in order to adequately carry out the research required in their chosen specialty. These program requirements are embodied in the student’s “approved program” and reflect certain departmental requirements, as well as the doctoral degree requirements. These degree requirements adhere to standards defined by the Graduate School of Engineering and Management faculty. These basic requirements are discussed in this section.

Admission to the Ph.D. Program

Admission to the doctoral program in the Department of Engineering Physics requires:

- B.S. GPA of >3.0
- Master’s degree in Physical Science or Engineering or Physics
- M.S. GPA of >3.5
- GRE scores of 550 verbal and 650 quantitative, or higher, on old scale; equivalent scores on new scale have been chosen as 156 verbal and 151 quantitative.

Interested candidates should contact the Air Force Institute of Technology Admission (AFIT/ENER) for details on selection and admission procedures. Civilian applicants should also contact Department of Engineering Physics faculty in research area or interest; or, contact Department Head.

General Ph.D. Degree Requirements

A summary of the general Air Force Institute of Technology Graduate School of Engineering and Management doctoral degree requirements is listed here for the convenience of the reader. For more complete information and for final authority on these requirements, the reader should consult the current applicable Graduate School of Engineering and Management Operating Instruction ENOI 36-114*. In addition, the policies regulating the Air Force Institute of Technology Doctoral Program as set by the Air Force Institute of Technology Doctoral Council are contained in a series of policy letters** that are a “must” reading for all doctoral students. A set of these policy letters can be found on the Air Force Institute of Technology web pages.

*Operating Instructions: http://org.eis.afit.edu/dept/en/OperatingInstructions/Forms/AllItems.aspx

**AFIT Doctoral Council policy letters:
http://org.eis.afit.edu/dept/en/doctrotalcouncil/policyltrs/Forms/AllItems.aspx
Engineering Physics (ENP)

All DOD-sponsored military Ph.D. students must be enrolled in a minimum of 12 cr hrs each quarter. An approved education plan is required by the end of the first quarter of full-time enrollment. Modifications to the plan can be made after the first quarter.

The Ph.D. degree may be awarded for the successful completion of a curriculum that has the approval of the faculty as meriting the degree. To satisfy the specific requirements for this degree, the student must have:

1. Been admitted to candidacy for the doctoral degree at least one year before receipt of the degree. Admission to candidacy is granted by the Dean of the Graduate School of Engineering and Management. The requirements for candidacy are:
   - Completion of a M.S. degree in an appropriate discipline
   - Completion of at least 36 quarter hours of coursework beyond the M.S. degree in an approved program with an average of at least 3.0 on all courses taken.
   - Approval by the student’s research committee of a prospectus for the dissertation project.
   - Satisfactory completion of the specialty courses and specialty examinations
   - Satisfactory completion of the mathematics requirement.

2. Completed an approved program of study. This consists of:
   - Three consecutive quarters of full-time coursework in residence, plus any additional hours necessary to total at least 36 quarter hours in residence beyond the M.S. degree. Of the 36 quarter hours in residence, 24 quarter hours must be successfully completed in the specialty area.
   - An average grade of at least 3.0 over all courses attempted after admission to the program.

3. Satisfactorily completed and submitted an acceptable dissertation on an approved research project.

4. Satisfactory completion of the mathematics requirement.

5. Completed all of the above requirements within eight years from the beginning of their full-time doctoral studies, and not more than four years after admission to candidacy.

6. Been recommended for the degree by the academic department and the Faculty Council Academic Standards Committee of the Graduate School of Engineering and Management.
Engineering Physics (ENP)

Department Core Requirements for the Ph.D.

The Department of Engineering Physics offers Ph.D. programs in the areas of Applied Physics, Materials Science and Engineering, Nuclear Engineering, and Optical Sciences and Engineering.

Courses that constitute a program of study will be determined by the Research Advisor (must be chosen by end of first quarter) and must be approved by the Department Head. The faculty have specified a set of core requirements to be met by candidates for the Ph.D. degree in the various disciplines offered by the department. These requirements are designed to ensure that students who enter the program with varied backgrounds will develop sufficient knowledge in their chosen doctoral area to qualify for the Ph.D. degree in that area. A typical specialty or major sequence of courses will usually consist of three core courses, plus an in-depth specialty sequence of six courses typically at the 7XX or 8XX level that lays the groundwork for the dissertation research.

A written specialty exam is normally taken during the 5th quarter (after completion of most required courses). Prior to this exam, the student’s research committee is established by formal memo subject to approval of Dept Head.

Upon completion of lecture/lab courses, the full-time military Ph.D. student must enroll in a minimum of 11 research hours (NENG 999, PHYS 999, for example) each quarter; all PhD military students are required to enroll in PHYS 798 (1 cr hr) each quarter, thus giving a total of 12 cr hrs once classes are completed. Non-military students must take 48 cr hrs of 999 research hours in their program.
**Engineering Physics (ENP)**

**Materials Science**

**Program Description**

The goal of the Materials Science program is to provide a student who has a background in engineering or physical science with the knowledge of materials science and engineering necessary for work in the fields of structural and non-structural materials for aerospace systems. Such positions may range from those requiring very detailed and advanced level work in a specific discipline to those involving broad responsibilities and requiring interaction among many disciplines.

The Materials Science program is under joint supervision of the Department of Aeronautics and Astronautics (Structural Materials) and the Department of Engineering Physics (Electrical and Optical Materials, i.e., Non-Structural Materials). This program is normally six quarters in length. Five quarters are devoted to coursework, and one quarter is devoted to thesis research.

The program provides core preparation in thermodynamics and kinetics of materials, mechanical, electronic, and optical properties of materials, material characterization, material selection and processing, and mathematics. The materials studies emphasize atomic models of structure composition and properties. Each student is also required to take an in-depth study and perform research either in structural materials (metallic, composite, polymer, ceramics, etc.) or non-structural materials (electronics, optical, magnetic, dielectric, nanoscale, nuclear, etc.). Emphasis is placed on applications of fundamental knowledge to the design, development, test, and evaluation of materials for Air Force and DOD systems. The student will master at least one specialty area in optical materials, electronic materials, dielectric materials, magnetic materials, nanoscale materials, nuclear materials, or computational materials science. Such positions may range from those requiring very detailed and advanced level work in a specific discipline to those involving broad responsibilities and requiring interaction among many disciplines.

**Program Educational Objectives (PEOs)**

The PEOs of the Materials Science program ensure that graduates are prepared to perform the following tasks successfully:

- Possess a solid background in the fundamental areas of materials science and engineering (structural and non-structural materials, thermodynamics and kinetics, materials characterization, and materials selection and processing).
- Possess an in-depth knowledge in at least one specialty area.
- Possess experience in conducting and documenting an independent investigation, a thesis, or a problem of Air Force interest.
Engineering Physics (ENP)

Program Outcomes (POs)

The Pos of the Materials Science program describe what students will know or be able to perform upon degree completion:

- Demonstrate a high level of understanding of mathematics, science, and engineering as it applies to properties and characterization of structural materials, electronic materials, and optical materials.
- Demonstrate the ability to measure, analyze, and report results of measuring and modeling of materials properties.
- Demonstrate the ability to develop, describe, and conduct significant research to meet a specific materials science objective.
- Demonstrate educational accomplishments in materials science by presenting results of a research investigation into a problem of current or future defense interest that they planned and executed.

School and Program Admission Criteria

DEGREE REQUIRED: An undergraduate degree in Materials Science, Mechanical Engineering, Chemistry, Physics or related Engineering disciplines. The following courses are required: Introduction to Materials, Physical Chemistry, or Materials Chemistry. Waivers may be approved by department review.

MATHEMATICS REQUIRED: Ordinary Differential Equations
TEST REQUIRED: GRE - 153V/148Q.
GPA REQUIRED: Overall - 3.0; Mathematics - 3.0; Major - 3.0

USAF EDUCATION CODES: Air Force students are typically assigned one of the following education codes: 4FYY, Materials Science and Engineering, General; 4KCB, Mechanical Properties of Materials; 4FBY, Electronic and Optical Materials; 4GCK, Nuclear Chemical Engineering; 4FCY Ceramic Engineering. Current sponsors of Air Force military education quotas are 4FYY - AFRL/RXPSE (WPAFB and Robins AFB), 4KCB - AFRL/RXLMN (WPAFB), 4NCY - AFRL/RXLMP (WPAFB), 4FBY - AFRL/RDHP (Kirtland AFB), AFRL/RXLP and AFRL/RYD (WPAFB).

Waivers to the above criteria may be granted on a case-by-case basis. Therefore, individuals whose academic credentials fall below any of the above criteria are encouraged to apply and allow the department to perform an academic evaluation. Please refer to the latest version of the Department Brochure for complete program details (available upon request).
Mathematics and Statistics (ENC)

Department Head: Alan V. Lair, PhD
2950 Hobson Way Building 641, Room 227
Wright Patterson AFB OH 45433-7765
Phone: (937) 255-3098 (DSN 785-3098)
Fax: (937) 656-4413
E-mail address: enc@afit.edu
Website: https://www.afit.edu/enc

The Department of Mathematics and Statistics offers the Master of Science (MS) and Doctor of Philosophy (PhD) degree programs in applied mathematics. Specialization can be from a variety of areas within mathematical analysis, including numerical analysis, and statistics.

Programs

Master of Science

- Applied Mathematics (M.S.)

Doctor of Philosophy

- Applied Mathematics (Ph.D.)

Faculty

Professor

<table>
<thead>
<tr>
<th>Name</th>
<th>Research Areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benjamin F. Akers</td>
<td>nonlinear waves, numerical analysis, fluid mechanics</td>
</tr>
<tr>
<td>Matthew C. Fickus</td>
<td>Fourier series, wavelets, applied harmonic analysis</td>
</tr>
<tr>
<td>Alan V. Lair</td>
<td>partial differential equations, functional analysis</td>
</tr>
<tr>
<td>Mark E. Oxley</td>
<td>partial differential equations, wavelets, information fusion</td>
</tr>
<tr>
<td>Christine M. Schubert</td>
<td>biostatistics, classification methods, information fusion</td>
</tr>
<tr>
<td>Kabban</td>
<td></td>
</tr>
<tr>
<td>Edward D. White, III</td>
<td>biostatistics, design of experiments, regression</td>
</tr>
<tr>
<td>Aihua W. Wood</td>
<td>partial differential equations, electromagnetics, rarefied gas dynamics</td>
</tr>
</tbody>
</table>

Associate Professor

<table>
<thead>
<tr>
<th>Name</th>
<th>Research Areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>William P. Baker</td>
<td>asymptotic and perturbation methods, wave propagation</td>
</tr>
<tr>
<td>Dursun A. Bulutoglu</td>
<td>design of experiments, combinatorial optimization</td>
</tr>
</tbody>
</table>

Assistant Professor

<table>
<thead>
<tr>
<th>Name</th>
<th>Research Areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Timothy S. Anderson</td>
<td>computational statistics, uncertainty quantification, analytics</td>
</tr>
<tr>
<td>Travis J. Bemrose</td>
<td>applied harmonic analysis, frame theory</td>
</tr>
</tbody>
</table>
# Mathematics and Statistics (ENC)

<table>
<thead>
<tr>
<th>Name</th>
<th>Research Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eric L. Brooks</td>
<td>statistical machine learning, big data</td>
</tr>
<tr>
<td>Andrew J. Geyer</td>
<td>design of experiments, combinatorial optimization</td>
</tr>
<tr>
<td>Robert B Hartlage</td>
<td>large-scale math programming, network optimization</td>
</tr>
<tr>
<td>Jeremy D. Jordan</td>
<td>operations research, analytics, network optimization</td>
</tr>
<tr>
<td>Tony Liu</td>
<td>approximation theory, numerical analysis</td>
</tr>
<tr>
<td>Dana F. Morrill</td>
<td>numerical analysis, fluid mechanics</td>
</tr>
<tr>
<td>Beau A. Nunnally</td>
<td>biostatistics, classification systems</td>
</tr>
<tr>
<td>Jonathan S. Turner</td>
<td>analysis, combinatorics, optimization</td>
</tr>
<tr>
<td>Daniel E. Reynolds</td>
<td>environmental statistics</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Title</th>
<th>Name</th>
<th>Research Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assistant Professor</td>
<td>Amy L. Magnus</td>
<td>computational intelligence, biometrics, information fusion, constraint programming</td>
</tr>
<tr>
<td>Emeritus</td>
<td>Professor</td>
<td></td>
</tr>
<tr>
<td>Research Assistant Professor</td>
<td>Dennis W. Quinn</td>
<td>partial differential equations</td>
</tr>
<tr>
<td>Professor Emeritus</td>
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<td>Emeritus</td>
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<td>Professor Emeritus</td>
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Mathematics and Statistics (ENC)

Applied Mathematics (M.S.)

Program Description

The Logistics program (LOGSCI) provides students with the opportunity to learn and exercise state-of-the-art management knowledge and tools to solve defense acquisition and logistics problems. In addition, students have the opportunity to pursue a systems view of logistics management. For DoD-sponsored full-time or part-time students, the LOGSCI program requires 12 months (4 academic quarters) of full-time study and begins in June of each year, or 36 months (12 academic quarters) of part-time distance-learning-based study beginning in January of each year. Typically, only those DoD sponsored students selected for in-residence may participate in full-time program and only those DoD-sponsored students selected for the distance-learning track may participate in the part-time program. Other individuals, such as civilian DoD employees or defense contractor employees may participate in this program as space allows. This program leads to a Master of Science in Logistics.

Program Educational Objectives (PEOs)

Graduates are well-prepared to use mathematical and statistical techniques to make significant progress toward solving problems of interest to the AF, DoD and DHS. They are equipped to collaborate with the science and technology community to address questions of national defense and security.

Graduates will be able to:
- Understand an applied problem well enough to give a mathematical formulation of it
- Analyze a new problem rigorously and propose credible solutions
- Communicate mathematical concepts effectively by written and oral means

Program Outcomes (POs)

School and Program Admission Criteria

DEGREE REQUIRED: Bachelor’s in mathematics or statistics, or in science or engineering with a strong background in mathematics.

MATHEMATICS REQUIRED: A senior-level mathematical analysis course.

TEST REQUIRED: GRE - 153V/148Q

GPA REQUIRED: OVERALL - 3.0; MATH - 3.0; MAJOR - 3.0

Waivers to the above criteria may be granted on a case-by-case basis. Therefore, individuals whose academic credentials fall below any of the above criteria are encouraged to apply.
Mathematics and Statistics (ENC)

Degree Requirements

Core Courses - 16 hours

Out-of-Department sequence - 8 hours

Specialization - 12 hours

Thesis - 12 hours
Mathematics and Statistics (ENC)

Applied Mathematics (Ph.D.)

Program Description

The aim of the doctoral program is to provide comprehensive knowledge of existing theory and how it applies to problems in science and engineering along with the opportunity to extend the world’s knowledge significantly beyond those bounds. A student seeking a Doctor of Philosophy degree should have a Master’s degree in mathematics, statistics, science, or engineering. Being an applied program, particular emphasis is placed on educating students to recognize the relevance of analytical and numerical methods to the solution of specific problems and to enable them to develop new methods when they are needed. The education aims to produce an applied mathematician or applied statistician with the ability to develop new theoretical results and apply them as the need arises. Central to this goal is the research part of the program. Both the ability to conduct the research successfully and to report it in a coherent and fully documented dissertation is essential to the program. The program is kept sufficiently flexible, however, to permit students to develop their own specific interests.

Program Outcomes (POs)

• Graduates will be able to understand and evaluate critically the literature of the field.
• Graduates will be able to apply appropriate principles and procedures to the recognition, evaluation, interpretation, and understanding of issues and problems at the frontiers of knowledge.
• Graduates will have acquired the knowledge, skills, ethics, and independence of thought and action expected of a scholar.
• Graduates will have extended and effectively communicated knowledge in his/her field.

School and Program Admission Criteria

DEGREE REQUIRED: Master’s in mathematics or statistics, or in science or engineering and a strong background in mathematics or statistics.

TEST REQUIRED: GRE -156V/151Q
GPA REQUIRED: 3.5 in Master’s

Waivers to the above criteria may be granted on a case basis. Therefore, individuals whose academic credentials fall below any of the above criteria are encouraged to apply.

Degree Requirements

Specialization (24 hours)

Out-of-Department Requirements (8 hours)

Dissertation Research (48 hours)

Admission to candidacy
Mathematics and Statistics (ENC)

One year before graduation

In-residence study
Three (3) quarters of full-time study in residence during any contiguous four-quarter period Present Dissertation at a Public Defense
Operational Sciences (ENS)

Department Head: Joseph J. Pignatiello, PhD
2950 Hobson Way Building 641, Room 201
Wright Patterson AFB OH 45433-7765
Phone: (937) 255-3636 x3136 (DSN 785-3636 x3136)
Fax: (937) 656-4943 (DSN 986-4943)
E-mail address: ens@afit.edu
Website: https://www.afit.edu/ENS

The Department of Operational Sciences offers world class graduate programs in Operations Research, and Logistics and Supply Chain Management, and Operations Management. Our faculty is comprised of experts in all major areas of operations research and logistics and supply chain management whose research has been substantially funded by Department of Defense, government, and industry sources. Members of the department are recognized leaders in the advancement of the methodology and application of operations research and logistics management.

Our faculty and staff are dedicated to:

- Offering degree programs that prepare the next generation of defense and industry analysts and leaders,
- Creating cutting edge knowledge that contributes to solving the major problems facing modern society, focusing on the defense of that society,
- Responding to the needs of all of our customers and research partners, and
- Providing an environment of rigor and mentorship that fosters academic excellence.

Facilities

The Department of Operational Sciences is home to two AFIT Centers of Excellence.

The Center for Operational Analysis (COA) is a multidisciplinary research and education center focused on defense-related operational modeling and analysis. The COA was formally recognized in March of 2003. Expanding the mission of the former Center for Modeling, Simulation, and Analysis, the COA is dedicated to research and education in operational analysis with an emphasis on enhancing warfighter efficiency and effectiveness at all levels.

Visit the COA on line at https://www.afit.edu/COA/.

The Scientific Test and Analysis Techniques in Test and Evaluation Center of Excellence (COE) received its initial funding in 2012, following a request by the Office of the Deputy Assistant Secretary of Defense, Developmental Test and Evaluation (DASD, DT&E) that Air Education and Training Command designate such a center within the AFIT Graduate School. This request reflects acknowledgment of AFIT as a leader in the field of Test and Evaluation (T&E). Goals of the new COE are to improve T&E planning, execution, and assessment, and to develop more rigorous, scientific, and statistically based T&E design methodologies.

Visit the COE on line at: https://www.afit.edu/STAT/.
Operational Sciences (ENS)

In addition to the COA and the COE, six research-focused laboratories reside within the department, providing tools, methods, and analysis to support students and their research:

- Combat Modeling Laboratory
- Future Operations Investigation Laboratory
- Joint Deployment & Distribution Environment Laboratory
- Manpower Personnel Modeling Laboratory
- Science of Test Research Laboratory
- Sensor Fusion Laboratory

Programs

Master of Science

- Logistics (distance learning)
- Logistics and Supply Chain Management
- Operations Management (IDE Air Mobility)
- Operations Research

Doctor of Philosophy

- Logistics
- Operation Research

Certificate

- Cost Capability Analysis
- Data Science
- Supply Chain Management (distance learning)
- Test and Evaluation (distance learning)

Faculty

Professor Darryl K. Ahner dynamic programming applications, queuing applications, mathematical control theory and model predictive control of complex systems, missile defense, combat modeling algorithm development, models for supply chain management

William A. Cunningham, III strategic mobility, cost/benefit analysis, econometric modeling, costing privatization and A-76 studies, modal choice, network analysis, location analysis, supply chain management, RFID

Richard F. Deckro information operations and information assurance, reconstruction and stabilization, measures of effectiveness and assessment, behavioral modeling including social networks, modeling fourth generation operations, counter insurgency and irregular warfare, a
<table>
<thead>
<tr>
<th>Name</th>
<th>Research Interests</th>
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</thead>
<tbody>
<tr>
<td>Raymond R. Hill, Jr.</td>
<td>applied statistics in the application of design of experiments methodologies to test and evaluation, mathematical optimization in the use of heuristic search methods for addressing particularly hard problems, and applied simulation modeling and analysis w</td>
</tr>
<tr>
<td>Joseph J. Pignatiello</td>
<td>statistical process monitoring, change-point models, design and analysis of experiments, reliability, statistical data analysis, robust, and six sigma methods</td>
</tr>
<tr>
<td>Seong-Jong Joo</td>
<td>sourcing, transportation, performance measurement and benchmarking, inventory management</td>
</tr>
<tr>
<td>Jeffery D. Weir</td>
<td>decision analysis, applied statistics, deterministic optimization</td>
</tr>
<tr>
<td>Frank Ciarallo</td>
<td>Strategies for Centralization of Stock in Pharmaceutical Distribution Networks, Study of Aircraft Component Failures Leading to Lumpy Spare Part Demands, Two-Echelon Inventory Systems with Transshipment and Quantity Discounts, Warehouse Picking Operations</td>
</tr>
<tr>
<td>Brian J. Lunday</td>
<td>theoretical research interests include math programming, game theoretical models and algorithmic design for global optimization; application research interests include network design, network interdiction, network restoration, facility location, resource al</td>
</tr>
<tr>
<td>John O. Miller</td>
<td>computer simulation, ranking and selection, agent based modeling, combat modeling, network centric warfare, high performance computing, applied statistics, and nonparametric statistics</td>
</tr>
<tr>
<td>Matthew J. Robbins</td>
<td>applied statistics, approximate dynamic programming, decision analysis, game theory, Markov decision processes, network science, simulation</td>
</tr>
<tr>
<td>Jason R. Anderson</td>
<td>transportation, logistics management, inventory, sourcing, operations management, simulation</td>
</tr>
<tr>
<td>Timothy W. Breitbach</td>
<td>supply chain finance, logistics, inventory and petroleum management, qualitative and quantitative supply chain analysis</td>
</tr>
<tr>
<td>Lance E. Champagne</td>
<td>agent-based simulation, combat simulation, emergent system behavior</td>
</tr>
<tr>
<td>Bruce A. Cox</td>
<td>linear and convex optimization, robust optimization, optimal control</td>
</tr>
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</table>
### Operational Sciences (ENS)

<table>
<thead>
<tr>
<th>Name</th>
<th>Research Interests</th>
</tr>
</thead>
<tbody>
<tr>
<td>John M. Dickens</td>
<td>service-dominant logic, value and value-creation, supply chain resilience, transaction cost economics, self-determination theory, resource-based view, experiments, survey, simulation methodologies</td>
</tr>
<tr>
<td>Phillip R. Jenkins</td>
<td>dynamic programming, approximate dynamic programming, Markov decision processes, stochastic programming, applied statistics, machine learning, multi-objective optimization</td>
</tr>
<tr>
<td>Phillip M. LaCasse</td>
<td>applied machine learning, applied statistics, smart manufacturing: defect prediction, preemption, big data, data science, sports analytics</td>
</tr>
<tr>
<td>Adam D. Reiman</td>
<td>airlift metrics, routing, scheduling, and fuel efficiency, energy efficiency, supply and demand, value-focused thinking, heuristic search algorithms</td>
</tr>
<tr>
<td>Thomas P. Talafuse</td>
<td>reliability, reliability growth, optimization, stochastic processes, design of experiments, applies statistics, risk analysis</td>
</tr>
<tr>
<td>Marcelo Zawadzki (BR)</td>
<td>resource allocation against emerging threats, multi-criteria analysis</td>
</tr>
<tr>
<td>Professor of Practice</td>
<td></td>
</tr>
<tr>
<td>Mark A. Gallagher</td>
<td>applied statistics, forecasting, decision analysis, linear programming</td>
</tr>
<tr>
<td>Adjunct Faculty</td>
<td></td>
</tr>
<tr>
<td>Nathaniel D. Bastian</td>
<td>multiple objective optimization, stochastic programming, decisions analysis, simulation, statistical computing, applied econometrics, production economics, machine learning, graph mining, data science</td>
</tr>
<tr>
<td>Trevor J. Bihl</td>
<td>control systems, cyber security, power systems, sensor data exploitation, statistics, data mining, signal processing</td>
</tr>
<tr>
<td>Bradley C. Boehmke</td>
<td>supply chain analytics and data science, big data analytics, organizational economics, resource orchestration, business intelligence, operations software tool development</td>
</tr>
<tr>
<td>Sarah E. Burke</td>
<td>design of experiments, response surface methodology, statistical process monitoring, time series analysis, statistical design and analysis for multi-response systems</td>
</tr>
<tr>
<td>Matthew A. Douglas</td>
<td>social sustainability in supply chains and transportation, ethics and ethical decision-making, management/technological innovation diffusion in organizations/supply chains, leading and sustaining transformation, cross-functional relationships/integration</td>
</tr>
</tbody>
</table>
## Operational Sciences (ENS)

<table>
<thead>
<tr>
<th>Name</th>
<th>Research Areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kevin J. Gaudette</td>
<td>supply chain design, distribution network optimization, sports analytics, process design, performance management, stochastic modeling, simulation</td>
</tr>
<tr>
<td>Alex J. Gutman</td>
<td>design of experiments, computer experiments, supersaturated designs, response surface methodology, Bayesian statistics, machine learning, regression modeling, classification, decision analysis</td>
</tr>
<tr>
<td>Shane N. Hall</td>
<td>determining optimal allocation/utilization of scarce or high-valued resources with specific applications in the health-care and military sectors</td>
</tr>
<tr>
<td>Sharon G. Heilmann</td>
<td>employee turnover, mentoring, training transfer</td>
</tr>
<tr>
<td>Jeremy P. Hendrix</td>
<td>systems engineering, operations research, VBA, data analysis, simulation</td>
</tr>
<tr>
<td>Joseph R. Huscroft</td>
<td>supply chain management, reverse logistics, reverse logistics metrics, innovation and flexibility in the supply chain, operations management, information systems impact on the supply chain, transportation and distribution</td>
</tr>
<tr>
<td>Daniel Johnstone</td>
<td>inventory optimization, multi-echelon service parts supply networks, supply chain risk management, supply chain resilience, constraint-based management in production environments</td>
</tr>
<tr>
<td>Kyle F. Kolsti</td>
<td>computational methods for test data analysis, reliability and availability</td>
</tr>
<tr>
<td>Daniel D. Mattioda</td>
<td>collaboration and flexibility in the supply chain, reverse logistics, international logistics, using simulation to model supply chain processes</td>
</tr>
<tr>
<td>James F. Morris</td>
<td>leveraging operations research, social network analysis, practical application within the intelligence community</td>
</tr>
<tr>
<td>Steven C. Oimoen</td>
<td>applied statistics, design of experiments</td>
</tr>
<tr>
<td>Francisco Ortiz, Jr.</td>
<td>design of experiments, advanced regression techniques, multiple response optimization and genetic algorithms, metallurgy and control systems</td>
</tr>
<tr>
<td>Carl R. Parson</td>
<td>dynamic programming, stochastic processes, military operations research, stochastic resource allocation, optimization</td>
</tr>
<tr>
<td>David K. Peterson</td>
<td>readiness-based sparing (RBS) inventory management, sustainment planning and assessment for system-of-systems</td>
</tr>
<tr>
<td>Name</td>
<td>Research Areas</td>
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<tr>
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<tr>
<td>Edward K. Pohl</td>
<td>risk, reliability, engineering optimization, healthcare and supply chain risk</td>
</tr>
<tr>
<td></td>
<td>analysis, decision making, quality</td>
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<tr>
<td>William F. Rowell</td>
<td>cybersecurity test and evaluation, T&amp;E of software intensive systems, automated</td>
</tr>
<tr>
<td></td>
<td>software testing, T&amp;E of autonomous systems</td>
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<tr>
<td>James R. Simpson</td>
<td>quality engineering, statistically designed experiments, response surface</td>
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<tr>
<td></td>
<td>methods, statistical process control, robust, regression methods, engineering</td>
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<tr>
<td></td>
<td>statistics, simulation, operations research and supply chain management</td>
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<tr>
<td>Christopher M. Smith</td>
<td>decision analysis, risk analysis, data mining, network analysis, social media</td>
</tr>
<tr>
<td>Daniel W. Steeneck</td>
<td>inventory management, remanufacturing, scheduling, service parts management,</td>
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<tr>
<td></td>
<td>supply chain analytics, retail operations</td>
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<tr>
<td>Steven N. Thorsen</td>
<td>information fusion, classification theory, application of receiver operating</td>
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<tr>
<td></td>
<td>characteristic (ROC) manifolds</td>
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<tr>
<td>Leonard F. Truett, III</td>
<td>use of experimental designs for quality improvement, response surface</td>
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<tr>
<td></td>
<td>methodology, statistical quality control, regression analysis</td>
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<tr>
<td>G. Geoffrey Vining</td>
<td>The mechanisms with which organizational identity and organizational culture</td>
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<td></td>
<td>are formed, the interaction between organizational leadership and culture, the</td>
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<td>effective means for modifying organizational culture</td>
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<tr>
<td>Adjunct Instructor</td>
<td>Erin B. Lunday</td>
</tr>
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<td></td>
<td>effective means for modifying organizational culture</td>
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</tbody>
</table>
Operational Sciences (ENS)

Logistics (M.S.)

Program Description

The Logistics program (LOGSCI) provides students with the opportunity to learn and exercise state-of-the-art management knowledge and tools to solve defense acquisition and logistics problems. In addition, students have the opportunity to pursue a systems view of logistics management. For DoD-sponsored full-time or part-time students, the LOGSCI program requires 12 months (4 academic quarters) of full-time study and begins in June of each year, or 36 months (12 academic quarters) of part-time distance-learning-based study beginning in January of each year. Typically, only those DoD sponsored students selected for in-residence may participate in full-time program and only those DoD-sponsored students selected for the distance-learning track may participate in the part-time program. Other individuals, such as civilian DoD employees or defense contractor employees may participate in this program as space allows. This program leads to a Master of Science in Logistics.

Program Educational Objectives (PEOs)

Our Program Educational Objectives (expectations two or more years beyond graduation) are to produce graduates who:

• Breadth. Apply foundational logistics concepts and sound analytical principles to efficiently and effectively advance Air Force and DoD logistics capabilities.
• Depth. Are well educated, highly-valued, and successful logisticians.
• Professionalism. Professionally communicate technical solutions and results.
• Lifelong Learning. Continue to pursue lifelong multidisciplinary learning.

Program Outcomes (POs)

Our Student Outcomes (student/knowledge/skills/abilities upon graduation) produce graduates who:

• Critical thinking skills. Can critically analyze situations, information, and data
• Problem solving skills. Can formulate problem statements, ascertain and collect the relevant data, and utilize the correct methodology in order to both delineate and solve problems in the real world
• Communication skills. Can effectively communicate to peers, subordinates, and supervisors in a professional manner both orally and in writing
• Logistics specific knowledge. Have developed a thorough understanding of the logistics, mobility, and supply chain discipline as required to make strategic level managerial decisions in the logistics area

Additional Information

All students are required to complete a research or design project under the direction of a faculty advisor. This study project requirement provides an introduction to the research process, strengthens the student’s writing skills, and augments the AFIT/ENS research program. It is intended for students to apply the processes, methods, and tools, acquired throughout their academic program, to a relevant DoD war fighting problem. The project is documented in an advisor approved format and defended orally. Students will take 4 to 6 course hours (depending on track) of LOGM 791 and 4 hours of LOGM 601.
Operational Sciences (ENS)

School and Program Admission Criteria

DEGREE REQUIRED: Any Field
MATHEMATICS REQUIRED: College Algebra with grade of B or better
TEST REQUIRED: GMAT – 550; or GRE Scores of at least 153V/148Q
GPA REQUIRED: OVERALL - 3.0; MATH - 3.0
Board selected for in-residence or distance-learning program

Waivers to the above criteria may be granted on a case by case basis. Therefore, individuals whose academic credentials fall below any of the above criteria are encouraged to apply.

Degree Requirements

Detailed current information on this program, including degree requirements and suggested course sequence by term, is contained in the complete Program Guide at http://www.afit.edu/ENS/

Core Courses
- LOGM 520 - Managerial Economics
- LOGM 570 - Principles of Inventory Management
- LOGM 601 – Principles and Methods of Research
- LOGM 617 - Transportation Systems and Strategic Mobility
- LOGM 620 - Activity Based Costing/Management
- LOGM 542 - Management of Logistics Organizations

Track Sequence
  Resident Track:
  - LOGM 567 Lean Operations Mgmt
  - LOGM 660 Strategy for Logistic

  Distance-Learning Track:
  - LOGM 569 Maintenance & Production Mgmt
  - LOGM 565 Strategic Sourcing
  - LOGM 568 Intro to Supply Chain Mgmt

Tools
- STAT 521 - Applied Statistical Data Analysis
- OPER 501 - Quantitative Decision Making

Capstone
- LOGM 627 - Supply Chain Management

Graduate Research Project
- LOGM 791 - Research Project for Operational Science
Operational Sciences (ENS)

Logistics (Ph.D.)

Program Description

The Doctor of Philosophy (PhD) degree entails completion of rigorous coursework requirements that prepare the student for advanced research and analysis in a chosen field of study. The doctoral degree is generally characterized as a research degree with substantial emphasis placed on the completion of the dissertation research. The PhD program in Logistics is typically 36 months in length beyond the MS degree. The degree builds on an analytical core with a flexible program that can accommodate supply chain management, acquisition, inventory theory, transportation, and operations management thrust areas. The degree has strong interdisciplinary support, with typical technical methods options in reliability, optimization, applied statistics, or systems engineering areas.

Program Outcomes (POs)

Our Student Outcomes (student knowledge/skills/abilities) produce graduates who:

• Will be able to understand and evaluate critically the literature of the field
• Will be able to apply appropriate principles and procedures to the recognition, evaluation, interpretation, and understanding of issues and problems at the frontiers of knowledge
• Will have acquired the knowledge, skills, ethics, and independence of thought and action expected of a scholar
• Will have extended and effectively communicated knowledge in his or her field

School and Program Admission Criteria

DEGREE REQUIRED: M.S. degree in logistics, supply chain management, operations research, operations management, industrial engineering, or other relevant field. Successful completion of a Master’s thesis is very desirable.

TEST REQUIRED: GRE scores of at least 156V/151Q.

GPA REQUIRED: A quality bachelor's degree with grades averaging at least 3.0 on a 4.0 scale. A quality Master’s degree with grades averaging at least 3.5 on a 4.0 scale.

Degree Requirements

Requirements for the PhD Degree include 36 quarter-hours of coursework beyond the Master’s degree and a period of full-time research leading to successful completion of the doctoral dissertation. In addition to the Core courses (18 hours), the three required coursework areas are: technical methods (6 hrs), mathematics requirement (8 hrs), and an elective (4 hrs).

Detailed current information on this program, a complete Program Guide, and degree requirements are available at http://www.afit.edu/ENS/

Residency Requirement

The residency requirement for the PhD Program is three quarter hours of full-time study in residence during any contiguous four-quarter period.
Operational Sciences (ENS)

Core Courses - 18 hours
- LOGM 601 – Principles and Methods of Research
- LOGM 617 - Transportation Systems and Strategic Mobility
- LOGM 627 - Supply Chain Management
- LOGM 636 - Service Operations Management
- OPER 674 - Joint Mobility Modeling
- LOGM 768 - Advanced Topics in Logistics
- LOGM 770 - Advanced Inventory Theory

Technical Methods and Electives - 
6 hours minimum (technical methods)
4 hours (elective)
The technical methods and electives courses together foster interdisciplinary opportunities in areas such as operations research, statistics, and systems engineering. A particular choice of technical and elective courses constitute an area of specialty. Typical areas of specialty include: Reliability, Optimization, Applied Statistics, and Systems Architecture. A program of study would be tailored to the student’s research thrust, and is established in consultation with the Advisor. Technical methods area courses may consist of courses from more than one department as long as these courses form an integrated program designed to make the student an expert in the chosen area of research. In some cases this may require more than 6 hours. These specialty courses normally build on the individual student's MS program and will include a minimum of first year graduate courses.
A list of courses supporting the technical methods requirement is available in the Program Guide at http://www.afit.edu/NS/

Mathematics Required - 8 hours (minimum) selected from:
- MATH 621 - Linear Algebra
- MATH 633 - Graph Theory
- STAT 694 - Design of Experiments
- STAT 696 - Applied General Linear Models

Dissertation Research
As with all doctoral programs, the AFIT resident PhD. Program requires completion of a doctoral dissertation. The dissertation research consists of at least 48 quarter hours of supervised research and should result in a significant and original archival contribution to the literature of the field. The AFIT dissertation is also generally oriented toward a topic of relevance to the US Air Force.
Operational Sciences (ENS)

Operations Management (M.S.)

Program Description

The OPSMGMT program is the formal graduate study portion for various Intermediate Developmental Education (IDE) programs in the US Air Force. The goal of the OPSMGMT program is to cultivate a core of officers with an in-depth education in operations management, quantitative decision making, and critical thinking skills to lead the Air Force in the future. The IDE programs consist of the degree granting portion, plus additional professional development courses combined with trips to joint and major commands around the globe. As such, this enhances the AFIT degree portion of the IDE program, providing the military with a professional, degree-granting program, similar to executive management degree programs in civilian institutions. The curriculum consists of eight core courses in the areas of operations management, process improvement, organizational management, quantitative decision making, and research methods. The remainder of the curriculum is tailored for each of the IDE programs using specialty tracks. Each specialty track has 15 hours of electives available to complete the degree requirements for the program. Courses are taught individually in a compressed schedule. The program also requires a graduate research paper that examines a topic pertaining to the operational Air Force. Each program will be 12 months long (four academic quarters) and will involve a Permanent Change of Station (PCS) to various locations, depending on the particular IDE program. Class size is limited to 16 students. Students typically come from operational and support AFSCs in the Air Force.

Program Educational Objectives (PEOs)

Our Program Education Objectives (expectations two or more years beyond graduation) are to produce graduates who:

- **Breadth.** Apply foundational managerial and leadership concepts and sound analytical principles to efficiently and effectively advance Air Force and DoD capabilities.
- **Depth.** Are well educated, highly-valued, and successful officers within their respective career field.
- **Professionalism.** Professionally communicate technical solutions and results.
- **Lifelong Learning.** Continue to pursue lifelong multidisciplinary learning and to become a well-informed and well-educated consumer of analysis.

Student Learning Outcomes (SLOs)

Upon completion of the program, the student will possess:

- **Intellectual skills (analytic inquiry).** Disaggregates, adapts, reformulates, and employs in a paper or project principal ideas, techniques, or methods at the forefront of the field.
- **Intellectual skills (quantitative fluency).** Articulates and undertakes multiple appropriate applications of quantitative methods, concepts and theories.
- **Intellectual skills (communication fluency).** Creates sustained, coherent arguments or explanations and reflections on his/her work of that of collaborators (if applicable) in two or more media to both specialized and general audiences.
- **Specialized knowledge.** Initiates, assembles, arranges, and reformulates ideas, concepts, designs, and techniques in carrying out a project directed at a challenge in the field beyond conventional boundaries.
Operational Sciences (ENS)

School and Program Admission Criteria

DEGREE REQUIRED: Any field
MATHEMATICS REQUIRED: College Algebra
TEST REQUIRED: GMAT score of at least 550; or GRE of at least 153 (verbal) and 148 (quantitative) on the Education Testing Service (ETS) 2012 GRE Concordance Table (which is based upon performance of all examinees who tested between 1 August 2011 and 30 April 2012); or at least 500 (verbal) and 600 (quantitative) for GRE tests taken/scored under the old scale ETS used prior to August 2011 test dates.
GPA REQUIRED: OVERALL – 3.0; MATH – 3.0

Waivers to the above requirements may be granted on an individual basis by the Department of Operational Sciences. Admission procedures are specified in the AFIT home page (www.afit.edu).

Degree Requirements

Detailed current information on this program, including degree requirements and suggested course sequence by term, is contained in the complete Program Guide.

Core Courses - 15 hours
- LOGM 545 – Introduction to Management and Organizations
- LOGM 568 – Introduction to Supply Chain Management
- LOGM 619 – Transportation Policy and Strategic Mobility
- IMGT 669 – Business Process Improvement

Choose one of the following:
- LOGM 569 – Production and Operations Management
- LOGM 636 – Service Operations Management

Specialty Sequence - 15 hours
Courses from an approved specialty sequence are required. Specialty sequences are listed below. Required courses for each specialty are listed in the Program Guide.

Logistics and Air Mobility (LOGAIR) and Nuclear Deterrence & Policy (NDP) (LOGAIR)
- LOGM 617 - Transportation Systems and Strategic Mobility
- LOGM 621 - Air Transportation Management
- LOGM 626 - Supply Chain Management
- LOGM 634 - Reliability, Maintainability and Supportability
- LOGM 674 - Joint Mobility Modeling

Research Foundation - 11 hours
- LOGM 525 – Statistics for Mobility Managers
- LOGM 601 – Principles and Methods of Research
- OPER 501 – Quantitative Decision Making

Graduate Research Paper - 7 hours
- LOGM 791 – Research Project for Mobility Managers
Operational Sciences (ENS)

Operations Research (M.S.)

Program Description

Operations Research is the discipline of applying advanced analytical methods to help make better decisions. It provides rational bases for decision making by seeking to understand and structure complex problems and to use this understanding to predict system behavior and improve system performance. Much of this work is done using analytical and numerical techniques to develop and manipulate mathematical and computer models of organizational and operational systems composed of people, equipment, and procedures. Operations Research draws upon ideas from engineering, management, mathematics, and psychology to contribute to a wide variety of application domains; the field is closely related to several other fields in the decision sciences: applied mathematics, decision analysis, computer science, economics, industrial engineering, and systems engineering. Operations research is distinguished by its broad applicability and by the wide variety of career opportunities and work styles it embraces. Within the field, some OR professionals remain generalists while others specialize in particular tools or problem domains.

Program Educational Objectives (PEOs)

Our Program Education Objectives (expectations two or more years beyond graduation) are to produce graduates who:
• Breadth. Apply foundational operations research analysis techniques to efficiently and effectively advance Air Force, DoD, and other government inter-agency organizations, as well as other employer capabilities
• Depth. Are well educated, highly-valued, and successful operations research analysts
• Professionalism. Professionally communicate technical analytical assessments, solutions, and results
• Lifelong Learning. Continue to pursue lifelong multidisciplinary learning

Program Outcomes (POs)

Our Student Outcomes (student knowledge/skills/abilities) produce graduates who:
• Critical thinking and problem solving skills. Have the ability to classify, formulate, and solve operations research problems
• Operations research specific knowledge. Have knowledge of operations research areas such as probabilistic modeling, applied statistics, mathematical programming, simulation, and decision analysis to directly support decision and policy making activities
• Communication Skills. Develop written and oral communications skills necessary to present complex problems to a decision- making audience: problem definition, modeling methodologies, including solution advocacy that utilizes rigorous analytical support

School and Program Admission Criteria

DEGREE REQUIRED: Baccalaureate degree in operations research, mathematics (not math education), engineering, physics, computer science, or quantitative economics, or other quantitative discipline, provided in each case that curriculum includes sufficient mathematics as noted below.
MATHEMATICS REQUIRED: Calculus I & II (integral and differential calculus), and an advanced calculus
Operational Sciences (ENS)

course, (i.e. multivariable calculus).
TEST REQUIRED: GRE - 153V/148Q.
GPA REQUIRED: OVERALL - 3.0; MATH - 3.0

Waivers to the above criteria may be granted on a case by case basis. Therefore, individuals whose academic credentials fall below any of the above criteria are encouraged to apply.

Degree Requirements

Detailed current information on this program, a complete Program Guide, sample curriculum, and degree requirements are available http://www.afit.edu/ENS

Core Courses
• OPER 510 - Introduction to Mathematical Programming
• OPER 540 - Stochastic Modeling and Analysis I
• OPER 542 - Decision Analysis
• OPER 561 - Discrete-Event Simulation
• OPER 610 - Linear Programming
• OPER 679 – Empirical Modeling
• OPER 685 – Applied Multivariate Analysis I

Required for ALL U.S. Military Students
• OPER 544 – Operational Decision Support Systems
• OPER 544L – Operational Decision Support Systems Lab
• OPER 595 – Issues in Defense Analysis
• OPER 638 – Assessing Operational Cost and Risk

Mathematics or Statistics
• MATH 523 - Numerical Analysis and Linear Algebra
• STAT 587 - Applied Probability and Statistical Analysis

Elective
At minimum, 6 hours in elective courses must be taken.

Thesis
• OPER 799 - Thesis Research
• TENS 799 - Thesis Completion

Specialty Sequence (Optional)
In addition to the core and thesis requirements, all students are encouraged to develop in-depth knowledge in at least one specialty area. A specialty sequence consists of at least three courses selected from one of the following specialty areas: Deterministic Operations Research, Probabilistic Operations Research, Simulation, Decision Analysis, Applied Statistics, Information Operations/Information Warfare (IO/IW), or Operational Modeling.
Operational Sciences (ENS)

Operations Research (Ph.D.)

Program Description

The Doctor of Philosophy (Ph.D.) degree entails completion of rigorous coursework requirements that prepare the student for advanced research and analysis in the field. The doctoral degree is characterized as a research degree with substantial emphasis placed on the completion of the dissertation research. Close interaction between the student and his/her research advisory committee plays a pivotal role in the successful completion of the PhD. program. Equally important is the discipline and dedication of the student, as independent study is a critical element for timely completion of the program.

Program Outcomes (POs)

Our Student Outcomes (student knowledge/skills/abilities upon graduation) produce graduates who:

• Will be able to understand and evaluate critically the literature of the field
• Will be able to apply appropriate principles and procedures to the recognition, evaluation, interpretation, and understanding of issues and problems at the frontiers of knowledge
• Will have acquired the knowledge, skills, ethics, and independence of thought and action expected of a scholar
• Will have extended and effectively communicated knowledge in his or her field

School and Program Admission Criteria

DEGREE REQUIRED: M.S. degree in operations research, mathematics, engineering, statistics, or other highly quantitative area of study. Successful completion of a Master’s thesis is very desirable.
TEST REQUIRED: GRE - 156V/151Q.
GPA REQUIRED: A quality bachelor's degree with grades averaging at least 3.0 on a 4.0 scale. A quality Master’s degree with grades averaging at least 3.5 on a 4.0 scale.

A baccalaureate-to-doctoral admission may also be granted in some circumstances to applicants who are entering directly from an undergraduate program without a Master’s degree. In such case, the requirement to hold a Master’s degree will be met during the student's PhD. Program. All applications are referred to the Operations Research faculty of the Department of Operational Sciences for review and recommendation. Waivers to the above criteria may be granted on a case by case basis. Therefore, individuals whose academic credentials fall below any of the above criteria are encouraged to apply.

Degree Requirements

Requirements for the PhD. Degree include 41 (for a well prepared student not needing to take the Core courses) to 53 quarter- hours of coursework beyond the Master’s degree and a period of full-time research leading to successful completion of the doctoral dissertation. In addition to the Core courses, the three required coursework areas are: specialty area requirements (24 hrs), minor area requirements (9 hrs), and mathematics requirements (8 hrs).
Detailed current information on this program, a complete Program Guide, and degree requirements are available at http://www.afit.edu/ENS/
Operational Sciences (ENS)

Residency requirement
The residency requirement for the PhD. Program is three quarters of full-time study in residence during any contiguous four-quarter period.

Core Courses
Specialization Areas - 24 hours
Typical choices for area of specialization are: optimization, stochastic operations research, simulation, applied statistics, or decision analysis. A list of courses supporting each specialization area is available in the Program Guide at http://www.afit.edu/ENS/

Minor Courses - 9 hours
This sequence is intended to broaden the student’s exposure to graduate coursework. Successful completion of the minor area of study may also include completion of a minor examination requirement. Operations Research PhD. Students have considerable flexibility when establishing a minor area of study. A student may choose an area within Operations Research other than his or her specialty area or the minor may also originate in another department (provided that the minor is acceptable to the other Department and that it is supported by that Department). Some examples of minor areas may include applied statistics, mathematics, or computer science. A list of Department of Operational Sciences minors and courses supporting those minors is available in the Program Guide at http://www.afit.edu/ENS/

Mathematics Required - 8 hours

Dissertation Research - 48 hours
As with all doctoral programs, the AFIT resident PhD. Program requires completion of a doctoral dissertation. The dissertation research consists of at least 48 quarter hours of supervised research and should result in a significant and original archival contribution to the literature of the field. The AFIT dissertation is also generally oriented toward a topic of relevance to the US Air Force.
Operational Sciences (ENS)

Logistics and Supply Chain Management (M.S.)

Program Description

The LSCMGT program provides students with the opportunity to learn and exercise state-of-the-art management knowledge and tools to solve defense acquisition and logistics problems. The curriculum includes courses in statistics, operations research, organization and management theory, inventory systems, transportation and strategic mobility, maintenance and production management, financial management, and economics. In addition, students have the opportunity to of either pursuing an Operational Logistics, Operational Maintenance, Petroleum Management, Life Cycle Logistics, or Nuclear Logistics Management track. Upon completion students are granted a Master of Science Degree.

Program Educational Objectives (PEOs)

Our Program Educational Objectives (expectations two or more years beyond graduation) are to produce graduates who:

• Breadth. Apply foundational logistics concepts and sound analytical principles to efficiently and effectively advance Air Force, DoD, and other employer logistics and supply chain management capabilities
• Depth. Are well educated, highly-valued, and successful logisticians and supply chain experts
• Professionalism. Professionally communicate technical solutions and results
• Lifelong Learning. Continue to pursue lifelong multidisciplinary learning

Program Outcomes (POs)

Our Student Outcomes (student knowledge/skills/abilities upon graduation) produce graduates who:

• Critical thinking skills. Can critically analyze situations, information, and data
• Problem solving skills. Can formulate problem statements, ascertain and collect the relevant data, and utilize the correct methodology in order to both delineate and solve problems in the real world
• Communication skills. Can effectively communicate to peers, subordinates, and supervisors in a professional manner both orally and in writing
• Logistics specific knowledge. Have developed a thorough understanding of the logistics, mobility, and supply chain discipline as required to make strategic level managerial decisions in the logistics area

School and Program Admission Criteria

DEGREE REQUIRED: Any Field
MATHEMATICS REQUIRED: College Algebra with a grade of C or higher
TEST REQUIRED: GMAT – 550; or GRE Scores of at least 153V/148Q.
GPA REQUIRED: OVERALL - 3.0; MATH - 3.0

Waivers to the above criteria may be granted on a case by case basis. Therefore, individuals whose academic credentials fall below any of the above criteria are encouraged to apply.
Operational Sciences (ENS)

Degree Requirements

Each student who graduates with a Master of Science in Logistics and Supply Chain Management must have a foundation in the theoretical and applied aspects of business, as specified by the International Association for Management Education (IAME) and The Association of Advance Collegiate Schools of Business (AACSB), consisting of: calculus, applied statistics (probability and distributions), managerial economics, and organization and management theory. If a student can demonstrate successful completion of a course in an undergraduate or previous graduate program, a waiver may be granted for those prerequisites. Otherwise, students identified with deficiencies are expected to fulfill this requirement by taking (as appropriate) MATH 291, STAT 525, STAT 535, LOGM 520, and LOGM 542. Detailed current information on this program, a complete Program Guide, sample curriculum, and degree requirements are available http://www.afit.edu/ENS/

Management Core Courses
• LOGM 542 - Management of Logistics Organizations
• LOGM 601 - Principles and Methods of Research
• OPER 505 - Business Analytics I
• STAT 525 - Applied Statistics

Logistics and Supply Chain Management Core
• LOGM 565 - Strategic Sourcing
• LOGM 569 - Maintenance and Production Management
• LOGM 570 - Principles of Inventory Management
• LOGM 612 - Maintenance and Sustainment
• LOGM 617 - Transportation Systems and Strategic Mobility

Specialty Sequence
Operational Logistics (OL)
• LOGM 619 - Transportation Policy and Strategic Mobility
• LOGM 630 - Forecasting Management
Operational Maintenance (OM)
• LOGM 631 - Scheduling: Theory and Application
• LOGM 634 - Reliability, Maintainability and Supportability
Petroleum Management (PM)
• LOGM 630 - Forecasting Management
• LOGM 651 - Seminar in Petroleum Management
Life Cycle Logistics (LC)
• LOGM 630 - Forecasting Management
• OPER 638 - Assessing Operational Cost and Risk
Nuclear Logistics Management (NL)
• LOGM 634 - Reliability, Maintainability and Supportability
• NENG 500 - Nuclear Weapons Strategy and Policy
Research Foundation
• LOGM 601 - Principles and Methods of Research
Thesis
• LOGM 799 - Thesis Research
• TENS 799 - Thesis Completion
Operational Sciences (ENS)

Supply Chain Management Certificate (DL)

Program Description

The purpose of the Graduate Certificate in Supply Chain Management is to provide the students with graduate level education in the fundamentals of Supply Chain Management (SCM), with particular emphasis on Department of Defense (DoD) and Air Force specific applications. Statistical data analysis and basic quantitative modeling, to include linear programming, simulation analysis, and heuristics, are included. The objectives of this program are to educate Air Force Logistics professionals in the above topics and to enable them to apply state of the art analytical and problem solving techniques to Air Force and DoD specific supply chain management problems, as well as enabling them to use the concepts of lean in similar situations.

Program Outcomes (POs)

Our Student Outcomes (student knowledge/skills/abilities) produce graduate certificate conferees who exhibit:
- The acquisition of a broad understanding of the principles and concepts of supply chain management and statistical concepts
- The ability to apply analytical techniques to SCM problems in the DoD environment
- Improved problem solving ability, critical thinking skills, and the ability to communicate

School and Program Admission Criteria

DEGREE REQUIRED: Bachelors Degree or equivalent
MATHEMATICS REQUIRED: College Algebra
TEST REQUIRED: None
GPA REQUIRED: OVERALL - 3.0

Waivers to the above criteria may be granted on a case by case basis. Therefore, individuals whose academic credentials fall below any of the above criteria are encouraged to apply.

Related Programs

The Supply Chain Certificate program includes courses that may be applied to Department of Operational Sciences logistics Master’s degree programs, depending upon the specific course and program.
Operational Sciences (ENS)

Certificate Completion Requirements

Successful completion of the Supply Chain Certificate program requires a cumulative grade point average on all course work of a 3.0 (based on a 4.0 scale). Time to completion is 5 quarters. There is no exit examinations required, and no final project. However, there are numerous projects and assignments required in the various courses that give an opportunity for the student to apply their knowledge to broad problems. Detailed current information on this program is available http://www.afit.edu/ENS/

Core Courses
- LOGM 565 - Strategic Sourcing
- LOGM 568 - Introduction to Supply Chain Management
- LOGM 569 - Maintenance and Production Management
- OPER 505 - Business Analytics I
- STAT 583 - Introduction to Probability and Statistics
Operational Sciences (ENS)

Cost Capability Analysis Certificate

Program Description
The CCACP is a graduate level program centered on the principles of decision analysis, the impact of risk assessment in decision making, and the role of operational cost analysis. The curriculum consists of five graduate level courses for a total of 17 graduate credits. The course sequence provides both a theoretical foundation of analysis techniques and insight concerning the interpersonal skills necessary for effective application of such techniques to real world decisions. The CCACP is designed to support part-time students. All students are expected to participate in the CCACP via one in-residence AFIT course for each of five quarters until completing the full certificate requirements.

Program Outcomes (POs)
- Knowledge of the fundamental principles of both single and multiobjective decision analysis including structuring decision problems, identifying objectives and effective ways to measure them, and analysis techniques for obtaining insight from the models developed.
- A thorough understanding of risk assessment, risk analysis, and cost estimation as well as their impact on the decision making process in both military and industrial applications.
- Awareness of the intricacies of working with multiple stakeholders, often with conflicting priorities and preferences, and the necessary facilitation skills for resolving those conflicts in order to move through the decision-making process.

School and Program Admission Criteria
DEGREE REQUIRED: Bachelors Degree or equivalent
MATHEMATICS REQUIRED: College Algebra
TEST REQUIRED: None
GPA REQUIRED: OVERALL - 3.0

Waivers to the above criteria may be granted on a case by case basis. Therefore, individuals whose academic credentials fall below any of the above criteria are encouraged to apply.

Certificate Completion Requirements
Successful completion of the CCACP requires a cumulative GPA on all course work of a 3.0 (based on a 4.0 scale). Cumulative time to completion is normally 5 quarters. All required courses must be completed within a four year time period. There are no exit examinations required, and no final project. However, there are numerous projects and assignments required in the various courses that give an opportunity for the student to apply their knowledge to broad problems.

Graduate Courses
- OPER 543 - Decision Analysis
- OPER 638 - Assessing Operational Cost and Risk
- OPER 643 - Multiobjective Decision Analysis
- OPER 645 - Risk Modeling and Analysis
- OPER 743 - Decision Analysis Practice
Operational Sciences (ENS)

Data Science Certificate

Program Description

The DSCP provides students with a thorough understanding of data science and its ability to operationalize data insights to enable evidence-based decision-making through military and industrial applications. Topics include the formulation of data-driven problems, application of advanced analytic techniques, managing large and complex data sets, and leveraging open source programming languages to create scalable, user-defined analytic products and applications.

Program Outcomes (POs)

Our Student Outcomes (student knowledge/skills/abilities) produce graduate certificate conferees who exhibit:

- Knowledge of the fundamental data science capabilities and pipeline.
- Mastery of key facets of data investigation, including data wrangling, cleaning, sampling, management, modeling, communication, and analytic reproducibility.
- Competency in employing algorithmic solutions to address data science problems.
- Familiarity with storing and accessing large and complex data from a variety of sources.
- Prowess in applying software engineering practices to create and enable reproducible and scalable data analysis applications.
- Proficiency in applying statistical and machine learning methods to make sense out of data sets, both large and small.
- Aptitude for what analyses are possible given a particular data set, including both the state of the art of the field and inherent limitations.
- Fluency for speaking to disparate groups within an organization to implement data science applications and solutions.

Certificate Completion Requirements

DSCP is designed to support part-time or full-time students looking to specialize in the data science domain. Students will train on open source programming languages and packages that are currently (or projected) supported on DoD systems, thus enabling students to quickly transition with gained data science skills in their immediate follow-on operational assignments. All students are expected to participate in DSCP via in-residence AFIT courses for consecutive quarters until completing the full certificate requirements. In addition to taking a core class, students must take a minimum of one course from each Data Science Capability category. Students must attain a grade point average of at least 3.00 for all graded courses comprising the certificate. Due to the new nature of the certificate some new classes are being created to better support the vision of this certificate. New classes must be offered at least three times before they can be permanently added to the department course catalog and officially added to the certificate requirements. Until those classes are officially added, students who take those non-permanent courses, noted with * in the list below, will be given a waiver to include the non-permanent course as satisfying the requirement for that category.
## Operational Sciences (ENS)

Graduate Courses (non-permanent classes)

### Area I (choose 1)
- CSCE 586 - Design and Analysis of Algorithms
- OPER 679 - Empirical Modeling
- STAT 696 - Applied General Linear Models

### Area II (choose 1)
- CSCE 523 - Artificial Intelligence
- OPER 685 - Multivariate Analysis I

### Area III (choose 1)
- CSCE 623 - Statistical Machine Learning
- OPER 655 - Multivariate Analysis I

### Area IV (choose 1)
- CSCE 689 - Distributed Software Systems
- IMGT 561 - Applications of Database Management Systems I
- IMGT 680 - Advanced Topics in Data Management and Analysis

### Area V (choose 1)
- CSCE 823 - Artificial Neural Networks
- OPER 684 - Quantitative Forecasting Techniques
- OPER 782* - Data Science Practice
- OPER 785 - Multivariate Analysis II

### Timeline
A student must complete all required courses within a four-year time period.
Operational Sciences (ENS)

Test and Evaluation Certificate (In-residence and DL)

Program Description

The AFIT Test and Evaluation Certificate Program (TECP) provides students a fundamental understanding in the statistical concepts required for supporting analysis in the Test and Evaluation (T&E) Community. Particular emphasis is given to incorporating past, present, and future DoD T&E examples from all aspects of test (developmental, operational, etc) into the curriculum to tailor the applications of the methodology and approaches within each course. Current T&E focus in design of experiments (DOE) and reliability, maintainability, and availability (RM&A) analysis are addressed in required courses to complete the T&E Certificate Program. TECP targets individuals within the acquisition or analysis career fields working within research, developmental, or operational test stationed at engineering centers, test ranges, test centers, program offices or headquarters.

Program Outcomes (POs)

Our Student Outcomes (student knowledge/skills/abilities) produce graduate certificate conferees who exhibit:

• The ability to identify and apply basic concepts required for supporting statistical analysis within the T & E Community
• The ability to design experiments and conduct reliability, maintainability, and availability analysis in response to the operational needs of the Air Force and Department of Defense
• Improve problem solving ability, critical thinking skills, and test planning skills

School and Program Admission Criteria

DEGREE REQUIRED: Bachelor's degree or equivalent in an appropriate engineering or scientific discipline (mathematics, physical science, engineering, or computer science is highly desirable.)
MATHEMATICS REQUIRED: Calculus I and II
TEST REQUIRED: None
GPA REQUIRED: Overall - 3.0; Math - 3.0

Waivers to the above criteria may be granted on a case by case basis. Therefore individuals whose academic credentials fall below any of the above criteria are encouraged to apply.

Related Programs

The TECP includes courses that comprise the Applied Statistics specialty in the Graduate Operations Research in-resident Master’s degree program. The TECP is also a specialty area in the distance learning and in-residence Systems Engineering Master’s degree program.
Operational Sciences (ENS)

Certificate Completion Requirements

Graduate Courses (DL Students)
• LOGM 634 - Reliability, Maintainability and Supportability
• OPER 679 - Empirical Modeling
• OPER 688 - Operational Experimentation
• OPER 689 - Advanced Statistical Methods for Test
• OPER 791 - Research Project for Operational Sciences
• STAT 583 - Introduction to Probability and Statistics

Graduate Courses (In-residence Students)
• LOGM 634 - Reliability, Maintainability and Supportability
• OPER 679 - Empirical Modeling
• OPER 683 - Response Surface Methodology
• OPER 685 - Applied Multivariate Methods I
• OPER 688 - Operational Experimentation
• STAT 587 - Introduction to Probability and Statistics
The Department of Systems Engineering and Management provides defense-focused graduate education through interdisciplinary research projects developing integrated solutions for the U.S. Air Force, the Department of Defense, and various national agencies. The department has three primary thrust areas: Engineering and Technology Management, Environmental Engineering and Science, and Systems Engineering. The department offers a Doctor of Philosophy (PhD) degree in Systems Engineering and Master of Science degrees in five major multi-disciplinary fields: Cost Analysis, Engineering Management, Environmental Engineering and Science, Industrial Hygiene, and Systems Engineering.

Facilities
The Department of Systems Engineering and Management maintains several laboratory facilities in support of its academic and research programs. The laboratory facilities include the following dedicated areas:

- Analytical Chemistry Laboratory
- Environmental Microbiology Laboratory
- Environmental Remediation Laboratory
- Human Systems Laboratory
- Industrial Hygiene Laboratory
- Quantum Information Laboratory
- Unmanned Aerial System (UAS) Laboratory
- Outdoor Unmanned Air Vehicle Test Facility

Programs

Master of Science

- Cost Analysis
- Engineering Management
- Environmental Engineering & Science
- Industrial Hygiene
- Systems Engineering

Master of Engineering

- Applied Systems Engineering
Systems and Engineering Management (ENV)

Doctor of Philosophy

- Systems Engineering with specializations in autonomous systems, control and optimization, cyber/information systems, decision analysis, environmental systems, human systems, industrial hygiene, infrastructure systems, modeling and simulation, navigation, operations research, optimization, quantum information, reliability, space systems, and unmanned aerial systems

Certificate

- Systems Engineering Certificate
- Human Systems Certificate

Faculty

Professor

Adedeji B. Badiru
project systems modeling and control, economic analysis, computer simulation, mathematical modeling, industrial technology transfer

John M. Colombi
model-based systems engineering, system of systems (SoS) engineering, executable architecture, design optimization, complex systems science, human-systems, optimal design, defense acquisition analysis, unmanned air vehicle (UAV) design and integration

Michael R. Grimaila
computer and electrical engineering, computer/network security, information security, mission assurance, modeling and simulation, quantum cryptography, quantum information, systems engineering

Willie F. Harper, Jr.
water quality, biological processes, advanced oxidation, infrastructure security, biosensing, biofuels, unit process modeling, quantum chemical computations, sustainability

David R. Jacques
systems engineering, architecture, system and system-of-system level design for mission effectiveness, autonomous and/or cooperative multi-agent systems, small UAS development and flight test

Michael E. Miller
systems engineering, human factors, human systems modeling, human interaction with automation and human-display integration

Associate Professor

Alfred E. Thal, Jr.
facility/infrastructure management, engineering management, project management, process improvement, economic analysis, innovation, sustainability
## Systems and Engineering Management (ENV)

<table>
<thead>
<tr>
<th>Title</th>
<th>Name</th>
<th>Specialization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assistant Professor</td>
<td>Christopher M. Chini</td>
<td>energy sustainability, water security, infrastructure resilience, energy-water nexus</td>
</tr>
<tr>
<td></td>
<td>Casey W. Cooper</td>
<td>industrial hygiene</td>
</tr>
<tr>
<td></td>
<td>Amy M. Cox</td>
<td>systems engineering, user innovation, design, flexibility, system architecture, flight test</td>
</tr>
<tr>
<td></td>
<td>Justin D. Delorit</td>
<td>engineering management, economics and policy analysis, demand forecasting, climate and extreme event risk analysis, hydroclimatology, forecasting, water-energy-food nexus</td>
</tr>
<tr>
<td></td>
<td>Scott T. Drylie</td>
<td>cost analysis, economic institutional analysis, market processes, organizational dynamics, acquisition reform</td>
</tr>
<tr>
<td></td>
<td>John J. Elshaw</td>
<td>leadership, human-technology interaction (virtual teams, electronic monitoring, distance leadership), workgroup and team processes within organizations, social networks, organizational climate and culture, cross-cultural leadership and communication, cogn</td>
</tr>
<tr>
<td></td>
<td>Robert D. Fass</td>
<td>cost analysis, risk analysis, decision analysis and optimization, leadership, organizational performance, research methods, government acquisition system, strategic alliances, project management</td>
</tr>
<tr>
<td></td>
<td>Thomas C. Ford</td>
<td>systems architecture, interoperability, resiliency, model-based systems engineering, systems modeling and simulation, space systems, systems integration</td>
</tr>
<tr>
<td></td>
<td>Jason K. Freels</td>
<td>applied statistics, lifecycle management, maintainability, optimization, reliability, reliability modeling and analysis, response surface methods, statistical data analysis, stochastic modeling and analysis, stochastic systems analysis, structural mechanics</td>
</tr>
<tr>
<td></td>
<td>Andrew J. Hoisington</td>
<td>infrastructure asset management, environmental engineering, built environment, indoor air quality, microbiome of built environment, microbiome influencing human performance</td>
</tr>
<tr>
<td></td>
<td>Clay M. Koschnick</td>
<td>economic analysis, dynamic programming, econometrics, decision analysis, systems engineering</td>
</tr>
<tr>
<td></td>
<td>Joseph P. Kristbaum</td>
<td>systems engineering, decision making in complex organizations, systems modeling</td>
</tr>
</tbody>
</table>
## Systems and Engineering Management (ENV)

<table>
<thead>
<tr>
<th>Name</th>
<th>Research Interests</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brent T. Langhals</td>
<td>data management and analysis, data analytics, human computer interaction, systems</td>
</tr>
<tr>
<td></td>
<td>engineering, resource management, knowledge management</td>
</tr>
<tr>
<td>David S. Long</td>
<td>systems architecture, complex systems, systems of systems, human systems</td>
</tr>
<tr>
<td></td>
<td>integration, project management, organizational development</td>
</tr>
<tr>
<td>John McGuirl</td>
<td>cognitive systems engineering, human interaction with automation</td>
</tr>
<tr>
<td>Eric G. Mbonimpa</td>
<td>sustainability and life, environmental</td>
</tr>
<tr>
<td></td>
<td>sustainability, life cycle assessment, surface water quality modeling, disinfection</td>
</tr>
<tr>
<td></td>
<td>of water using solar radiation, water quality and treatment</td>
</tr>
<tr>
<td>Mark G. Reith</td>
<td>systems engineering, cyber operation, weapon system security, mission assurance,</td>
</tr>
<tr>
<td></td>
<td>cyber teaming</td>
</tr>
<tr>
<td>Jonathan &quot;Dan&quot; Ritschel</td>
<td>cost analysis, economic institutional analysis, acquisition reform, public choice</td>
</tr>
<tr>
<td>Steven J. Schuldt</td>
<td>engineering management, project management, construction management, optimal</td>
</tr>
<tr>
<td></td>
<td>resource utilization, multi-objective optimization, genetic algorithms, risk</td>
</tr>
<tr>
<td></td>
<td>management, installation resiliency, sustainability</td>
</tr>
<tr>
<td>John X. Situ</td>
<td>systems engineering, stochastic optimization, meta-heuristics, multi-objective</td>
</tr>
<tr>
<td></td>
<td>decision analysis, and dynamic programming</td>
</tr>
<tr>
<td>Jeremy M. Slagley</td>
<td>industrial hygiene, environmental management, waste to energy</td>
</tr>
<tr>
<td>John E. Stubbs</td>
<td>environmental engineering and science, water treatment and remediation</td>
</tr>
<tr>
<td>Torrey J. Wagner</td>
<td>systems engineering, renewable energy systems, electro-optics, agile software</td>
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<tr>
<td></td>
<td>development</td>
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<tr>
<td>Douglass S. Dudis</td>
<td>energy systems engineering</td>
</tr>
<tr>
<td>Ryan D. L. Engle</td>
<td>computer engineering, data analytics, quantum cryptography</td>
</tr>
<tr>
<td>Robert M. Eninger</td>
<td>industrial hygiene, pharmacokinetic modeling, air sampling, burn pit emissions</td>
</tr>
<tr>
<td>Alice “Betsy” Grimes</td>
<td>continuous learning, organization behavior, psychology</td>
</tr>
<tr>
<td>Juan Leon</td>
<td>infectious disease, epidemiology, outbreak response</td>
</tr>
<tr>
<td>David R. Mattie</td>
<td>inhalation toxicology, toxicokinetics</td>
</tr>
<tr>
<td>Logan O. Mailloux</td>
<td>systems engineering, cyber security, quantum information, weapon systems security</td>
</tr>
</tbody>
</table>

### Adjunct Faculty

- Douglas S. Dudis
- Ryan D. L. Engle
- Robert M. Eninger
- Alice “Betsy” Grimes
- Juan Leon
- David R. Mattie
- Logan O. Mailloux
# Systems and Engineering Management (ENV)

<table>
<thead>
<tr>
<th>Name</th>
<th>Research Interests</th>
</tr>
</thead>
<tbody>
<tr>
<td>Robert Patterson</td>
<td>human decision making, human interaction with automation</td>
</tr>
<tr>
<td>Michael A. Rottmayer</td>
<td>energy systems engineering</td>
</tr>
<tr>
<td>Christina F. Rusnock</td>
<td>human factors, human performance modeling, simulation of cognitive workload, project management</td>
</tr>
<tr>
<td>Terry A. Wilson</td>
<td>systems engineering, data analytics, information and knowledge management, unmanned systems</td>
</tr>
</tbody>
</table>
The Applied Graduate Systems Engineering (ASE) program is offered by the Graduate School of Engineering and Management, Department of Systems Engineering and Management (www.afit.edu/ENV). The ASE program confers a Master of Engineering (ME) in Applied Systems Engineering and is available to part-time distance learning (DL) students only. ASE is nominally a 36-month program, depending on class availability and student course load. Program requirements for ASE are similar to the Graduate Systems Engineering (GSE) program with the key difference being the replacement of the thesis. In lieu of a 12-credit thesis, ASE students must complete at least two engineering analysis courses and one capstone project.

For more information about online/distance learning (DL) SE programs, or about general DL opportunities and application procedures, please visit AFIT Office of Extension Services, www.afit.edu/DL/.

The program takes students with traditional engineering backgrounds (mechanical, electrical, computer, aeronautical, etc.) and produces graduates who understand, and can effectively use, the tools and techniques of systems engineering and systems science. Within a few years after graduation, graduates are expected to:

• Make positive programmatic and/or system engineering impacts, resulting in successful outcomes
• Employ sound systems engineering processes and tools across the acquisition lifecycle
• Provide technical leadership to teams; promote and facilitate integration and communication across interdisciplinary teams; sustain and increase an effective professional and technical network

The following student outcomes are those competencies that students are expected to achieve by program completion. Graduates will:

• Thoroughly understand the SE processes across the lifecycle
• Apply SE processes and sound engineering principals in a systematic manner to solve contemporary defense-focused problems
• Proficiently use analytical tools for implementing SE processes and methods
• Effectively communicate technically complex ideas and concepts in both written and spoken formats
• Develop a detailed understanding in at least one Air Force relevant domain (air, space or cyberspace) or technical specialization

The general requirements for admission to the Master of Engineering in Applied Systems Engineering are as follows:

DEGREE REQUIRED: Any engineering degree (Aeronautical, Astronautical, Aerospace, Chemical, Civil, Computer, Industrial, Mechanical, Electrical, or Systems Engineering) or a degree in Engineering Science. A degree in science (e.g. physics), math or computer science will be considered for admission to a non-ABET
Systems Engineering and Management (ENV)

Master of Science program on a case-by-case basis. Courses in calculus-based physics and dynamical systems (circuits or engineering dynamics) are required.

MATHEMATICS REQUIRED: Ordinary Differential Equations
TEST REQUIRED: GRE - 153V/148Q.
GPA REQUIRED: OVERALL ≥ 3.0; MATH ≥ 3.0; MAJOR ≥ 3.0

Waivers to the above criteria may be granted (on an individual basis) by the Department of Systems and Engineering Management. Therefore, individuals whose academic credentials fall below any of the above criteria may still apply.

For more information on specific admission procedures to AFIT programs, please refer to the AFIT Office of Admissions web page at www.afit.edu/ADMISSIONS/.

Degree Requirements

Core Courses

16 hours
These courses emphasize the current body of knowledge for systems engineers:
• SENG 520 Foundations of Systems Engineering
• SENG 593 Agile Software Systems Engineering
• SENG 640 System Architecture
• SENG 610 Systems Engineering Management or SENG 670 Advanced Topics in DoD Systems Engineering

Mathematics Courses

4 hours
Students must complete at least one course in graduate mathematics or math science (3-4 credit hours). The recommended probability and statistics course is:
• STAT 583 Introduction to Probability and Statistics

Students with sufficient knowledge in probability and statistics may take an alternate math course that is more appropriate to their coursework and/or research with SE Program Chair approval.

Specialization Track

12 hours
This sequence of courses is intended to provide the student with technical depth in an Air Force-related domain of application. While the number of courses in each sequence may vary, it is three or more courses for 12 or more credit hours, one of which must be at the 600-level or above. For online/distance students, the human systems and space systems tracks are currently available.
Systems Engineering and Management (ENV)

Analytical Toolset

12 hours
The intent of this program element is to provide the student with technical depth in multiple engineering analysis methodologies. There are six Analytical Toolset courses available as part of the ASE program; students must take three.

- HFEN 620 Human Systems Modeling
- QMGT 680 Project Risk Analysis
- SENG 570 Systems Process Improvement
- SENG 585 Reliability in Systems Design
- SENG 620 Quantitative Analytical Methods
- SENG 660 Advanced Principles of Engineering Design

Capstone

4 hours
In this course, students will apply and integrate prior program content as part of a culminating capstone project in Systems Engineering (SE). A capstone project consists of an investigation into a topic of current interest to the Air Force and/or the Department of Defense and should demonstrate a systems approach to that topic using SE methods, processes, or tools. The specific investigation topic of the capstone project is proposed by the student and is approved and monitored by a member of the SE faculty. Projects are generally performed on an individual basis, but may be accomplished as a group with instructor permission. Results of the capstone project are provided in a formal written report.

- SENG 798 Master’s Capstone Project
The Graduate School of Engineering and Management, Department of Systems Engineering and Management offers the Master of Science in Cost Analysis (GCA). The GCA program is designed to advance the knowledge and creative problem solving skills needed to effectively estimate program resources within the global military, U.S. Department of Defense (DOD) and the United States Air Force (USAF) environments. The curriculum integrates a strong foundation in quantitative concepts and techniques with specific military cost-related topics to prepare students to contribute effectively in a variety of complex and challenging roles in the global military arena. Besides the weapon system cost sequence, the curriculum includes courses in mathematical methods, quantitative decision-making, economics, cost management, risk, systems engineering and maintenance and production management.

Program Educational Objectives (PEOs)

- Program graduates are well-prepared to use analytical techniques to make significant progress toward solving problems of interest to the Air Force, DoD and Homeland Security
- Graduates will be independent, trusted advisors in proposing, developing, and implementing policy as judged by their immediate supervisors in the areas of financial management, cost estimation, and cost analysis as a result of excellent and consistent application of decision making and research tools to real issues confronting the staff
- Effectively communicate using both oral and written communications
- Understand and apply concepts and techniques of descriptive and inferential statistics to analyze problems under conditions of risk and uncertainty
- Understand and apply concepts, methods, and tools related to cost estimating in a program acquisition context
- Understand and apply concepts from a wide range of business disciplines within the specific context of DoD resource estimation
- Conduct and present methodical research to creatively solve complex and ambiguous problems and support resulting decisions with appropriate documentation

School and Program Admission Criteria

DEGREE REQUIRED: Business, Economics, Finance or Math preferred
MATHEMATICS REQUIRED: Calculus (but not necessarily including) differential equations and at least one course in statistics.
TEST REQUIRED: GMAT- 550 (28 - Verbal, 37 - Quantitative, 4.5 - analytical writing); GRE - 153V/148Q
GPA REQUIRED: OVERALL - 3.0; MATH - 3.0

Waivers to the above criteria may be granted on a case by case basis. Therefore, individuals whose academic credentials fall below any of the above criteria are encouraged to apply.
Systems Engineering and Management (ENV)

Degree Requirements

Cost Specialty Core Courses

24 hours

- COST 510 - Principles of Cost Estimating
- COST 520 - Advanced Concepts in Cost Estimating
- COST 610 - Project Risk Analysis
- COST 630 - Defense Cost Economics
- COST 674 - Seminar in Advanced Cost Analysis
- EMGT 550 - Engineering Economic Analysis

Analytic Core Courses

12 hours

- STAT 525 - Applied Statistics for Managers I
- STAT 535 - Applied Statistics for Managers II

Other

8 Credits

- ECON 520 - Managerial Economics
- SENG 520 - Systems Engineering Fundamentals
- SENG 610 - Project Management

Thesis

12 hours
Program Description

The Engineering Management degree is accredited by the Engineering Accreditation Commission of ABET (Accreditation Board for Engineering and Technology). For students with an ABET-accredited undergraduate degree, the degree title is “Master of Science in Engineering Management.” For students without an ABET-accredited undergraduate degree, the degree title is “Master of Science.” The degree reflects the importance of enhancing the interface between technology and management in environments dominated by Science, Technology, Engineering, and Mathematics (STEM) fields. The program is thus designed for individuals operating in a technical environment who wish to be more prepared to integrate technical and managerial skills within a decision-making context. The strength of the program is its multidisciplinary approach in which core management principles are integrated with technical specialization areas. Upon completion of the degree, students will have a better appreciation of the broad field of engineering management and a better understanding of the integrative nature of processes and relationships inherent in most technology-driven organizations.

Program Educational Objectives (PEOs)

The Program Educational Objective broadly describes what graduates are expected to attain within 2-5 years after graduation. For the Engineering Management program, graduates are expected to be well positioned to lead in a technical environment, both independently and collaboratively, while applying decision-making and analytical tools to solve operational problems. They are expected to be able to propose, develop, and implement effective policy through a holistic systems approach in their area of specialization as judged by their immediate supervisors.

Student Outcomes (SOs)

Upon graduation, students in the Engineering Management program are expected to be able to accomplish the following:

• Create coherent explanations and reflections on work in two or more media to both general and specialized audiences.
• Analyze and distinguish the integrative nature of processes and relationships within the engineering management field and within their respective technical environments.
• Apply and evaluate the concepts, methods, and tools related to planning, organizing, leading, and controlling resources and processes in a technology-focused organization.
• Apply and evaluate the principles of organizational behavior related to managing people-centric processes in a technology-focused organization.
• Develop information-based recommendations and support more informed decisions through the application of critical thinking skills and appropriate analytical techniques.
• Conduct and present methodical research, using a systems thinking approach and the application of advanced knowledge, to analyze problems and recommend solutions.
Systems Engineering and Management (ENV)

School and Program Admission Criteria

All students working in a STEM-related environment are welcome to apply. Although the core elements of the program do not require specific knowledge from any particular engineering discipline, students must be comfortable with technical concepts and topics. The general requirements for admission to the Master of Science program in Engineering Management include the following:

• An undergraduate degree in an appropriate area of engineering or science; an undergraduate degree from another STEM-related discipline will be acceptable provided it contains significant technical coursework or is accompanied by work experience in a technology-focused organization.

• Mathematics courses to include at least one year of college-level calculus and a course in probability and statistics. Applicants without a previous course in probability and statistics, and who otherwise have strong academic backgrounds, may be admitted but will be required to take a probability and statistics course in their initial quarter.

• A cumulative undergraduate GPA of 3.0 (on a 4.0 scale); the GPA in mathematics-related courses should be at least 3.0.

• Either the Graduate Record Examination (GRE) or Graduate Management Admissions Test (GMAT) is required. For the GRE, scores of at least 153 on the verbal portion and 150 on the quantitative portion are required (500 verbal and 600 quantitative for tests taken prior to 1 August 2011). Weaknesses in one area may be offset by strengths in the other area, provided the combined score exceeds 305. For the GMAT, a score of at least 550 is required.

Deficiencies in any of these areas may be waived on a case-by-case basis, or corrected through additional coursework, as approved by the Curriculum Committee. Students in the local area who do not meet these criteria may register for individual courses as a part-time student (space available) but are expected to meet the above criteria prior to seeking formal admission into the program as a degree-seeking student.

Curriculum Description

The Engineering Management program is available to both full-time students (typically referred to as sponsored/quota students) and part-time students. In-residence students nominally complete the program in 18 months (6 academic quarters). Depending on course availability and student course load, part-time students nominally complete the program in 36 months. Part-time students take courses either in-residence or through a distance learning (DL) modality.

The minimum curriculum satisfying the degree requirements consists of the following components. A minimum of 48 credit hours is required for the degree.

• Two methods courses provide a strong background central to problem solving and informed decision-making (minimum of 8 credit hours).
  • STAT 521 (DL only) or STAT 535 (in-residence only)
  • SENG 620 (DL only) or RSCH 630

• The engineering management core represents an interdisciplinary approach to the degree and establishes a framework to help integrate courses and applied research streams (minimum of 14 credit hours).
  • ORSC 542
  • EMGT 550
  • SENG 610
  • SENG 570

• The focus sequence provides technical depth in an area of interest to the student. The sequence must consist of at least four courses totaling a minimum of 14 credit hours. Example sequences include Facilities
Systems Engineering and Management (ENV)

and Infrastructure Management, Science & Technology Management, Information & Technology Management, and Human Factors Engineering. Additionally, provisions are available to tailor sequences to meet specific student needs.

• The thesis is a mandatory requirement (12 credit hours) for all students and must address a real-world problem involving engineering management.
• Electives are offered in addition to strict degree requirements and broaden the student's horizons and/or provide more in-depth knowledge in a specific area of interest.

In addition to degree requirements, and to demonstrate full-time status, all DoD-sponsored full-time students must complete an average of 12 credit hours per quarter (i.e., 72 total credit hours). The credit hour requirement may be achieved by taking additional courses of interest, participating in internships, engaging in directed readings courses, or conducting additional research.
The Graduate School of Engineering and Management, Department of Systems Engineering and Management offers two programs in the Environmental Engineering and Science and Industrial Hygiene thrust area. The two programs, which offer Master of Science degrees in Environmental Engineering and Science and Industrial Hygiene, are described below.

Environmental Engineering and Science Program

The Environmental Engineering and Science Program offers graduate education relevant to environmental management. The teaching and research activities focus on pollutant transport, water treatment, air quality, remediation, sustainability, hydrology, microbiology, and policy. The degree requirements include specified core courses, specialty sequences, thesis, and electives. The program offers an ABET-accredited track and a non-ABET-accredited track. The ABET-accredited track places more emphasis on science and engineering principles. The non-ABET track has more emphasis on environmental management and decision making.

Program Educational Objectives (PEOs)

The Environmental Engineering and Science Program is designed to provide DoD career professionals with relevant graduate education in the principles of environmental engineering and science. The educational objective of the environmental engineering and science program is that within a few years of program completion, graduates, who would be serving as DoD officers and career professionals, will demonstrate that they can apply the principles of environmental engineering and science (encompassing air, water, and soil media) to successfully accomplish their duties across the spectrum of DoD environmental consulting and management duties. These abilities may be validated through voluntary professional certification, as appropriate (e.g., PE, CEM, BCEEM, QEP).

Student Outcomes (SOs)

Upon graduation, students in the Environmental Engineering and Science major will be able to:

- Apply knowledge of mathematics through differential equations, probability and statistics, calculus-based physics, chemistry, earth science, biological science, and fluid mechanics
- Formulate material and energy balances
- Analyze the fate and transport of substances in and between air, water, and soil phases;
- Conduct laboratory experiments, and analyze and interpret the resulting data in more than one major environmental engineering focus area (e.g., air, water, land, environmental health)
- Design environmental engineering systems that include considerations of risk, uncertainty, sustainability, life-cycle principles, and environmental impacts
- Demonstrate understanding of concepts of professional practice, project management, and the roles and responsibilities of public institutions and private organizations pertaining to environmental policy and regulation
- Apply advanced principles and practice relevant to the program educational objectives.
Systems Engineering and Management (ENV)

Upon graduation, students in the Environmental Science and Management major will be able to
• Apply knowledge of mathematics, probability and statistics, physics, chemistry, and biology to solve environmental problems
• Formulate material and energy balances
• Analyze the fate and transport of substances in and between air, water, and soil phases
• Conduct laboratory experiments, and analyze and interpret the resulting data in more than one major environmental engineering focus area (e.g., air, water, land, environmental health)
• Consider risk, uncertainty, sustainability, life-cycle principles, and environmental impacts when making decisions
• Demonstrate understanding of concepts of professional practice, project management, and the roles and responsibilities of public institutions and private organizations pertaining to environmental policy and regulation
• Apply advanced principles and practice relevant to the program educational objectives.

School and Program Admission Criteria

The general requirements for admission to the Master of Science program in Environmental Engineering and Science are:
• A Bachelor’s degree from an ABET accredited engineering program or a B.S. degree in a science related to environmental science, such as physics, biology, chemistry or industrial hygiene.
• A cumulative undergraduate GPA of 3.0 (on a 4.0 scale) and minimum GRE scores of 153 verbal and 148 quantitative (or 500 verbal and 600 quantitative for GREs taken prior to 1 Aug 2011).
• Introductory statistics course*
• An introductory environmental engineering course*.
• Calculus through ordinary differential equations (for the ABET-accredited option) -or- Two semesters of Calculus (for non-ABET accredited track)
• An introductory environmental engineering course*.

*Courses can be taken in first quarter if not yet completed
NOTE: Deficiencies in the above areas may be waived or corrected through additional coursework on a case-by-case basis by the Department of Systems Engineering and Management.

Industrial Hygiene Program

Program Description

This program was developed considering guidelines established by ABET and subject areas from the Certified Industrial Hygienist exam from the American Board of Industrial Hygiene. The Master's degree of this program is accredited by the Applied and Natural Science Accreditation Commission of ABET (http://www.abet.org). Students will receive the degree Master of Science in Industrial Hygiene, upon successful completion of all graduation requirements.

In addition, the Industrial Hygiene program was developed in coordination with the Environmental Engineering and Science degree program. Both programs were motivated by a request from the AF
Bioenvironmental Engineering (BE) career field. The Environmental Engineering and Science program was offered for the first time in the Fall of 2003, while the Industrial Hygiene program began later in the Fall of 2006. The curriculum includes department core course offerings in statistics, risk analysis, and sustainable design. The program curriculum includes course offerings in industrial hygiene anticipation/recognition/evaluation/control, radiation protection, epidemiology, and toxicology.

Program Educational Objectives (PEOs)

- Our graduates have achieved positions of leadership as occupational/environmental health consultants, instructors, or similar positions of responsibility
- Our graduates have applied their education to address difficult technical problems for the Air Force, sister service, civilian, or foreign industrial and community environments within tactical, operational, and strategic frameworks
- Our graduates have attained voluntary professional board certification as Certified Industrial Hygienists

Student Outcomes (SOs)

Upon graduation the student will be able to:
- Anticipate and recognize agents, factors, and stressors
- Evaluate agents, factors, and stressors for hazard potential
- Control hazards presented by agents, factors, and stressors

School and Program Admission Criteria

The general requirements for admission to the Master of Science program in Industrial Hygiene are:
- Admitted students must hold an earned baccalaureate that prepares them to apply the basic principles of college-level mathematics, inorganic and organic chemistry, physics, and biology. Examples include a bachelor’s degree from a regionally accredited program in engineering or science related to environmental science, such as physics, biology, chemistry or industrial hygiene.
- GRE: Verbal $\geq 153$ (500 if taken prior to August 2012); Quantitative $\geq 148$ (600 if taken prior to 1 August 2012)
- A cumulative undergraduate GPA of 2.75 or higher

NOTE: Deficiencies in the above areas may be waived or corrected through additional coursework on a case-by-case basis by the Department of Systems Engineering and Management.
Systems Engineering and Management (ENV)

Human Systems Certificate

Program Description

AFIT offers a Graduate Certificate in Human Systems (HS), consisting of a series of two core courses, two elective courses and a capstone project. These courses are part of the engineering management and systems engineering degree programs and may also be used as a minor concentration in another AFIT degree program. If the certificate is earned as a minor concentration in another AFIT degree program, the requirement for the capstone project may be met by the student’s thesis (with SE curriculum chair approval).

Under certain circumstances, this program can be offered via distance learning for part-time remote students. These courses use prerecorded lectures, supplemented with live webinars. The target audience is active duty military, DOD civilians, and contractors with traditional science or engineering backgrounds, usually working in laboratories, test centers, product centers, or in a requirements/capability planning office. Each course is offered during an AFIT academic quarter. If taking one course per quarter, this program can be completed in 15 months.

Program Outcomes (POs)

The HS Certificate Program takes students with traditional science or engineering backgrounds and produces graduates who can effectively use the tools and knowledge of human factors and human factors engineering to approach and analyze the design of systems for human use.

- The HS graduates will understand the systems engineering process and the role of the human factors engineer within the systems engineering process.
- HS graduates will demonstrate application of HS evaluation, design, and experimental processes on contemporary problems of interest to the DOD.
- HS graduates will understand many of the tools and activities of the human factors engineer and other human systems integration oriented disciplines in the design of complex human-machine systems.
- HS graduates will be able to identify deficiencies and/or gaps in the current human factors body of knowledge, and will be capable of proposing new approaches to bridge these gaps.
- HS graduates will demonstrate the ability to effectively communicate technically complex ideas and concepts in both spoken and written formats.

School and Program Admission Criteria

DEGREE REQUIRED: Candidates must have completed a bachelor’s degree in engineering or scientific field. At least one course in engineering design is recommended.

MATHEMATICS REQUIRED: Basic calculus and probability and statistics.

TEST REQUIRED: None

GPA REQUIRED: Overall – 3.0

Waivers to the above criteria may be granted on a case by case basis. Therefore, individuals whose academic credentials fall below any of the above criteria are encouraged to apply.
Systems Engineering and Management (ENV)

Degree Requirements Core Courses

- SENG 520 – Systems Engineering Fundamentals
- HFEN 560 – Human Factors

Capstone Project

- SENG 798 – SPECIAL STUDY – GROUP OR INDIVIDUAL CAPSTONE PROJECT

Elective Courses (select two of the following)

- SENG 560 – Human Systems Integration
- HFEN 610 – Human Performance Measurement
- HFEN 620 – Human Performance Modeling
- HFEN 663 – Human-Computer Interaction
- HFEN 665 – Human-Agent Interaction
- HFEN 670 – Human Interaction Technologies
Systems Engineering and Management (ENV)

Systems Engineering (M.S.)*

Program Description

Systems Engineering (SE) is the process by which a customer’s needs are satisfied through the conceptualization, design, modeling, testing, implementation, and operation of a working system. There are a range of levels of systems engineering, from product systems engineering used for a standalone product or vehicle platform, to design and integration of so-called “systems of systems” (such as an air operations center or missile defense system), to enterprise wide systems engineering that span an entire organization (such as mobility forces or space command).

The focus on SE becomes especially important in the analysis and synthesis of large and complex systems, such as those that arise regularly in Department of Defense and Air Force problems. Such examples include: space systems, missile defense, Battle Management/Command and Control, network-centric systems, and generally most business and combat support Information systems. Over the last few decades, Systems Engineering has matured into its own discipline, with a foundation on system science using tools and repeatable processes from product development and systems engineering management. Recently, with the pervasive deployment of complex interconnected networked systems, the use of architecture has taken a central role in communicating the system of systems and enterprise-wide solutions.

The Graduate Systems Engineering (GSE) program is an ABET accredited program leading to a Master of Science (MS) degree in Systems Engineering. This program is provided to both resident students and part-time students via online/distance-learning (DL) modality. In full time residence, it is nominally a six quarter (18 month) program, with students normally entering in September and graduating in March. For distance learning, it is nominally a 24 month to 36 month program, depending on class availability and part-time course load. For more information about distance learning or about this specific program, and to apply, go to AFIT’s Extension Services website http://www.afit.edu/DL/

Program Educational Objectives (PEOs)

The SE program takes students with traditional engineering backgrounds (mechanical, electrical, aerospace, etc.) and produces graduates who can effectively use the tools and techniques of both systems science and traditional engineering disciplines to approach and analyze complex problems, design feasible solutions, and select an appropriate solution. It is expected that graduates possessing these skills will go on to make substantive contributions to capability development within the DoD. Within a few years after graduation, graduates are expected to:

- Make positive programmatic and/or system engineering impacts, resulting in successful outcomes
- Employ sound systems engineering processes and tools across the acquisition lifecycle
- Provide technical leadership to teams; promote and facilitate integration and communication across interdisciplinary teams; sustain and increase an effective professional and technical network
Systems Engineering and Management (ENV)

Student Outcomes (SOs)

The Systems Engineering program provides a substantial technical foundation in system architecture, analysis and design as well as opportunity for specialization within a traditional engineering discipline. The program culminates with an individual thesis or group design project typical of a defense system project. In the design study, the student will apply their individual technical expertise, exercise their system design skills, and experience the group dynamics of a team design effort while solving a realistic defense system problem. Finally, the program provides the necessary education to qualify full-time quota students for the academic degree code assigned to them on entry into the program. Student Outcomes (SOs), those competencies that students are expected to achieve by the completion of the program, are as follows:

AFIT SE graduates will:
- Thoroughly understand the SE processes across the lifecycle
- Apply SE processes and sound engineering principals in a systematic manner to solve contemporary defense-focused problems
- Proficiently use analytical tools for implementing SE processes and methods
- Effectively communicate technically complex ideas and concepts in both written and spoken formats
- Develop a detailed understanding in at least one Air Force relevant domain (such as air, space or cyberspace) or technical specialization
- Conduct independent research on topics related to systems engineering, systems science and/or its application, including identifying and scoping a problem, synthesizing published work, formulating a design solution, planning and executing a valid research methodology, engineering a model or prototype, and/or analyzing and evaluating results and data

School and Program Admission Criteria

The general requirements for admission to the Master of Science in Systems Engineering program are as follows: DEGREE REQUIRED: Any engineering degree (Aeronautical, Astronautical, Aerospace, Chemical, Civil, Computer, Industrial, Mechanical, Electrical, or Systems Engineering) or a degree in Engineering Science. A degree in science (e.g. physics), math or computer science will be considered for admission to a non-ABET Master of Science program on a case-by-case basis. Courses in calculus-based physics and dynamical systems (circuits or engineering dynamics) are required.
MATHEMATICS REQUIRED: Ordinary Differential Equations
TEST REQUIRED: GRE - 153V/148Q.
GPA REQUIRED: OVERALL - 3.0; MATH - 3.0; MAJOR - 3.0

Waivers to the above criteria may be granted (on an individual basis) by the Department of Systems and Engineering Management. Therefore, individuals whose academic credentials fall below any of the above criteria may still apply.

For more information on specific admission procedures to AFIT programs, please refer to the AFIT Office of Admissions web page at www.afit.edu/ADMISSIONS/.
Systems Engineering and Management (ENV)

Degree Requirements

The GSE program requires a minimum of 48 credit hours covering the following program elements: core courses, mathematics or math science requirement, a distribution course requirement, engineering depth to include an applicable education code sequence, an individual thesis or group project, and any additional Air Force and/or ABET requirements. The program elements are discussed below.

Core Courses

16 hours
There are four Systems Engineering core courses. These courses provide a common breadth of knowledge and the basic building blocks for all Air Force and DoD Systems Engineers. All core courses are 4 credit hours.

- SENG 520 Foundations of Systems Engineering
- SENG 593 Agile Software Systems Engineering
- SENG 640 System Architecture
- SENG 610 Systems Engineering Management or SENG 670 Adv. Topics in DoD Systems Engineering

Mathematic Courses

4 hours
Students must complete at least one course in graduate mathematics or math science (3-4 credit hours). The recommended probability and statistics course is:

- STAT 583 Introduction to Probability and Statistics

Specialization Track

12 hours
This sequence of courses is intended to provide the student with technical depth in a particular Air Force domain or an engineering analysis area. Available track options are summarized below. While the number of courses in each sequence may vary, it is three or more courses for 12 or more credit hours, one of which must be at the 600-level or above.

- Unmanned Systems
- Space Systems
- Cyberspace/ Info Systems
- Human Systems
- Navigation Systems
- Reliability
- Modeling and Simulation
- Optimization
- Decision Analysis
- SE Control and Optimization
- SE Operations Research
Systems Engineering and Management (ENV)

Research Methods

4 hours
A research methods course is an important foundation course for any graduate program. This requirement provides an understanding of basic research techniques and concepts related to scientific inquiry. Students will advance along the research process by introducing the basic tools needed to critically analyze claims made through written and oral means, and determine the degree to which these claims are valid.

- RSCH 630 Research Methods

Thesis

12 hours
The breadth of the systems engineer is generally captured through an understanding of processes, ranging from general systems engineering processes to specialized aspects of component design, manufacturing, testing and operations. Systems engineering education transcends the normal engineering education by requiring a deep understanding of key technical processes and their supporting methodologies and tools. The processes are most effectively understood through repeated application and the resulting lessons learned, with knowledge often captured through substantial team projects and hands-on experience.

The team or individual works on a major project of DoD or Air Force interest allowing the students to apply systems engineering methods, processes, tools and language to a real problem. The individual thesis or group project for the GSE program will be minimum of 12 credit hours of SENG 799, typically spread over 3 or more quarters.

ABET Requirements

Only students possessing an ABET accredited undergraduate degree will be qualified to earn the Master of Science in Systems Engineering. Students admitted to the Systems Engineering program without an ABET accredited undergraduate degree will earn a Master of Science degree accredited by the North Central Association of Colleges and Schools.
Systems Engineering and Management (ENV)

Systems Engineering (Ph.D.)

Program Description

The Department of Systems Engineering and Management offers a doctoral program which leads to the award of a PhD. The Doctor of Philosophy degree is a research degree that recognizes mastery in the field of Systems Engineering, a demonstrated ability to conduct independent research and the dissemination of significant and original contributions to the Systems Engineering body of knowledge. The Graduate School of Engineering and Management specifies the degree requirements for the school’s doctoral program which are summarized below.

School and Program Admission Criteria

The general requirements for admission to the PhD program are as follows.

DEGREE REQUIRED: An engineering Masters degree (Aeronautical, Astronautics, Aerospace, Chemical, Civil, Computer, Industrial, Mechanical, Electrical, or Systems Engineering). Other relevant Masters degrees, together with an engineering BS, may be considered on a case-by-case basis.

TEST REQUIRED: GRE – 156V/151Q

GPA REQUIRED: OVERALL - 3.5

Waivers to the above criteria may be granted on a case by case basis. Therefore, individuals whose academic credentials fall below any of the above criteria may apply.

For more information on specific admission procedures to AFIT programs, please refer to the AFIT Office of Admissions web page at www.afit.edu/ADMISSIONS/

Degree Requirements

The PhD degree program consists of two phases:

Coursework

36 hours

Phase 1 includes course work and examination period of 4- 6 academic quarters. All requirements for admission to candidacy (course work, examination, committee selection and approval of research prospectus) are met. A minimum of 36 hours (post-MS) consisting of 28 hours of integrated coursework which supports the student’s area of research specialization and 8 hours of mathematics. This coursework will normally be at the 600-level or above.

Dissertation

48 hours

Phase 2 is dedicated to research. This lasts 12-24 months and the PhD candidate devotes their full attention to a research problem described in their prospectus, under the direction of an approved advisor and committee. At least 48 hours must be taken (at least one year residency requirement) of SENG 999, Dissertation Research, leading to the successful defense of the PhD. dissertation.
Systems Engineering and Management (ENV)

Systems Engineering Certificate

Program Description

The Department of Systems Engineering and Management has offered a Systems Engineering Certificate (SEC) since 2003. As most disciplined engineers in acquisition perform many systems engineering activities, this graduate certificate is highly relevant to most developmental engineers. Such techniques include: modern Model-based systems engineering (MBSE) methods and tools, agile software development, the use of System Modeling Language (SysML) and architecture frameworks.

The Certificate can be earned as a minor concentration as part of another AFIT degree or accomplished independently entirely via online/distance learning. The target audience is active duty military, Air Force civilians, and contractors with traditional engineering backgrounds, usually working in laboratories, test centers, product centers, logistics centers, or in a requirements/capability planning office. If taking one course per quarter, this program can be completed in 12 months part-time. Completion of this certificate also provides a pathway for engineers to continue into an AFIT SE Master’s program, thesis or non-thesis option, resident or online.

Student Outcomes (SOs)

The SE Certificate Program takes students with traditional engineering backgrounds (mechanical, electrical, aerospace, etc.) and produces graduates who can effectively use the modern tools and techniques of systems engineering. SE Certificate Graduates will:

- Thoroughly understand select SE processes and tools across the lifecycle
- Apply SE processes and sound engineering principals in a systematic manner to solve contemporary defense-focused problems
- Analyze and evaluate Air Force high-interest, systems engineering policy, challenges and solutions

School and Program Admission Criteria

DEGREE REQUIRED: Any engineering degree (Aeronautical, Astronautics, Aerospace, Chemical, Civil, Computer, Industrial, Mechanical, Electrical, or Systems Engineering) or a degree in Engineering Science. Calculus-based physics and a course in dynamical systems (circuits or engineering dynamics) are required.  
MATHEMATICS REQUIRED: Ordinary Differential Equations  
TEST REQUIRED: None  
GPA REQUIRED: OVERALL - 3.0; MATH - 3.0; MAJOR - 3.0

Waivers to the above criteria may be granted on a case by case basis. Therefore, individuals whose academic credentials fall below any of the above criteria are encouraged to apply. For more information on specific admission procedures to AFIT programs, please refer to the AFIT Office of Admissions web page at www.afit.edu/ADMISSIONS/.
Systems Engineering and Management (ENV)

Degree Requirements Core Courses

16 hours

There are four Systems Engineering core courses. These courses provide a common breadth of knowledge and the basic building blocks for all Air Force and DoD Systems Engineers. All core courses are 4 credit hours.

- SENG 520 Foundations of Systems Engineering
- SENG 593 Agile Software Systems Engineering
- SENG 640 System Architecture
- SENG 610 Systems Engineering Management or
- SENG 670 Advanced Topics in DoD Systems Engineering
## Course Descriptions

**Aeronautics and Astronautics (ENY)**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
<th>Terms Offered</th>
<th>Prerequisite</th>
</tr>
</thead>
<tbody>
<tr>
<td>AERO 500</td>
<td>Introduction to Aeronautical Engineering</td>
<td>4</td>
<td>Summer</td>
<td></td>
</tr>
<tr>
<td>AERO 517</td>
<td>Fluid Measurement</td>
<td>4</td>
<td>Spring</td>
<td>AERO-534 or Permission of Instructor</td>
</tr>
<tr>
<td>AERO 518L</td>
<td>Fluid Measurement Lab</td>
<td>0</td>
<td>Spring</td>
<td></td>
</tr>
<tr>
<td>AERO 533</td>
<td>Incompressible Aerodynamics</td>
<td>4</td>
<td>Fall</td>
<td></td>
</tr>
<tr>
<td>AERO 534</td>
<td>Aerodynamic Fundamentals</td>
<td>4</td>
<td>Fall</td>
<td></td>
</tr>
<tr>
<td>AERO 536</td>
<td>High Speed Aerodynamics</td>
<td>4</td>
<td>Winter and Summer</td>
<td></td>
</tr>
<tr>
<td>AERO 537</td>
<td>Advanced Aerodynamics</td>
<td>4</td>
<td>Spring</td>
<td>AERO-534</td>
</tr>
<tr>
<td>AERO 543</td>
<td>Advanced Computational Modeling for Aerodynamics</td>
<td>4</td>
<td>Spring</td>
<td></td>
</tr>
<tr>
<td>AERO 551</td>
<td>Numerical Methods for Computational Fluid Dynamics</td>
<td>4</td>
<td>Fall</td>
<td></td>
</tr>
<tr>
<td>AERO 580</td>
<td>Technical Communications for Aerospace Engineers</td>
<td>3</td>
<td>Summer</td>
<td></td>
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<tr>
<td>AERO 580L</td>
<td>Technical Communications for Aerospace Engineers Lab</td>
<td>1</td>
<td>Summer</td>
<td></td>
</tr>
</tbody>
</table>

**Course Descriptions:**

- **Introduction to Aeronautical Engineering**
  - Introduction to fluid mechanics, airfoil and wing aerodynamics, steady and accelerated aircraft performance, and stability and control.

- **Fluid Measurement**
  - Introduction to instrumentation and procedures used in the calibration of measurement systems and measurement of the static and dynamic response of fluid and thermal systems. Notes: Instrumentation includes os sensors, Schlieren flow visualization, and other measurement systems at the discretion of the instructor.

- **Incompressible Aerodynamics**
  - Dynamics of incompressible, inviscid and viscous flow fields. Topics include kinematics and dynamics of flow fields, potential flow theory, circulation theory of lift, characteristics of airfoils, fixed wings and rotary wings, introduction to laminar and turbulent boundary layers.

- **Aerodynamic Fundamentals**
  - Introduction to the dynamics of both incompressible and compressible flows, with specific applications for external aerodynamics problems such as lift generation by 2-D airfoils and 3-D wings. Topics fundamental to incompressible flow include potential flow, thin airfoil theory, lifting line theory, and an overview of boundary layers. Topics fundamental to compressible aerodynamics include 1-D compressible flow within a pipe, wave motion, normal and oblique shocks, and Prandtl-Meyer expansions.

- **High Speed Aerodynamics**
  - Theory of compressible aerodynamics including classical gas dynamics, wave motion, normal and oblique shocks, Prandtl-Meyer expansions, linear airfoil theory, similarity rules and the method of characteristics.

- **Advanced Aerodynamics**
  - Introduction to advanced topics in classical aerodynamics. Topics of coverage include linear airfoil theory for transonic flow, the method of characteristics applied to supersonic nozzle design, Crocco's theorem, Taylor-Maccoll solution of supersonic flow past a cone, ground effect, and fluid dynamics within shock tubes.

- **Advanced Computational Modeling for Aerodynamics**
  - Usage of commercial and government software packages for detailed modeling and analysis of internal and external aerodynamic flow fields to include in compressible and compressible viscous solutions with various turbulence models will be discussed. Topics will include techniques for mesh generation and adaptation, boundary condition definitions, flow solver options to include serial versus parallel processing, and scientific visualization of numerical results.

- **Numerical Methods for Computational Fluid Dynamics**
  - Application of numerical finite-difference methods to selected model equations from fluid mechanics and heat transfer: classification of partial differential equations (PDEs); development and analysis of finite difference representations of partial derivatives; analysis of consistency, stability, and accuracy of explicit and implicit finite difference solution schemes; implementation of selected finite difference schemes in FORTRAN or MATLAB.

- **Technical Communications for Aerospace Engineers**
  - This course is designed to provide an understanding of research in an applied sense. Work will be accomplished leading towards development of a master's quality thesis. Students will learn critical thinking, and communication skills. This will focus on how to review other people's work from literature and peers as well as writing effectively. The Assertion-Evidence technique will be taught to improve technical presentation of the work. The quarter will consist of a full literature review along with a conference type presentation of the work.
### Course Descriptions

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
<th>Credits</th>
<th>Terms Offered</th>
<th>Prerequisite(s)</th>
</tr>
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<tbody>
<tr>
<td>AERO 585</td>
<td>Aerospace System Design</td>
<td>4</td>
<td>Summer</td>
<td></td>
</tr>
<tr>
<td>AERO 610</td>
<td>Rotorcraft Aeromechanics</td>
<td>4</td>
<td>Winter</td>
<td>AERO-533</td>
</tr>
<tr>
<td>AERO 620</td>
<td>Helicopter Mission Performance and Flying Handling Qualities</td>
<td>4</td>
<td>Summer</td>
<td>AERO-610</td>
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<tr>
<td>AERO 622</td>
<td>Introductory Hypersonics</td>
<td>4</td>
<td>Spring</td>
<td>AERO-536</td>
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<tr>
<td>AERO 627</td>
<td>Turbulence</td>
<td>4</td>
<td>Winter</td>
<td>AERO-634</td>
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<tr>
<td>AERO 634</td>
<td>Viscous Flow Theory</td>
<td>4</td>
<td>Fall</td>
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<tr>
<td>AERO 640</td>
<td>Hypersonic Computational Fluid Dynamics</td>
<td>3</td>
<td>Spring</td>
<td>AERO-622</td>
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<tr>
<td>AERO 640L</td>
<td>Hypersonic Computation Fluid Dynamics Lab</td>
<td>1</td>
<td>Lab</td>
<td></td>
</tr>
<tr>
<td>AERO 652</td>
<td>Computational Fluid Dynamics</td>
<td>4</td>
<td>Winter</td>
<td></td>
</tr>
</tbody>
</table>

**AERO 585: Aerospace System Design**  
Team design project of an aircraft in response to a Request-For Proposal. Design methodology focuses on a military need and incorporates performance, cost supportability, deployment, manufacturing, product quality and environmental considerations. The project draws on all of the aeronautical disciplines and provides students experience in applications of such disciplines to military aircraft design.

**AERO 610: Rotorcraft Aeromechanics**  
This course provides the student with an understanding of the basics of rotorcraft aeromechanics. Primary areas of study include rotorcraft aerodynamics, dynamics of rotor blades, and rotorcraft aeroelasticity. Topics in aerodynamics include momentum theory, blade element theory, and rotorcraft performance. Dynamics of rotor blades includes topics in both rigid and elastic blade motion. Topics in aeroelasticity include vibration and stability of rotors and rotor-fuselage systems. While the primary emphasis in this course is on basic analytical techniques, the students are also introduced to more sophisticated methods commonly used in government and industry.

**AERO 620: Helicopter Mission Performance and Flying Handling Qualities**  
Influence of mission performance and flying qualities on helicopter design. Performance topics covered will include hover, forward flight, and mission performance; main rotor, fuselage, empennage, and tail rotor design; flight dynamics; ADS-33; and objective and subjective assessment of flying qualities. Students will complete two mini-design projects: one focused on mission performance, and the other focused on flying qualities.

**AERO 622: Introductory Hypersonics**  
Character of hypersonic flow and assumptions underlying inviscid hypersonic flow theories. Similarity, small disturbance and surface inclination methods are covered. The equivalence principle, blast wave methods, low density aerodynamics, high temperature aerodynamics and re-entry trajectories are also discussed.

**AERO 627: Turbulence**  
The course approaches turbulence predominantly from an experimental point of view. A statistical description of turbulence is presented in order to quantify the variations in the flow caused by turbulence. This leads to order of magnitude estimates for diffusion, transport, and dissipation of turbulence. These quantities are understood relative to the fundamental length scales that they occur at. The second part of the course looks closely at the fundamental equations when subjected to fluctuations around the mean levels. Reynolds time averaging of the Navier Stokes equations is presented along with discussion of the closure problem. Several methodologies are presented to solve the N-S equations including turbulent energy and vorticity balances. Turbulence modeling methods are presented and some application to Computational Fluid Dynamics is developed. The turbulence equations are then applied to Boundary-free shear flows and wall-bounded shear flows for internal and external flows.

**AERO 634: Viscous Flow Theory**  
Derivation of the Navier-Stokes equations. Exact solutions of the N-S equations, similarity variables. Boundary layer equation, Falkner-Skan solutions, momentum-integral methods. Factors affecting transition; turbulent boundary layers.

**AERO 640: Hypersonic Computational Fluid Dynamics**  
The use of commercial and government ITAR codes for the simulation of hypersonics mesh generation and resulting chemically reacting and thermally nonequilibrium flowfields that occur at hypersonic velocities. In addition, post-processing flow visualization and data reduction techniques will be studied.

**AERO 652: Computational Fluid Dynamics**  
Explicit and implicit algorithms for the solution of the compressible Euler equations in one and two dimensions: Development of finite difference and finite volume formulations of the governing equations; Transformation of PDEs to generalized curvilinear coordinates and the geometric conservation law; Flux and flux-difference splitting schemes; Total variation diminishing (TVD) schemes; Characteristic Variable Boundary Conditions; Implementation of selected 2-D solution schemes in FORTRAN.
Course Descriptions

**AERO 699 Master's Level Special Study** 1-12

Terms Offered: All

Prerequisite:
Directed study at an intermediate graduate level on a special topic which is not normally covered in a regularly scheduled course or as part of thesis research. Topic, format, and course requirements are determined by the faculty member directing the study. Requires submission of Special Studies Form and syllabus to the department for registration.

**AERO 729 Theory of Gases for Aerodynamics and Propulsion** 4

Terms Offered: Spring

Prerequisite: AERO-622 and AERO-579
Introduction to the behavior of gases. Gases are treated as interacting particles and the collective behavior is studied as an ensemble of semi-random events. The evolution of gas properties from the molecular viewpoint to the continuum viewpoint will be examined. Applications of interest include chemical reactions important to hypersonic aircraft and scramjet engines as well as current and future high pressure ratio gas turbine engines.

**AERO 740 Nonequilibrium Hypersonic Flows** 4

Terms Offered: Fall

Prerequisite: AERO-622 and AERO-579
Analysis and study of the strong regions of thermodynamic, chemical, and mechanical nonequilibrium resulting from travel at hypersonic velocities. The resulting physical phenomena from the nonequilibrium - such as very high temperatures, high heat convection, chemical surface reactions, flowfield thermal radiation, and population inversions will discussed.

**AERO 753 Advanced Computational Fluid Dynamics** 4

Terms Offered: Spring

Prerequisite: AERO-652 or permission of instructor
Explicit and implicit algorithms for the solution of the incompressible and compressible Navier-Stokes equations in two and three dimensions: turbulence modeling; numerical grid generations; introduction to unstructured solution techniques; selected topics of current interest in CFD such as preconditioning for low-speed flows, high-order methods, convergence acceleration techniques, parallelization; implementation of selected vicious solution schemes in FORTRAN.

**AERO 799 Thesis Research** 1-12

Terms Offered: All

Prerequisite:
This course is an in-depth study of a research topic selected from a wide variety of problems of current interest to the Air Force, with the results presented in a formal thesis and defense. Ordinarily, this course extends over several quarters, and no credit is given until the end of the last quarter. An oral presentation and defense of the research are required.

**AERO 899 Doctoral Level Special Study** 1-12

Terms Offered: All

Prerequisite:
Directed study for doctoral students on a special topic which is not normally covered in a regularly scheduled course or as part of dissertation research. Topic, format, and requirements of the course are determined by the faculty member directing the study. Requires submission of Special Studies Form and syllabus to the department for registration.

**AERO 999 Dissertation Research** 1-12

Terms Offered: All

Prerequisite: The topic for dissertation research is selected from a wide variety of problems of current interest to the Air Force. The results of the study are reported in a dissertation written under the supervision of a member of the department faculty and are defended in a formal oral defense. As a full-time effort, this study ordinarily extends over at least six quarters.

**ASYS 525 Linear Systems Analysis** 4

Terms Offered: Fall

Prerequisite: This course covers the underlying theory of linear time invariant and time varying dynamic systems. The modeling of engineering systems with an emphasis on mechanical systems is covered. Analysis techniques include classical analysis in the continuous time domain and frequency domain as well as modern state space analysis techniques for linear systems.

**ASYS 530 Introduction to Space Programs and Operations** 3

Terms Offered: Fall

Prerequisite: This course examines the history and current status of military space operations. Topics include the history of space flight, the relationships between military and civil space programs, space law, U.S. space policy, military space missions, U.S. military space organizations, and non-U.S. space programs. Introduction to standard space mission analysis software.

**ASYS 530 Intro to Space Programs & Operations** 1

Terms Offered: Fall Winter and Spring

Prerequisite: This course examines the history and current status of military space operations. Topics include the history of space flight, the relationships between military and civil space programs, space law, US space policy, military space missions, US military space organizations, and non-US space programs. Introduction to standard space mission analysis software.
# Course Descriptions

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
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</thead>
<tbody>
<tr>
<td>ASYS 531</td>
<td>Space Mission Analysis and System Design</td>
<td>4</td>
</tr>
<tr>
<td>ASYS 531L</td>
<td>Space Mission Analysis and System Design Lab</td>
<td>0</td>
</tr>
<tr>
<td>ASYS 535</td>
<td>Military Space Systems and Applications</td>
<td>1</td>
</tr>
<tr>
<td>ASYS 545</td>
<td>Linear Systems Analysis for Control</td>
<td>5</td>
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<tr>
<td>ASYS 565</td>
<td>Control and State Space Concepts</td>
<td>4</td>
</tr>
<tr>
<td>ASYS 625</td>
<td>Non-Linear Systems Analysis and Control</td>
<td>4</td>
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<tr>
<td>ASYS 630</td>
<td>Analysis and Design for Weapons Delivery</td>
<td>4</td>
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<tr>
<td>ASYS 631</td>
<td>Spacecraft Systems Engineering</td>
<td>4</td>
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<tr>
<td>ASYS 632</td>
<td>Satellite Design and Test</td>
<td>4</td>
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<tr>
<td>ASYS 632L</td>
<td>Satellite Design and Test Lab</td>
<td>0</td>
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<tr>
<td>ASYS 655</td>
<td>Non-Linear Systems Analysis and Control</td>
<td>4</td>
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<tr>
<td>ASYS 531</td>
<td>Space Mission Analysis and System Design</td>
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<td>ASYS 531L</td>
<td>Space Mission Analysis and System Design Lab</td>
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<td>ASYS 535</td>
<td>Military Space Systems and Applications</td>
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<td>Linear Systems Analysis for Control</td>
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<td>Satellite Design and Test</td>
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<tr>
<td>ASYS 632L</td>
<td>Satellite Design and Test Lab</td>
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</table>

## Terms Offered
- Winter
- Fall Winter and Spring
- Summer

## Prerequisites
- ASYS-525
- MECH-532 or permission of instructor
- ASYS-631
- ASYS-565
- ASYS-631

This course provides a detailed introduction to the application of space systems engineering processes throughout the life cycle with an emphasis on space mission analysis, systems design, and systems engineering management. Topics include space mission concept definition and analysis, concept of operations, engineering system requirements, system functional and physical partitioning, system integration, verification and validation, decision making, technical reviews, configuration and interface management, cost analysis, and risk management.

This course is designed to provide the student with a picture of worldwide space activities, with an emphasis on military space operations. Seminars will include classified presentations by intelligence analysts. Subjects covered will include operational and technical aspects of U.S. and foreign space systems and related topics of DoD interest. NOTE: This is a single 3 credit course divided over three quarters (students must enroll in all three quarters.)

This course provides a comprehensive overview of the design, manufacture, and testing of complex space systems. The key elements and subsystems components of several important classes of space systems are presented. The systematic approach necessary to effectively design space systems is illustrated through hands-on labs using satellite hardware and space testing facilities. Individual or group projects are conducted and presented.

This course provides the analytical basis for computing delivery trajectories and terminal effects of conventional weapons. It covers such topics as vacuum trajectories and atmospheric trajectories, powered trajectories and projectile stability. Terminal effects are quantified and related to potential targets and their damage criteria.

This course provides an introduction to the fundamental results of modern nonlinear control. The first half of the course will concentrate on the analytical tools that can be used to study a nonlinear system. Specific topics in this area are phase-plane analysis, stability, and Lyapunov theory, perturbation methods and describing functions. The second half of the course will cover several nonlinear control synthesis techniques such as feedback linearization, sliding mode, and model reference adaptive control.

Lab associated with ASYS-632
### Course Descriptions

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>Terms Offered</th>
<th>Prerequisite(s)</th>
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</thead>
<tbody>
<tr>
<td>ASYS 633</td>
<td>Spacecraft Safety and Survivability</td>
<td>4</td>
<td>All</td>
<td>MECH-532</td>
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<tr>
<td></td>
<td><strong>Introduction to safety and survivability of spacecraft and space operations. Preliminary topics will include the analysis of spacecraft failure modes and the development of probabilistic risk assessments. Next, statistical reliability analysis will be investigated using both non-parametric and parametric techniques, as well as safety design principles for launch, on-orbit, and reentry operations. Finally, a framework for spacecraft survivability will be discussed with related topics on resiliency and robustness. Prerequisites: MECH 532</strong></td>
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<tr>
<td>ASYS 635</td>
<td>Conventional Explosives and Effects</td>
<td>4</td>
<td>Winter</td>
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<td></td>
<td><strong>Introduction to conventional explosives engineering and the blast effects of conventional explosives. Chemical and thermodynamic theory of explosive compounds. Nonreactive and reactive shock waves. Shock wave effects in air and solids.</strong></td>
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<tr>
<td>ASYS 640</td>
<td>Aircraft Combat Survivability</td>
<td>4</td>
<td>Spring</td>
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<td></td>
<td><strong>Introduction into aircraft combat survivability engineering and effects of conventional weapons on aircraft systems. Probability theory, radar fundamentals, infrared fundamentals, counter-measures, weapons effects.</strong></td>
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<tr>
<td>ASYS 650</td>
<td>Advanced Explosives and Warhead Design</td>
<td>4</td>
<td>Fall</td>
<td>ASYS-635</td>
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<td><strong>An examination of basic warhead physics and advanced explosive phenomenon such as initiation and detonation. The course will also study the design of multiple warhead types such as fragmentation, blast, direct energy, and kinetic energy rod warheads.</strong></td>
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<tr>
<td>ASYS 699</td>
<td>Master's Level Special Study</td>
<td>1-12</td>
<td>All</td>
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<td></td>
<td><strong>Directed study at an intermediate graduate level on a special topic which is not normally covered in a regularly scheduled course or as part of thesis research. Topic, format, and course requirements are determined by the faculty member directing the study. Requires submission of Special Studies Form and syllabus to the department for registration.</strong></td>
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<tr>
<td>ASYS 765</td>
<td>Robust Control</td>
<td>4</td>
<td>Spring</td>
<td>ASYS-565</td>
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<td><strong>This course covers the fundamentals of linear multivariate control systems, with an emphasis on the design of robust and optimal controllers. Extensions to basic linear system theory are covered emphasizing multivariate analysis. Performance specification and limitations are discussed along with the selection of weighting functions to achieve desired levels of performance and stability robustness. Linear quadratic controller designs are presented.</strong></td>
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<tr>
<td>ASYS 899</td>
<td>Doctoral Level Special Study</td>
<td>4</td>
<td>All</td>
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<td></td>
<td><strong>Directed study for doctoral students on a special topic which is not normally covered in a regularly scheduled course or as part of dissertation research. Topic, format, and requirements of the course are determined by the faculty member directing the study. Requires submission of Special Studies Form and syllabus to the department for registration.</strong></td>
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<tr>
<td>MATL 545</td>
<td>Mechanical Properties of Materials</td>
<td>4</td>
<td>Fall</td>
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<td><strong>Course is designed to provide a background for the understanding of the mechanical behavior of metals, ceramics, polymers, and composites in aerospace applications. Topics include behavior of materials under simple and combined stress systems, elastic and plastic behavior, strengthening mechanics, fatigue, creep, residual stress, fracture, and mechanical testing.</strong></td>
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<tr>
<td>MATL 699</td>
<td>Master's Level Special Study</td>
<td>1</td>
<td>All</td>
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<td></td>
<td><strong>Directed study at an intermediate graduate level on a special topic which is not normally covered in a regularly scheduled course or as part of thesis research. Topic, format, and course requirements are determined by the faculty member directing the study. Requires submission of Special Studies Form and syllabus to the department for registration.</strong></td>
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<tr>
<td>MATL 799</td>
<td>Thesis Research</td>
<td>1</td>
<td>All</td>
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<td></td>
<td><strong>This course is an in-depth study of a research topic selected from a wide variety of problems of current interest to the Air Force, with the results presented in a formal thesis and defense. Ordinarily, this course extends over several quarters, and no credit is given until the end of the last quarter. An oral presentation and defense of the research are required.</strong></td>
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<th>Prerequisite</th>
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<tbody>
<tr>
<td>MECH 500</td>
<td>Fundamentals of Solid Mechanics</td>
<td>4</td>
<td>Fall</td>
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<td></td>
<td><strong>Prerequisite:</strong> Analysis of deformation, strain, and stress continuum. Introduction to elasticity, including definitions of stress, strain, compatibility, equilibrium, generalized Hooke's law, and boundary conditions. The Principle of Minimum Potential Energy is applied to beams in tension, shear, and bending. Torsion of bars with non-circular cross-sections is analyzed by applying St. Venant's Semi-Inverse Principle.</td>
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<tr>
<td>MECH 505</td>
<td>Introduction to Aircraft Structural Analysis and Mechanics</td>
<td>4</td>
<td>Spring and Summer</td>
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<td></td>
<td><strong>Prerequisite:</strong> This course covers fundamental aspects of structural analysis useful for understanding the response characteristics of aircraft/spacecraft components and materials. Topics include definitions and applications of stress, stiffness, strength, environmental aspects, failure analysis, impact response, fatigue and fracture, and relevant algorithms. Both metallic and non-metallic materials and their composites are included. All these aspects are related to tools development for optimum design, residual life evaluation, hazard detection, information evaluation and risk management.</td>
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<tr>
<td>MECH 515</td>
<td>Theory of Vibrations</td>
<td>4</td>
<td>Summer</td>
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<td></td>
<td><strong>Prerequisite:</strong> MECH-521 or Permission of Instructor</td>
<td></td>
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<td>Free and forced vibrations of damped and undamped systems with a finite number of degrees of freedom. Characteristic frequencies and mode shapes. Generalized coordinates and normal modes. Free and forced vibrations of simple continuous systems; transverse oscillations of strings, longitudinal and torsional oscillations of rods, and bending vibrations of beams. Energy Methods. Undergraduate dynamics and ordinary differential equations recommended.</td>
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<tr>
<td>MECH 521</td>
<td>Intermediate Dynamics</td>
<td>4</td>
<td>Fall</td>
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<tr>
<td></td>
<td><strong>Prerequisite:</strong> Three-dimensional kinematics using generalized vector notation, rotating and translating coordinate frames, particle and rigid body dynamics, equations of motion via direct and indirect methods, equations of motion via Lagrangian approach, aerospace vehicle applications.</td>
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<tr>
<td>MECH 529</td>
<td>Dynamics and Control of Flight Vehicles</td>
<td>4</td>
<td>Winter</td>
<td></td>
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<tr>
<td>MECH 532</td>
<td>Introductory Space Flight Dynamics</td>
<td>4</td>
<td>Fall and Winter</td>
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<td><strong>Prerequisite:</strong> Formulation and solution of the two-body problem in three dimensions. Orbital elements, reference frames, coordinate transformations, and basic orbital maneuvers. Formulation and description of basic attitude dynamics and control concepts, including spin, dual-spin, three-axis, and gravity gradient stabilization.</td>
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<tr>
<td>MECH 541</td>
<td>Mechanics of Composite Materials</td>
<td>4</td>
<td>Winter</td>
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<td></td>
<td><strong>Prerequisite:</strong> MECH-500</td>
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<td>Introduction to the analysis of composite materials. The nature and scope of composite materials are discussed as well as mechanical behavior. Micromechanics, macromechanics, and characterization of composite materials are presented. Emphasis is placed on gaining a basic understanding of composite materials behavior from both the applied mechanics and materials science aspects.</td>
</tr>
<tr>
<td>MECH 542</td>
<td>Introduction to Finite Element Analysis and Computer-Aided Design</td>
<td>4</td>
<td>Winter</td>
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<tr>
<td></td>
<td><strong>Prerequisite:</strong> ASYS-525, MECH-500 or MECH-545</td>
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<td>Introduce finite element analysis and Computer-Aided Design tools for analyzing, pre-, and post-processing finite element models. Review historical development of finite element analysis and related computational tools. Demonstrate finite element process for Truss elements. Program simple finite element code for Trusses. Learn graphics software in AFIT computer environment to model one-, two-, and three-dimensional structures. Use pre-processor to create geometric models and associated finite element meshes. Use post-processor to generate deformed geometry, X-Y plots, and contour plots. Present modeling guidelines and adaptive meshing techniques.</td>
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<tr>
<td>MECH 542L</td>
<td>Introduction to Finite Element Analysis and Computer-Aided Design Lab</td>
<td>0</td>
<td>Winter</td>
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<td></td>
<td><strong>Prerequisite:</strong> Lab associated with MECH-542</td>
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<tr>
<td>MECH 545</td>
<td>Aerospace Structural Analysis</td>
<td>4</td>
<td>Fall and Summer</td>
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<td><strong>Prerequisite:</strong> External loads on the aircraft, forces and load factors on space structures, sparwise airflow distribution, shear and bending in symmetrical and unsymmetrical beams, analysis of typical semimonocoque structures, wing beam theory, deflections in aircraft structures, energy methods, introduction to structural stability and structure-aerodynamic interactions.</td>
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<tr>
<td>MECH 600</td>
<td>Elasticity</td>
<td>4</td>
<td>Winter</td>
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<td></td>
<td><strong>Prerequisite:</strong> MECH-500 or permission of instructor</td>
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<td>A review of linear, infinitesimal continuum theory. Introduction to nonlinear elasticity. Solutions in curvilinear coordinate problems. Introduction to plate theory. Buckling and instability.</td>
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<tbody>
<tr>
<td>MECH 601</td>
<td>Introduction to Time-Dependent Material Behavior</td>
<td>4</td>
<td>Summer</td>
<td>MECH-500</td>
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<tr>
<td></td>
<td>The course provides a fundamental background in inelastic solid</td>
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<td>mechanics. Phenomenological aspects of inelastic material behavior and inelastic constitutive models are discussed. Topics include Kelvin-Voigt, Maxwell and Standard Linear Solid models for materials with internal variables, creep, stress relaxation, linear and nonlinear viscoelasticity. In addition, rate-independent plasticity, viscoplasticity, yield criteria, yield surfaces, and isotropic and kinematic hardening rules are discussed.</td>
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<tr>
<td>MECH 605</td>
<td>Fracture Mechanics</td>
<td>4</td>
<td>Spring</td>
<td>MECH-500, MECH-545 or permission of instructor</td>
</tr>
<tr>
<td></td>
<td>The course is designed to acquaint students with analytical and experimental techniques used to solve current fracture problems. Specific course objectives are to develop the linear elastic fracture mechanics principles which allow one to predict the critical crack size for a given component (i.e., predict fatigue crack growth, stress corrosion cracking, etc.) The role fracture mechanics can play in assuring fracture prevention is discussed, with emphasis on current USAF requirements.</td>
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<tr>
<td>MECH 620</td>
<td>Systems Optimization</td>
<td>4</td>
<td>Winter</td>
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<td>This course covers theory and procedures for optimizing multi-variable, nonlinear objective functions that measure system performance. Topics include: formulation of classical and Karush-Kuhn-Tucker (KKT) optimality conditions, numerical algorithms for solving different classes of problems, linear programming, gradient algorithms, search techniques for nonlinear problems, multi-objective optimization theory, and special topics illustrated with problems in aerospace design.</td>
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<tr>
<td>MECH 622</td>
<td>Functional Optimization and Optimal Control</td>
<td>4</td>
<td>Winter and Spring</td>
<td>ASYS-565</td>
</tr>
<tr>
<td></td>
<td>Variational techniques are applied to optimize linear and nonlinear dynamic systems with respect to prescribed constraints are considered. Optimization of functionals using the calculus of variations and Pontryagin's Maximum Principle, leading to the derivation and solution of the optimal control problem. Special topics include: &quot;bang-bang&quot; control, dynamic programming, terminal controllers and regulators, perturbation techniques and singular solutions.</td>
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<tr>
<td>MECH 628</td>
<td>Aircraft Control</td>
<td>4</td>
<td>Spring</td>
<td>MECH-529 and ASYS-565</td>
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<tr>
<td></td>
<td>Introduction to aircraft flight control systems. Response to control inputs. Use of classical control theory to analyze and design longitudinal and lateral autopilots. Digital computer techniques and response to random inputs.</td>
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<tr>
<td>MECH 629</td>
<td>Aircraft Handling Qualities and Performance</td>
<td>4</td>
<td>Summer</td>
<td>MECH-529</td>
</tr>
<tr>
<td></td>
<td>This course presents an overview of aircraft performance and handling qualities. Topics covered in performance include climb, cruise, and turn performance. The flying qualities portion includes aircraft dynamics, classical aircraft handling qualities, parameters, pilot modeling, pilot ratings, and their prediction.</td>
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<tr>
<td>MECH 632</td>
<td>Intermediate Space Flight Dynamics</td>
<td>4</td>
<td>Spring</td>
<td>MECH-521 and MECH-532</td>
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<td>Rigorous development of equations of motion of a rigid body in a gravitational field. Decoupling the translational and rotational equations of motion. Ballistic missile and interplanetary trajectories. The three-body problem and perturbation methods. Analysis of important problems in attitude dynamics and control, including reorientation, despin, control moment gyros, and reaction wheel systems. Introduction to attitude determination methods.</td>
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<tr>
<td>MECH 633</td>
<td>Spacecraft Maneuver and Rendezvous</td>
<td>4</td>
<td>Summer</td>
<td>MECH-532, ASYS-565, and MATH-508 or MATH-504, or permission of the instructor</td>
</tr>
<tr>
<td></td>
<td>This course serves as an introduction to the dynamic modeling and control of multiple spacecraft operating in close proximity. The first half of the course will focus on modeling relative satellite motion, including common state transition matrices and relative state realizations. The second half of the course will focus on control strategies for formation maintenance as well as rendezvous and proximity operations (RPO). A number of advanced topics such as perturbation mitigation, coupled rotational/translational motion, uncertainty propagation, and relative navigation will also be presented.</td>
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<tr>
<td>MECH 637</td>
<td>Astrodynamical Re-Entry</td>
<td>4</td>
<td>Fall</td>
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<tr>
<td>MECH 642</td>
<td>Finite Element Methods for Structural Analysis I</td>
<td>4</td>
<td>Spring</td>
<td>MECH-542 or permission of instructor</td>
</tr>
<tr>
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<td>Energy Principles are used throughout. Consideration is given to the formulation of Truss, Plane Stress and Strain, Beam, Plate and Shell elements. Isoparametric elements are considered. Vibration formulation of structures is presented. The use of Matlab coding and Abaqus is made use of throughout the course.</td>
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</tbody>
</table>
Course Descriptions

**MECH 644** Finite Element Methods for Structural Analysis II
Terms Offered: As Needed
Prerequisite: MECH-642
Advanced topics in finite element techniques. Formulation and solution of the system equations. Application to free forced response, stability, and nonlinear analysis.

**MECH 646** Structural Optimization
Terms Offered: Spring
Prerequisite: MECH-500
The objectives of this course are to emphasize multidisciplinary aspects of aerospace structural optimization. Problem formulation, interaction of different disciplines, surrogate models, sensitivity analysis, and design variable linking concepts with practical applications are the focus. Numerical optimization methods for shape, topology, and size optimization are presented.

**MECH 662** Introduction to Aeroelasticity
Terms Offered: Spring
Prerequisite: AERO-533 and MECH-515

**MECH 699** Master's Level Special Study
Terms Offered: All
Prerequisite: Directed study at an intermediate graduate level on a special topic which is not normally covered in a regularly scheduled course or as part of thesis research. Topic, format, and course requirements are determined by the faculty member directing the study. Requires submission of Special Studies Form and syllabus to the department for registration.

**MECH 712** Nonlinear Oscillations
Terms Offered: Spring
Prerequisite: MECH-720 or permission of instructor

**MECH 719** Vibration Damping and Control
Terms Offered: Fall
Prerequisite: MECH-515 and ASYS-565 or Permission of Instructor
A survey course in vibration damping and control providing the necessary background to analyze structural vibrations and design effective and efficient vibration suppression using either passive or active means. Topics covered include modal analysis, viscoelastic damping treatments, vibration absorbers, vibration isolators, and active feedback control using both traditional and adaptive structures technology. Method of instruction will include both lecture and laboratory sessions.

**MECH 719L** Vibration Damping and Control Lab
Terms Offered: Fall
Prerequisite: Lab associated with MECH-719

**MECH 720** Analytical Mechanics
Terms Offered: Fall
Prerequisite: MECH-521
Elements of the calculus of variations, virtual work, D'Alembert's principle, Lagrange's and Hamilton's equations of motion, applications to holonomic and nonholonomic systems, with emphasis on rigid body motion and gyroscopic instruments.

**MECH 731** Modern Methods of Orbit Determination
Terms Offered: Summer
Prerequisite: MECH-532
Introduction to probability theory. Statistical mission assessment. Derivation of the method of least squares in linear and nonlinear problems. Sequential estimation methods, including numerical instabilities and time weighting. Applications to the problem of determining and updating the orbital elements of satellites.

**MECH 732** Advanced Astrodynamics
Terms Offered: Winter
Prerequisite: MECH-521
Introduction to canonical dynamics and applications to the two body problem. Classical and canonical variation of parameter equations of motion. Forces influencing earth satellite motion are surveyed. Applications to earth satellite motion. Additional topics from resonance, stability, and periodic motion.

**MECH 733** Numerical Methods for Orbit Design
Terms Offered: Summer
Prerequisite: MECH-732 or Permission of Instructor; MECH-622 desired
Advanced topics in satellite trajectory analysis and design. Emphasis on tools enabling successful mission design in complex dynamical environments. Analysis of restricted and circular-restricted three-body problem, specifically the Earth-Moon-Satellite system. Development of satellite equations of motion using special perturbations and variational techniques. Introduction to satellite trajectory planning, with emphasis on computational guidance and control. Focus is on numerical trajectory planning and optimization algorithms that can be used on board for autonomous guidance.
## Course Descriptions

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>Terms Offered</th>
<th>Prerequisite</th>
</tr>
</thead>
<tbody>
<tr>
<td>MENG 501</td>
<td>Aerospace Propulsion</td>
<td>4</td>
<td>Fall</td>
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<tr>
<td>MENG 530</td>
<td>Chemical Rocket Propulsion</td>
<td>4</td>
<td>Winter</td>
<td>MENG-732 or Permission of Instructor</td>
</tr>
<tr>
<td>MENG 531</td>
<td>Space Propulsion and Power Systems</td>
<td>4</td>
<td>Summer</td>
<td></td>
</tr>
<tr>
<td>MENG 571</td>
<td>Fundamentals of Heat Transfer</td>
<td>4</td>
<td>Winter Spring and Summer</td>
<td></td>
</tr>
<tr>
<td>MENG 585</td>
<td>Air Breathing Engine Design</td>
<td>4</td>
<td>Summer</td>
<td>MENG-501 or Permission of Instructor</td>
</tr>
</tbody>
</table>

**MENG 501 Aerospace Propulsion**
- **Prerequisite:**
- Directed study for doctoral students on a special topic which is not normally covered in a regularly scheduled course or as part of dissertation research. Topic, format, and requirements of the course are determined by the faculty member directing the study. Requires submission of Special Studies Form and syllabus to the department for registration.

**MENG 530 Chemical Rocket Propulsion**
- **Prerequisite:**
- Development of performance parameters, analyses of combustion, fluid mechanics, and heat transfer as they pertain to rocket engines and motors, comparison of propellants, and analysis of simple rocket flight and staging.

**MENG 531 Space Propulsion and Power Systems**
- **Prerequisite:**
- Concept, theory and performance of chemical and nonchemical propulsion systems for use in space. Typical systems will include electrical, nuclear, liquid propellant, and exotic space propulsion systems. Concept, theory and performance of power generation methods for use in space. Systems studied will include low and high power systems intended for short term or long term applications. Chemical, solar, and nuclear devices and the energy conversion means for converting energy from these sources into useful electrical power will be studied. An overview of space mission requirements and how they impact propulsion and power system selection. Review of current and future trends in spacecraft propulsion and power generation.

**MENG 571 Fundamentals of Heat Transfer**
- **Prerequisite:**
- Course will cover the fundamentals of conduction, convection, and radiation heat transfer. The derivation and solution of the general heat conduction equation for one- and two- dimensional, steady and unsteady conduction problems will be covered. Solution techniques will be studied for forced convection in laminar and turbulent flows on internal and external surfaces. Lastly, an introduction to general radiation with solutions to relevant situations is included.

**MENG 585 Air Breathing Engine Design**
- **Prerequisite:**
- The laws of mechanics and thermodynamics are applied to determine the design point requirements for and the design of an aircraft gas turbine engine. Emphasis is placed on determining the engine type heat suited to the requirements of a specified aircraft mission. Computer analysis is used extensively in mission analysis, on-design engine performance analysis, and in component design.

**MENG 633 Fundamentals of Combustion**
- **Prerequisite:**
- This course is designed to provide an understanding of the fundamentals of combustion and combustion aerodynamics. An overview of the variety of topics in combustion will be covered including: Chemical thermodynamics; Chemical kinetics; Gas dynamics of reacting flows; Deflagration and detonation of premixed gases; Laminar flames, and Turbulent flames. Details of flame temperatures, structures, flame speeds, and flame lengths will be analyzed. Real combustion systems such as the Well Stirred Reactor, the Ultra Compact Combustor, and the Pulsed Detonation Engine will be discussed.

**MENG 673 Radiation Heat Transfer**
- **Prerequisite:**
- Study of methods for calculating heat transfer by thermal radiation. Integral equations are formulated for thermal radiation among surfaces with and without an intervening gas. Approximate engineering methods of solution are discussed and applied to components of satellite, propulsion, and solar energy systems. In addition, the radiative properties of gases and particulate media will be discussed.

**MENG 674 Convection Heat Transfer**
- **Prerequisite:**
- This course provides a treatment of convection heat transfer. Laminar and turbulent flows, internal and external flows, forced and free convection and steady and unsteady heat transfer are considered. High speed effects and experimental methods are examined with particular emphasis on thermal management. Various boundary conditions are examined along with two phase flows.
Course Descriptions

**MENG 699**  Master's Level Special Study  1-12

**Terms Offered**  All

**Prerequisite:**
Directed study at an intermediate graduate level on a special topic which is not normally covered in a regularly scheduled course or as part of thesis research. Topic, format, and course requirements are determined by the faculty member directing the study. Requires submission of Special Studies Form and syllabus to the department for registration.

**MENG 732**  Advanced Turbomachinery  4

**Terms Offered**  Spring

**Prerequisite:**  MENG-501

The principles of fluid mechanics, thermodynamics, heat transfer, and combustion are applied to gas turbine engines. Cycles and component performance are covered with emphasis on application in high performance aircraft propulsion systems.

**MENG 733**  Air Breathing Engine Design  4

**Terms Offered**  Summer

**Prerequisite:**  MENG-501 and MENG-732 or permission of instructor

The laws of mechanics and thermodynamics are applied to determine the design point requirements for and the design of an aircraft gas turbine engine. Emphasis is placed on determining the engine type heat suited to the requirements of a specified aircraft mission. Computer analysis is used extensively in mission analysis, on-design engine performance analysis, and in component design.

**MENG 899**  Doctoral Level Special Study  1-12

**Terms Offered**  All

**Prerequisite:**
Directed study for doctoral students on a special topic which is not normally covered in a regularly scheduled course or as part of dissertation research. Topic, format, and requirements of the course are determined by the faculty member directing the study. Requires submission of Special Studies Form and syllabus to the department for registration.

**TENY 799**  Thesis Completion  12

**Terms Offered**  All

**Prerequisite:**
Thesis Completion course for graduating students to be taken during the last quarter of study. Registration in TENY 799 for 12 non-billable credit hours is required for all master's students whose research advisors are in the Department of Aeronautics and Astronautics. The grade assigned to this course is the official thesis grade.

**Electrical and Computer Engineering (ENG)**

**CSCE 486**  Fundamentals of Data Structures and Program Design  4

**Terms Offered**  Summer

**Prerequisite:**
This course introduces the principles and methodologies used to design and implement small programs. The key principle of using hierarchical approaches to problem solving and program design is stressed as well as the importance of disciplined programming styles and program analysis techniques. Two critical parts of program design and implementation are the selection of the data structures used in the design and the programming language used to implement the program design. This course covers several of the basic data structures and demonstrates how data structure selection impacts program efficiency and maintainability. Additionally, the key features of structured and object-oriented programming languages such as data types, decision structures, and modularity will be covered. Several programming projects using a high-level programming language will be assigned to demonstrate the principles, methodologies, and data structures covered in this class.

**CSCE 486L**  Fundamentals of Data Structures and Program Design  0

**Terms Offered**  Summer

**Prerequisite:**
Lab associated with CSCE-486.

**CSCE 489**  Operating Systems  4

**Terms Offered**  Summer

**Prerequisite:**
This course is an introduction to the concepts and principles of computer operating systems with emphasis on memory management, processor management, I/O management, and system file structures. The objective is to give the student an understanding of operating systems and the necessary skills to evaluate and trade-off desirable features of operating systems, given specific user and resource requirements. The student will learn to develop and apply models in order to evaluate the performance of specific algorithms and the effect of algorithms on overall computer system performance. Case studies of current operating systems will be utilized to illustrate the application of the concepts and principles studied.

**CSCE 492**  Computer Systems Architecture  4

**Terms Offered**  Summer

**Prerequisite:**
The objective of this course is for students to understand the basic principles of Von Neumann computer architecture. Emphasis is placed on how a processor and its control unit, memory, and input/output devices are organized, and how they interact to form a computer system. Specific topics covered in the course include instruction set design, computer arithmetic, pipeline design, memory hierarchy, natural memory, and input/output.
Course Descriptions

CSCE 523 Artificial Intelligence 4
Terms Offered Winter
Prerequisite: CSCE-531 and CSCE-586
This course presents the major principles and techniques of artificial intelligence. Specifically, in-depth studies of core issues, such as knowledge representation and problem identification, formulation, and solving are pursued. Topics include knowledge representation (models of logic, predicate calculus, production-rules, semantic networks, symbolic and sub-symbolic representations), problem solving (search theorem-proving, reasoning), and knowledge-based systems (expert systems, natural language processing, vision, planning).

CSCE 525 Introduction to Cyber Warfare and Security 4
Terms Offered Fall and Summer
Prerequisite: This course studies the nature of Cyber Warfare and its ramifications for information system security and survivability, and information assurance. It provides a foundational understanding of operational considerations, tactical capabilities, limitations, strategic ramifications, policy, and legal guidelines associated with offensive and defensive cyberspace operations. Simultaneously, it engenders a systems-oriented viewpoint, while examining national information infrastructures, their vulnerabilities, interdependencies, threats, and opportunities for exploitation.

CSCE 526 Secure Software Design and Development 4
Terms Offered Fall
Prerequisite: This course provides instruction for secure development of software. We place emphasis on managerial and technical aspects of software development. This includes coverage of federal software development policies, software design and implementation decisions, and numerous errors software developers make when writing source code. A comprehensive project highlights the course, providing valuable insight into how malicious hackers use poorly written software to gain control of a computer, and potentially, an entire network.

CSCE 527 Cyber Forensics 4
Terms Offered Summer
Prerequisite: This seminar course discusses Cyber Forensics and its effects on both Information Warfare and traditional forensic sciences. Students will gain insight into the computer's role in crime and the digital evidence that is available in a computer-related investigation. Topics include the legal ramifications of evidence gathering, chain-of-custody, and methods for evidence preservation, identification, extraction, documentation, interpretation, and the tools available.

CSCE 528 Cyber Defense and Exploitation I 4
Terms Offered Winter
Prerequisite: This course discusses the hardware/software tools and techniques associated with the protection of computer systems and networks. Students will learn how to defend network resources against adversarial exploitation using various commercial and DoD tools. Course topics include techniques to hunt, identify and eradicate malicious actors. A cyber defense focused exercise will be conducted as a capstone for the course.

CSCE 528L Cyber Defense and Exploitation I Lab 0
Terms Offered Winter
Prerequisite: Lab associated with CSCE 528

CSCE 531 Discrete Mathematics 4
Terms Offered Fall
Prerequisite: This course provides more in-depth coverage, analysis, and application of set theory, binary relations, functions, and first-order predicate calculus from an undergraduate discrete math class. Specifically, more emphasis is placed on applying predicate calculus and practice doing proofs, both deductive and inductive, formal proofs, and informal proofs. New top areas include: set countability and resolution-based theorem proving. This course also provides detailed and varied examples of how discrete mathematics is applied in other graduate courses in computer science and engineering.

CSCE 532 Automata and Formal Language Theory 4
Terms Offered Winter
Prerequisite: CSCE-531
The objective of this course is to prepare the student with a basic foundation in the concepts of automata and formal language theory. Topics covered will include Turing machines, finite state automata, combinatorics, and formal language theory.

CSCE 544 Data Security 4
Terms Offered Spring
Prerequisite: This course presents the rudiments of data security. The emphasis is on cryptography, beginning with simple ciphers, and extending to public key cryptography based on sophisticated number-theoretic considerations. Other topics include key management, access controls and inference controls.
Course Descriptions

CSCE 554  Fundamentals of Performance Analysis and Experimental Design  4  
Terms Offered  Summer  
Prerequisite:  STAT-583 or STAT-586  
The purpose of this course is to present practical techniques for the measurement, simulation, and analysis of systems including computer systems, software, and communication networks. A systematic approach to performance evaluation is developed. This course will show how to use measured data to compare systems using elementary statistics including confidence intervals. Experimental designs such as single and multiple-factor experiments, full-factorial, and fractional factorial designs are presented. Development of regression models from measured data and effective presentation of data and results to decision makers is discussed. Other topics include: selection and characterization of workloads and practical simulation techniques. Time permitting: queuing theory and random-variate generation are covered.  

CSCE 560  Introduction to Computer Networking  4  
Terms Offered  Fall  
Prerequisite:  
This course provides an introduction to the fundamental concepts in the design and implementation of computer communication networks, their protocols, and applications. Students will understand and evaluate network protocols. The course discusses the basic performance and engineering trade-offs in the design and implementation of computer networks. Topics include: overview of network architectures, network topology design applications network/programming interfaces (e.g., sockets), transport protocols, flow control, routing, network protocols, data link protocols, addressing, and local area networks. Examples are drawn primarily from the internet (e.g., TCP, UDP, and IP) protocol suite. Sockets programming and network simulations are used to emphasis topics.  

CSCE 586  Design and Analysis of Algorithms  4  
Terms Offered  Fall  
Prerequisite:  
This course emphasizes the structure of data and the efficient and effective manipulation of such structures. Physical and logical organization of data is discussed along with data and algorithm abstraction using object-oriented design and abstract data types. Detailed procedures are developed for analyzing the time and space complexities of general algorithms as well as an introduction to NP completeness. Specific data structures discussed include generalized lists, trees, graphs, B-trees, and AVL-trees along with indexing, hashing, sorting, searching and recursive algorithms on specific structures. Well founded algorithm uses like divide-and-conquer, local searching, and global searching are also introduced. Course projects emphasize the analysis, reuse, and extension of existing designs and implementations.  

CSCE 587  Microprocessor Design and Synthesis  4  
Terms Offered  Spring  
Prerequisite:  CSCE-492 and/or permission of the instructor.  
This course provides a theoretical and practical experience in state-of-the-art microprocessor designs and design methodologies. This course teaches how to design, synthesize, and simulate microprocessors using VHDL, the very high speed integrated circuit Hardware Description Language. Students will make use of CAD tools and field programmable Gate Array hardware systems to design, program, simulate, synthesize, and implement various microprocessors and related components.  

CSCE 593  Introduction To Software Engineering  4  
Terms Offered  Fall  
Prerequisite:  
This course is concerned with the development of large-scale software systems. Techniques in software requirements elicitation, design, implementation, quality assurance, and project management are presented, along with discussion of the software development process. Emphasis is on object-oriented modeling using a subset of the Unified Modeling Language (UML). Techniques to facilitate the engineering of secure software systems are introduced. Hands-on experience is provided through individual homework problems and a group project.  

CSCE 593L  Introduction To Software Engineering Lab  0  
Terms Offered  Fall  
Prerequisite:  Lab associated with CSCE 593  

CSCE 623  Statistical Machine Learning  4  
Terms Offered  Spring  
Prerequisite:  CSCE-523  
This course introduces statistical machine learning and pattern recognition. Topics include supervised and unsupervised learning for classification, regression and clustering. Techniques include feature selection, feature transformation, linear and nonlinear modeling, as well as model performance assessment and interpretation. The course emphasizes making decisions in the trade space of learning theory, machine learning algorithm design and application.  

CSCE 625  Formal Analysis of Security Systems  4  
Terms Offered  As Needed  
Prerequisite:  
This course examines the security of computer systems and networks using the tools provided by propositional and predicate logic to discover underlying principles of security. Computer and network security is in a rapid state of change; principles of security, however, remain constant. This course takes the approach that the "key to understanding the problems in computer security is recognition that the problems are not new." The course synthesizes elements from computer networking, operating systems security, and data security within an analytic framework. Topics addressed include: access control matrices, protection models, confidentiality, integrity, representing identity, flow and confinement, and malicious logic and intrusion detection. Students taking this course will understand the threats to information resources and will learn about countermeasures and their fundamental limitations.
## Course Descriptions

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<tr>
<th>Course Code</th>
<th>Course Name</th>
<th>Credits</th>
<th>Terms Offered</th>
<th>Prerequisite:</th>
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</thead>
<tbody>
<tr>
<td>CSCE 629</td>
<td>Cyber Attack</td>
<td>4</td>
<td>Winter</td>
<td>CSCE-560 or Permission of Instructor</td>
</tr>
<tr>
<td></td>
<td>Course provides an introduction to cyber attack. Students learn to apply exploitation and attack methods to design and execute a viable attack strategy against computer systems/networks and humans using tools and techniques via hands-on labs and projects. Topics include identifying targets, reconnaissance, enumeration and scanning, gaining unauthorized access, denial of service attacks, maintaining access, and hiding attack evidence.</td>
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<tr>
<td>CSCE 629L</td>
<td>Cyber Attack Lab</td>
<td>0</td>
<td>Winter</td>
<td>Lab associated with CSCE 629</td>
</tr>
<tr>
<td>CSCE 631</td>
<td>Machines, Languages and Logic</td>
<td>4</td>
<td>Winter</td>
<td>CSCE-531, CSCE-532, and CSCE-586</td>
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<td></td>
<td>This course continues the theoretical development of computational machines, computational functions, and formal languages and their interrelationships. Topics include finite automata, regular expressions, pushdown automata, Turing machines, Post Machines, recursively enumerable sets, recursive sets, recursive functions, decidability and Gödel numbering. Associated algorithms on these computational models can be proven correct by developing a proof system using predicate calculus. Topics include first and second order predicate calculus, resolution, and unification. Using these foundations, designs are discussed from a computation viewpoint with emphasis on general computer software and hardware architectures.</td>
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<tr>
<td>CSCE 644</td>
<td>Cryptanalysis</td>
<td>4</td>
<td>Summer</td>
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<td>Covers the art and science of breaking codes and ciphers using both theoretical and real-world techniques for defeating cryptosystems. Theoretical and implementation-based attacks on classical and modern cryptographic systems and methods include attacks on stream and block ciphers, cryptographically strong hash functions, and public key systems. Topics include linear/differential cryptanalysis, factoring algorithms, side-channel attacks, time/memory tradeoffs, and attacks on randomness.</td>
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<tr>
<td>CSCE 654</td>
<td>Computer Communication Networks</td>
<td>4</td>
<td>Spring</td>
<td>CSCE-560 and STAT-583, STAT-586 or STAT-601</td>
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<tr>
<td></td>
<td>This is the intermediate course in networks and protocols. It examines the performance evaluation, design and management of networks using analytical, simulation and experimental methods to evaluate design and manage networks and protocols. Topics include queuing theory, simulations methods, wireless networks, mobility issues, network security, performance of multiple access, TCP/IP, and Asynchronous Transfer Mode (ATM) technologies, protocols, design of backbone and access networks, and network management methods and protocols.</td>
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<tr>
<td>CSCE 656</td>
<td>Parallel and Distributed Processing Algorithms</td>
<td>4</td>
<td>Spring</td>
<td>CSCE-586</td>
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<td>This course develops an understanding of classical results for parallel and distributed design and analysis of algorithms. It provides practical insights into efficient and effective implementation on contemporary parallel computational machines. Topics discussed include process communications, process synchronization, task scheduling, algorithm decomposition, real-time considerations and programming environments. Application areas emphasized include process communications, process synchronization, task scheduling, algorithm decomposition, real-time considerations and programming environments. A variety of programming assignments on parallel and distributed computers are required using a selected concurrent language.</td>
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<td>CSCE 660</td>
<td>Mobile, Wireless, and SCADA Device Security</td>
<td>4</td>
<td>Spring</td>
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<td>This course provides instruction on the vulnerabilities of mobile networks and associated devices. Students learn about the communication network operation, to include message/call routing and supporting hardware elements, as well as the mobile network's evolution and development. Vulnerabilities of various devices (smart phones, tablets, SCADA, etc) are discussed, providing opportunities for exploitation and implementation of security measures through lab exercises.</td>
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<tr>
<td>CSCE 660L</td>
<td>Mobile, Wireless, and SCADA Device Security Lab</td>
<td>0</td>
<td>Spring</td>
<td>Lab associated with CSCE 660.</td>
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<tr>
<td>CSCE 684</td>
<td>Information Visualization</td>
<td>4</td>
<td>Spring</td>
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<td>The purpose of this course is to teach the student how to use computer graphics techniques, i.e., color, space, animation, highlighting, layout, etc., to convey the meaning of their data. Supporting the topics on graphics design are lectures on computer graphics fundamentals, user interface design, and graphic support languages and hardware. Classroom lectures are reinforced by selected laboratory projects in user interface or information display design.</td>
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</table>
Course Descriptions

CSCE 686 Advanced Algorithm Design 4
Terms Offered Spring
Prerequisite: CSCE-586
This course provides a theoretical and practical foundation for understanding and analyzing the design, complexity and correctness of algorithms (control Structure) along with data structure and implementation considerations. The emphasis on computational models relating to NP complete problems is extended. Use of search algorithms (tree/graph, linear programming, dynamic programming, probabilistic, etc.) to solve NP complete problems is related to the selection of various problem solving strategies including the incorporation of heuristics. Formal properties of the various approaches are studied using graph theory and computational models. Additional focus on logic programming, knowledge representation and automated reasoning in concert with the above topics provide a foundation to computational theory. In particular, applications in artificial intelligence, knowledge-based systems, software engineering, database management, signal processing, VLSI, and computer architecture are related through algorithm modeling and current literature.

CSCE 687 Advanced Microprocessor Design Laboratory 4
Terms Offered Summer
Prerequisite: CSCE-687L
This is a project-oriented course which emphasizes the application of microprocessor systems to practical problems. Students working in small groups will be expected to design and implement a microprocessor based project. This includes hardware and software design, implementation and testing. A final report is required.

CSCE 687L Advanced Microprocessor Design Lab 0
Terms Offered Fall
Prerequisite: CSCE-687L
Lab associated with CSCE 687

CSCE 689 Distributed Software Systems 4
Terms Offered Winter
Prerequisite: CSCE-686
The objective of the course is to extend the fundamentals of computer operating systems (OS) into distributed systems and to map those concepts to the implementation of actual systems. Topics extending OS include distributed operating systems, multiprocessor operating systems, distributed file systems, distributed scheduling (including deadlock issues), fault tolerance, distributed transaction processing, and client server systems. Topics focused on large scale distributed systems include cloud computing/security and virtualization.

CSCE 692 Design Principles of Computer Architecture 4
Terms Offered Winter
Prerequisite: CSCE-686
The objective of this course is for the student to understand and be able to apply the fundamental principles of computer architecture design. An emphasis is placed upon the use of quantitative metrics to evaluate cost/performance tradeoffs and upon the use of actual performance data to evaluate design alternatives. Specific topics include construction set architecture design, pipelining, super scalar/VLIW processors, out-of-order execution, compiler optimization, memory system design, and input/output systems.

CSCE 693 Software Evolution 4
Terms Offered Winter
Prerequisite: CSCE-593
This course explores the management, modification, and quality assurance of large-scale secure software systems as they evolve over time. Relevant techniques and processes from CSCE-593 and CSCE-694 are discussed as they apply to the evolution software. Emphasis is on case-studies of software evolution within commerical and governmental organizations. Additional concepts such as program understanding, reverse-engineering, configuration management, and the role and use of software engineering tools are also introduced and applied. Course concepts are reinforced through individual homework exercises and a group software evolution project.

CSCE 698 Research Seminar 0
Terms Offered Winter and Spring
Prerequisite: CSCE-687
This course provides a forum for the students to gain an understanding of the graduate education process, department requirements and advice for preparing and writing the thesis, research milestones and deadlines, the scientific method, experiment design and analysis, and current DOD research interests in computer engineering, computer science, and computer systems.

CSCE 699 Master's Level Special Study 1-12
Terms Offered All
Prerequisite: CSCE-686
Directed study at an intermediate graduate level on a special topic which is not normally covered in a regularly scheduled course or as part of thesis research. Topic, format, and course requirements are determined by the faculty member directing the study. Requires submission of Special Studies Form and syllabus to the department for registration.

CSCE 723 Advanced Topics in Artificial Intelligence 4
Terms Offered Summer
Prerequisite: CSCE-623
This course treats topics selected to prepare students for research in artificial intelligence and for the application of artificial intelligence in the solution of commercial and military problems. Typical topics are knowledge-engineering, learning, constraint-satisfaction, neural networks, knowledge acquisition, model and case-based reasoning, nonmonotonic reasoning, blackboard systems, and theorem proving.
Course Descriptions

CSCE 725  Reverse Engineering  4
Terms Offered: Spring
Prerequisite: 
This course introduces the fundamentals of reverse engineering software binaries. The emphasis is on extracting information from compiled code and making targeted modifications. Other topics include reverse engineering wireless devices, network protocols, and cyber-physical systems.

CSCE 725L  Reverse Engineering Lab  0
Terms Offered: Spring
Prerequisite: 
Lab associated with CSCE 725

CSCE 754  Advanced Topics in Computer Networks  4
Terms Offered: Summer
Prerequisite: CSCE-560
This is the advanced course in networks and protocols. The objective of this course is to extend the fundamentals of computer communication systems into more advanced topics actively being researched. The course surveys current design and implementation techniques for development of high performance computer networks as well as to prepare students for doing research projects in this area. Topics are drawn from current papers in the field. Emphasis is given to the mathematical modeling and analysis of the advanced features to determine required system properties. These types of analyses are reinforced through simulation projects.

CSCE 790  Advanced Parallel and Distributed Computation  4
Terms Offered: As Needed
Prerequisite: CSCE-656
The purpose of this course is to study the current literature and to investigate topics of current interest in parallel and distributed computation with emphasis on high performance scalable computing. Extended insight into the details of software data and control decomposition for contemporary scalable architectures. Possible parallel and distributed computation topics are: discrete-event simulations, solutions to linear and non-linear ODE and PDE equations (vector/matrix algebraic operations), graph algorithms, logic programming, knowledge-based systems, probabilistic search, and cache memory performance. Depending upon student and instructor interest, applications are discussed from the following areas: imaging processing, signal processing, simulation, Computational Fluid Dynamics (CFD), Computational Electromagnetics (CEM), computational modern physics, artificial intelligence, and functional optimization. Contemporary scalable computational environments are evaluated as general parallel and distributed performance models.

CSCE 793  Advanced Topics in Software Engineering  4
Terms Offered: Spring
Prerequisite: CSCE-693
This course covers advanced current topics in the area of software engineering. Specific topics are oriented toward Air Force interest, local research needs, student interest and trends in software engineering research and practice.

CSCE 799  Thesis Research  1-12
Terms Offered: All
Prerequisite: 
The thesis topic is normally selected during CSCE 698, Research Seminar, from a wide variety of subjects of current interest to various Air Force and DoD organizations. The thesis is performed under the supervision of a faculty member who serves as the student's thesis advisor and chairman of his thesis committee. The results of the research are presented in a formal written thesis. An oral presentation and defense of the research is also required. A master's degree candidate must enroll in CSCE 799 for a total of 12 credit hours while working on his master's thesis. Ordinarily this course extends over the last three quarters of a student's program, with the student enrolling for 4 credit hours each quarter. The letter grade for the entire 12 hours of thesis is awarded in the final thesis quarter. A grade of in-progress (IP) or unsatisfactory (U) is awarded for the other quarters.

CSCE 823  Advanced Topics in Statistical Machine Learning  4
Terms Offered: Summer
Prerequisite: CSCE-623
This course covers topics selected to prepare students for research in statistical machine learning and for the application of statistical machine learning in the solution of commercial and military problems. Emphasis is on state-of-the-art learning paradigms and their relation to information theoretical methods. Material is emphasized through application of these techniques to pattern recognition, clustering, classification, regression and autonomous systems.

CSCE 886  Evolutionary Algorithms  4
Terms Offered: Summer
Prerequisite: CSCE-686
This course provides a theoretical and practical foundation for continuing the understanding and analysis associated with the design, complexity and correctness of evolutionary algorithms. Evolutionary algorithms using genetic algorithms, evolutionary strategies and classifiers are discussed as probabilistic search algorithms. Evolutionary data representation and fitness function selection along with associated operators and population dynamics are thoroughly developed. Formal properties of various evolutionary approaches are addressed using graph theory, predicate calculus and computational models. Evolutionary algorithm implementations are associated with proper data and control structure selection, implementation and visualization considerations for serial, parallel and distributed computation. Application problems in artificial intelligence, knowledge-based systems, software engineering, database management, signal processing, VLSI, simulation, scheduling, planning and computer architecture design are related through similarity of domain structures.

CSCE 899  Doctoral Level Special Study  1-12
Terms Offered: All
Prerequisite: Directed study for doctoral students on a special topic which is not normally covered in a regularly scheduled course or as part of dissertation research. Topic, format, and requirements of the course are determined by the faculty member directing the study. Requires submission of Special Studies Form and syllabus to the department for registration.

1-12 hours each quarter. The letter grade for the entire 12 hours of thesis is awarded in the final thesis quarter. A grade of in-progress (IP) or unsatisfactory (U) is awarded for the other quarters.
Course Descriptions

CSCE 999 Dissertation Research 1-12
Terms Offered All
Prerequisite:
This course supports doctoral research under the direction of a faculty research advisor from the Department of Electrical and Computer Engineering.

EENG 510 Linear Systems 4
Terms Offered Fall
Prerequisite:
The objective of this course is to develop tools for the analysis and simulation of linear dynamic systems. Emphasis is placed on state space analysis for estimation and control theory applications. Topics covered include: linearization of a nonlinear system, derivation of linear time-invariant and time varying state equations, and the continuous time solution; relations between the state equations and the system transfer function; eigenvalue/eigenvector and singular value analysis of the state equations; transformations to canonical forms; and controllability and observability properties.

EENG 527 Introduction to Fourier Optics 4
Terms Offered Fall
Prerequisite:
This course presents a systems approach to the analysis and design of both coherent and incoherent optical systems, with emphasis on application. Topics covered include: methods of analysis of two dimensional linear systems, scalar diffraction theory, Fourier transform properties of lenses, frequency analysis of imaging systems, spatial filtering concepts with selected applications, and holography. Important applications of Fourier Optics to Air Force systems are stressed throughout the course.

EENG 530 Fundamentals of Radio Frequency (RF) Analysis 4
Terms Offered Fall
Prerequisite:
This course will provide students with an understanding of modulated analog and digital signal analysis techniques and basic RF "front end" transmitter/receiver design. Topics include: modeling of modulated carrier signals with analysis of amplitude, frequency, and phase modulation and demodulation techniques. For a given communications, navigation, or radar system and signal description students will derive and explain analytical expressions of amplitude and angle modulated signals in the time and frequency domain. Students will demonstrate the proper application of LTI system principles, Fourier analysis, and a system's transfer function. Students will develop a fundamental knowledge of common real-world analog and digital signal analysis of digitally sampled analog amplitude and angle modulated signals in Matlab.

EENG 533 Navigation Using the Global Positioning System 4
Terms Offered Winter
Prerequisite:
This course provides a theoretical and practical foundation for understanding the Global Positioning System (GPS). Emphasis is on determining navigational information such as user position and velocity. Topics include satellite orbits, control, space, and user segments, signal structure, measurements, least-squares solution position and clock errors, error sources, dilution of precision availability, differential GPS, modernization, and Global Navigation Satellite Systems.

EENG 534 Fundamentals of Aerospace Instruments And Navigation System 4
Terms Offered Fall
Prerequisite:
Basic reference frames are defined and coordinate transforms are derived. The applicable laws of mechanics are used along with basic control system theory to analyze the kinematic and dynamic behavior of inertial sensors used in attitude and tracking systems. Vector and matrix notation are used throughout. Topics covered are the earth model, two-degree-of-freedom and single-degree-of-freedom tuned and floated mechanical gyroscopes, laser gyroscopes, linear accelerometers, inertial platforms, and unconventional inertial devices. Non-inertial navigation topics include radar, radio aids to navigation, optical trackers, and satellite navigation. The emphasis is on developing practical mathematical models useful to the guidance and control engineer. Examples are taken from current and planned Air Force systems.

EENG 535 Radar Systems Analysis 4
Terms Offered Winter
Prerequisite: EENG-530 or EENG-580
This course covers all aspects of radar from a systems point of view beginning with the definition and concluding with signal processing. Functional models of radar transmitters, antennae, receivers, and microwave propagation environments will be derived. The Radar Range Equation will be introduced to assess system performance in the presence of noise, clutter, and interference. Techniques of measurement and tracking of range, velocity, azimuth and bearing of a moving target are discussed. Matched filtering and ambiguity functions are introduced.

EENG 550 Introduction to Autonomy 2
Terms Offered Fall
Prerequisite:
This course gives a broad overview of autonomy and autonomy-related technology. It is intended to expose students to all aspects of autonomy and provide a common framework for understanding the challenges of developing, testing, and deploying autonomous systems within the Air Force and DoD enterprise. Topics include autonomy definitions and frameworks, cyber and autonomy, test and evaluation of autonomous systems, autonomy ethical considerations, artificial intelligence, unmanned aerial systems, and human/machine teaming.
Course Descriptions

EENG 562 Feedback Systems 4
Terms Offered Fall
Prerequisite:
This course covers the fundamental characteristics and design of linear feedback control systems. Root locus and frequency response methods of design are developed. A variety of electrical, mechanical, thermal and hydraulic systems are considered and are represented by block, signal flow, and simulation diagrams. System stability, performance and use of cascade compensation to improve performance are included. The state equation modeling of systems includes the use of physical variables and the transformation to phase variable and diagonal or normal form. Simulation and signal flow diagrams are used to represent the state equation formula. Use of CAD design programs are emphasized.

EENG 571 Satellite Communications 4
Terms Offered Winter
Prerequisite:
The objective of this course is to provide a comprehensive introduction to modern communications principles with particular emphasis on applications to satellite and space signals, multiplexing, demodulation, multiple access, coding, orbits, look angles, satellite hardware and link analysis.

EENG 576 Microwave Circuits 4
Terms Offered Fall
Prerequisite:
This course presents material on the application of electromagnetic theory to microwave propagation in wave guiding structures. Topics include Waveguides, Microwave Network Analysis, Impedance Matching and Tuning, Microwave Resonators, Power Dividers, Directional Couplers, and Hybrids.

EENG 580 Introduction to Signal Processing 4
Terms Offered Fall
Prerequisite:
This course presents an introduction to signal processing. Topics include I/O descriptions of discrete-time systems, Discrete Fourier Transforms, Fast Fourier Transforms, Z-transforms, sampling theory, and Finite Impulse Response filter design. This course will be taught at the level of Oppenheim and Schafer's Discrete-Time Signal Processing.

EENG 596 Integrated Circuit Technology 4
Terms Offered Fall
Prerequisite:
This course presents the theoretical and physical principles involved in realizing devices from silicon and gallium arsenide. Implementation and fabrication of integrated circuits is stressed. The concepts of crystal structure, energy bands, carrier concentration, and carrier transport phenomena are explained. Discusses the basic fabrication processes relevant to integrated circuits. The following topics are developed: crystal growth, epitaxy, oxidation, dielectric and metallic film deposition, diffusion and ion implantation, lithography, and etching.

EENG 599 Master's Level Special Study 1-12
Terms Offered All
Prerequisite:
Directed study at an beginner graduate level on a special topic which is not normally covered in a regularly scheduled course or as part of thesis research. Topic, format, and course requirements are determined by the faculty member directing the study. Requires submission of Special Studies Form and syllabus to the department for registration.

EENG 622 Advanced Electromagnetics I 4
Terms Offered Fall
Prerequisite:
Maxwell's equations and governing boundary conditions in the time and frequency domains are explored for various media. The wave equation is developed for the rectangular and cylindrical coordinate systems. The propagation, polarization, reflection, and transmission of plane waves are investigated. Vector potentials and Green's functions are studied. Fundamental theorems aiding in radiation and scattering applications are analyzed. The concept of radar cross section is introduced. Rectangular and cylindrical wave-guiding systems are examined. The course offers a balance of mathematical analysis, physical insight, and practical application.

EENG 624 Electromagnetic Characterization of Materials 4
Terms Offered Winter
Prerequisite: EENG-622
The theory and measurement of the electromagnetic properties of materials are investigated. Fundamental properties of materials are studied, including complex permittivity and permeability, anisotropy, and dispersion along with their associated physical cal models. Low and high frequency calibration and measurement techniques in the frequency and time domains are explored. Students apply concepts to items of current Air Force interest.

EENG 624L Electromagnetic Characterization of Materials Lab 0
Terms Offered Winter
Prerequisite:
Lab associated with EENG 624

EENG 625 Antennas 4
Terms Offered Winter
Prerequisite: EENG-622
The basis of this course is the electromagnetic field produced by known source distributions, and fundamental antenna concepts such as gain, reciprocity, equivalence, duality, polarization and radiation pattern. The general behavior of dipoles, loops, and wire antennas is developed. An introduction to arrays of identical antennas is presented. Aperture antennas, including horns and reflectors, and their feed structures are studied.
### Course Descriptions

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<thead>
<tr>
<th>Course Code</th>
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<th>Credits</th>
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<td>EENG 627</td>
<td>RCS Analysis, Measurement, and Reduction</td>
<td>Summer</td>
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<td>EENG-630</td>
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<td>EENG 628</td>
<td>Advanced Electromagnetic Waves</td>
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<td>EENG 629</td>
<td>Electronic Warfare I</td>
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<tr>
<td>EENG 630</td>
<td>Applications of Electromagnetic Theory</td>
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<td>EENG 631</td>
<td>Advanced Antennas</td>
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<td>EENG 633</td>
<td>Global Navigation Satellite System Receiver Design</td>
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<td>EENG 634</td>
<td>Computational Methods in Electromagnetics</td>
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<td>EENG-622</td>
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<tr>
<td>EENG 635</td>
<td>Inertial Navigation Subsystems</td>
<td>Winter</td>
<td>4</td>
<td>EENG-534</td>
</tr>
</tbody>
</table>

**EENG 622**
Analytical and numerical techniques to solve electromagnetic radiation and scattering problems. Both low and high frequency methods are discussed. The principal subjects are the geometrical theory of diffraction, physical optics, and the method of moments. The strengths and limitations of these methods as applied to complex practical problems are discussed. A substantial amount of computer programming of the methods is involved.

**EENG 627**
Radar Cross-Section (RCS) characteristics of simple and complex shapes. Methods of RCS reduction. Radar Absorbing Materials (RAM) and Radar Absorbing Structures (RAS). Design requirements and performance of RCS measurement systems. Frequency and time domain analysis of RCS data. Statistical processing of RCS data. Includes extensive laboratory RCS measurements.

**EENG 627L**
RCS Analysis, Measurement and Reduction Lab.

**EENG 628**
The focus of this course is methods for analyzing the propagation of electromagnetic waves. It begins with a review of plane wave propagation in unbound media and the reflection and transmission of waves at planar interfaces. The uniqueness of solutions to Maxwell's equations to the homogeneous vector wave equation are then addressed. Solutions to the wave equation in rectangular, cylindrical and spherical coordinates are examined. Numerous boundary value problems are considered including rectangular and circular waveguides and cavities, the spherical cavity, and scattering by cylinders and spheres. The course concludes with a look at constructing Green's functions for boundary value problems involving the inhomogeneous scalar wave equation.

**EENG 629**
Graduate level course with an in-depth analysis, synthesis, and design of electronic warfare (EW) systems. Radar electronic protection (EP) systems and electronic warfare electronic attack (EA) and electronic support (ES) interactions and EW component and system design considerations will be studied. Detailed analysis of EA countermeasures and ES techniques versus modern radars that employ pulse compression, pulse Doppler, monopulse, ultra-low sidelobes, and other EP systems will be accomplished during the course. This course is unclassified with open enrollment.

**EENG 630**
Applications of Electromagnetic Theory

**EENG 631**
Advanced Antennas

**EENG 633**
Global Navigation Satellite System Receiver Design

**EENG 634**
Computational Methods in Electromagnetics

**EENG 635**
Inertial Navigation Subsystems
### Course Descriptions

#### EENG 636 Micro-Electro-Mechanical Systems (MEMS) Lab
**Terms Offered:** Winter

**Prerequisite:**
This course covers the history, design, fabrication, and basic modeling of Micro-Electromechanical Systems (MEMS). The fabrication methods include surface-micro machining, and micromolding. A broad range of sensors, actuators, and transducers will be surveyed to include: electrostatic, electro-thermal, bi-layer, thermal bimorph, piezoelectric, and magnetic actuation schemes and various advanced sensor schemes. This course will include a weekly three hour laboratory wherein students will design classical MEMS devices, to include: electrostatic actuators, electro-thermal actuators, bi-layer actuator, and hinged structures. The MEMS devices will be designed with the aid of the computer aided drawing program L-Edit, and submitted for fabrication in the silicon MUMPS process. The fabrication designs will be ready for testing in the follow-on course for this class EENG 777 Advanced MEMS.

#### EENG 636L Micro-Electro-Mechanical Systems (MEMS) Lab
**Terms Offered:** Winter

**Prerequisite:**
Lab associated with EENG 636

#### EENG 644 Alternative Navigation Methods
**Terms Offered:** Winter

**Prerequisite:**
This course covers several non-GPS navigation techniques which can be used to complement GPS when it is not available. The course covers several current non-GPS navigation approaches, and will include study of the relevant literature and a series of projects which enable the student to interact deeply with the approaches using both simulated and real data.

#### EENG 653 Introduction to VLSI Design
**Terms Offered:** Fall

**Prerequisite:**
The purpose of this course is to equip the student with the fundamentals of VLSI design, including semiconductor physics at the introductory level and CMOS logic, technology, interconnections, design rules, layout, simulation, and verification. The focus is on each element of the design cycle. At each stage in the cycle, both the theoretical concepts and the appropriate computer-aided design (CAD) tools are presented together. Practical experience is gained through the design of circuits of relatively low complexity.

#### EENG 653L Introduction to VLSI Design Lab
**Terms Offered:** Fall

**Prerequisite:**
Lab associated with EENG 653

#### EENG 658 Light Detection and Ranging Systems
**Terms Offered:** Winter and Spring

**Prerequisite:** STAT-586 and EENG-580
This course presents a systems approach to the analysis and design of both coherent and incoherent LiDAR systems. Topics covered include range equations and detection considerations, fundamentals of incoherent and coherent receivers, radar waveform types, imaging system fundamentals, effects of atmospheric propagation, methods for computing detection probabilities and false alarm rates, as well as an introduction to subsystems and components. Selected portions of the material will be implemented within discrete computer simulations.

#### EENG 663 Signal Detection and Estimation
**Terms Offered:** Spring

**Prerequisite:** EENG-665
This course covers methods of extracting information from noisy observations of a signal. In particular, this includes random and non-random parameter estimation and methods of detection and classification. The estimation theory includes maximum likelihood, minimum mean squared error, and a maximum posteriori estimators; and the Cramer-Rao lower bound. The detection theory includes Bayesian, minimax, and Neyman-Pearson detection; multiple hypotheses; composite detection; and receiver operating characteristics.

#### EENG 665 Random Signal and Systems Analysis
**Terms Offered:** Winter

**Prerequisite:** STAT-586 or STAT-601
An introduction to the theory of random signals. The concepts developed include: random signals, moments, correlation functions, stationarity, ergodicity, power spectral density, joint processes and their cross-correlation, random signals in linear systems, specific types of random processes, and adaptive filter theory.

#### EENG 668 Advanced Radar System Analysis
**Terms Offered:** Spring

**Prerequisite:** EENG-535 and STAT-586
This course investigates the effect of waveform selection on modern radar system performance. The topics of SAR, MTI, and adaptive digital beamforming are introduced and the effects of different waveforms on radar performance analyzed. The matched filter and ambiguity function are covered in detail. The course introduces the student to current radar system research areas with an emphasis on recent publications.

#### EENG 669 Digital Communications I
**Terms Offered:** Winter

**Prerequisite:** EENG-530 and STAT-586
This course presents significant considerations for designing and analyzing digital communication systems, with primary emphasis on baseband performance. The course develops a mathematical representation of digital signals including signal space concepts. The use of source decoding for efficient descriptions of information sources is motivated. Channel coding concepts are developed and shown to improve communication system performance. Techniques of block and convolutional channel coding are summarized, hard and soft decision decoding is discussed and system performance is analyzed.
Course Descriptions

EENG 670 Digital Communications II 4
Terms Offered Spring
Prerequisite: EENG-669 and EENG-665
This course presents significant considerations for designing and analyzing digital communication systems, with emphasis on bandpass signaling and multiple access applications. The course examines coherent and noncoherent detection of digital bandpass signals in Gaussian channels and the corresponding error performance for binary and M-ary signaling. Modulation and coding tradeoffs are discussed. Methods of synchronization at the carrier, symbol, and frame rates are examined. Multiplexing and multiple access networking techniques are also explored, to include an introduction to spread spectrum systems.

EENG 672 Statistical Optics 4
Terms Offered Winter
Prerequisite: EENG-527 or OENG-644
This course presents a systems approach to the analysis and design of electro-optics systems with emphasis on the stochastic nature of the received optical fields. Topics to be covered include the temporal and spatial coherence properties of light, propagation of coherence properties of light, effects of partial coherence on imaging systems, and imaging in the presence of randomly inhomogeneous media. The end of the course will emphasize applications such as speckle imaging, imaging using adaptive optics, and interferometric imaging. The course is designed to give students the ability to analyze and design optical systems which require the consideration of the non-deterministic nature of the light itself as well as its interaction with the optical system.

EENG 673 Spread Spectrum Communications 4
Terms Offered Summer
Prerequisite: EENG-670
This course focuses on multiple access (MA) communications, with design and analysis of spread spectrum (SS) communications systems used to introduce fundamentals. Various forms of MA communications are considered in light of current and emerging techniques being employed for commercial digital communications. This include direct sequence SS, frequency hopping SS, time and frequency division multiplexing and orthogonal frequency division multiplexing (OFDM). A major portion of the course is dedicated to applications of spread spectrum techniques, such as code division multiple access, Global Positioning System, low probability of intercept, and anti-jam communications.

EENG 675 Semiconductor Devices 4
Terms Offered Winter
Prerequisite: Take PHYS-570 or MATL-560
This course is the focal point of the electronic devices sequence. The major types of semiconductor devices will be analyzed in terms of the physical effects which govern device operation. From this study, design equations, circuit models and performance limitations are developed. After a review of quantum mechanics and pertinent conduction theory, the major device categories are presented. These topics include PN-junction diodes, bipolar and field effect transistors, and metal-oxide semiconductor devices.

EENG 676 Microwave Electronic Devices 4
Terms Offered Spring
Prerequisite: EENG-576 and EENG-675
The theory of operation and design models for microwave devices in three general areas are developed: signal transmission components, thermionic power devices in microwave systems. Topics include microwave bipolar and field effect transistors, Gunn effect devices, avalanche-effect devices, PIN diodes, mixer and detector diodes, high electron mobility transistors as well as TWT's and magnetrons.

EENG 677 Optical Communication Systems 4
Terms Offered Spring
Prerequisite: EENG-530 and EENG-665
A systems approach to the analysis and design of guided and unguided optical communication systems. The concepts include: photon statistics, detector characteristics, noncoherent and coherent detection of optical signals, receiver models, optical transmitters, link calculations, free-space system design, optical fiber fundamentals, and fiber communication system design.

EENG 680 Multidimensional Signal and Image Processing 4
Terms Offered Spring
Prerequisite: EENG-580 and MATH-521
This course will study multidimensional signal and image processing techniques, to include: sampling in multiple dimensions, multi-dimensional Fourier transforms, sensor geometry models, projection theory, filtering, reconstruction, compression, and analysis.

EENG 695 VLSI System Design 4
Terms Offered Winter
Prerequisite: EENG-653 and CSCE-492
This course extends the fundamental concepts developed in EENG 653 to larger scale VLSI systems. A hierarchical design methodology is developed using VHDL. A variety of subsystem elements are presented including arithmetic circuits, memory structures, control structures, and datapath components. Each student will complete a design project of moderate complexity including VHDL specification, layout, and design verification. The result design will be submitted for fabrication to be tested in conjunction with EENG 795.

EENG 695L VLSI System Design Lab 0
Terms Offered Winter
Prerequisite: Lab associated with EENG 695

EENG 699 Master’s Level Special Study 1-12
Terms Offered All
Prerequisite:
Directed study at an intermediate graduate level on a special topic which is not normally covered in a regularly scheduled course or as part of thesis research. Topic, format, and course requirements are determined by the faculty member directing the study. Requires submission of Special Studies Form and syllabus to the department for registration.
Course Descriptions

EENG 700 Seminar in Remote Sensing and Communications Systems 1

Terms Offered: All

Prerequisite: This course is a student-participation seminar for students studying in the areas of antennas, propagation, electromagnetics, microwaves, communications, information and coding theories as applied to the broad areas of remote sensing and communications systems. Students are required to present research progress reports, analyses pertinent to their research. Students will also be required to practice drafting conference papers/presentations and journal papers, that, when appropriate, may be submitted for possible publication. The goal of this course is to foster an awareness of the open literature and IEEE publication standards for papers and presentations.

EENG 714 Advanced Topics in Radar Applications 4

Terms Offered: Summer

Prerequisite: EENG-535 and EENG-668

This capstone radar course provides the student theoretical and practical exposure to advanced radar applications of continuing and/or emerging interest within the radar community. Instructor-led lectures develop the core mathematical, signal and image processing, modeling and simulation, and measurement methods as applicable to various radar applications. In addition, students conduct laboratory experiments and measurements, and/or modeling and simulation according to methods and techniques in the current literature.

EENG 717 Advanced Topics in Microelectronic Devices 4

Terms Offered: Summer

Prerequisite: EENG-675

This course is a continuation of EENG-675. An associated processing technology laboratory provides students with hands-on experience in device fabrication. The subject matter in the course focuses on current Air Force problems. Topics include the reliability and degradation of IC’s, radiation damage and hardening of solid-state devices, compound semiconductors, charge control devices, electro-optic devices and magnetic bubble memories.

EENG 717L Advanced Topics in Microelectronic Devices Lab 0

Terms Offered: Summer

Prerequisite: Lab associated with EENG 717

EENG 734 Multi-Target Tracking 4

Terms Offered: Spring

Prerequisite: EENG-765

This course introduces the basic concepts related to multiple-target tracking along with detailed discussion of algorithms focused on this area of research. Various methods for filtering and prediction of both linear and non-linear systems are presented with an emphasis on Kalman filtering and particle filtering. Dynamic target models are presented and include airborne, seaborne, and ground targets. Multi-target multi-sensor issues such as data association, attribute data fusion, multiple sensor tracking, and multiple hypothesis tracking are discussed. The course is structured to include a lab session designed to allow students to implement the theory and explore the most recent developments in the open literature.

EENG 734L Multi-Target Tracking Lab 0

Terms Offered: Spring

Prerequisite: Lab associated with EENG 734

EENG 735 Inertial Navigation System Analysis and Integration 4

Terms Offered: Spring

Prerequisite: EENG-635 and EENG-712 or EENG-765

Optimal filtering theory is introduced and applied to the design of integrated navigation systems. The powerful properties of the Kalman filter are used to optimally combine the INS outputs with a variety of external measurements to extract superior navigation system performance. The Global Positioning System (GPS) mathematical and error models are derived and analyzed. Strap down INS computational algorithms are derived. Emphasis is placed on computational algorithms and their error performance. A substantial class project focuses on the benefits of INS integration (aiding) with external measurements, such as from the GPS.

EENG 765 Stochastic Estimation and Control I 4

Terms Offered: Winter and Spring

Prerequisite: EENG-510, EENG 562 and STAT-586

Probability theory and stochastic process theory are investigated to develop practical system models in the form of linear dynamic systems driven by known inputs, disturbances, and uncertainty. Using this model, the optimal estimator (Kalman filter) is derived and studied. Design of practical on-line filters, including performance analyses and aspects of implementation on digital computers, is accomplished for various Air Force applications.

EENG 766 Stochastic Estimation and Control II 4

Terms Offered: Spring

Prerequisite: EENG-765

Topics in linear estimation beyond those in EENG 765 are considered: frequency domain methods, square root filtering, optimal smoothing, and the extended Kalman filter as a means of applying linear estimation theory to nonlinear problems. Nonlinear filtering is then developed in detail, followed by stochastic digital controller design and performance analysis. The need for, and practical application of, these concepts in Air Force weapon systems are fully developed.
## Course Descriptions

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<td>Advanced Micro Electro Mechanical Systems (MEMS)</td>
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<td>Summer</td>
<td>EENG-636</td>
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<td>EENG 779</td>
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<td>EENG 779L</td>
<td>Nanotechnology Lab</td>
<td>0</td>
<td>Winter and Summer</td>
<td>Lab associated with EENG 779</td>
</tr>
<tr>
<td>EENG 780</td>
<td>Statistical Image Processing</td>
<td>4</td>
<td>Spring</td>
<td>EENG-663 and EENG-658</td>
</tr>
<tr>
<td>EENG 795</td>
<td>Advanced Topics in VLSI Systems</td>
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<td>Spring</td>
<td>EENG-695</td>
</tr>
<tr>
<td>EENG 795L</td>
<td>Advanced Topics in VLSI Systems Lab</td>
<td>0</td>
<td>Spring</td>
<td>Lab associated with EENG 795</td>
</tr>
<tr>
<td>EENG 799</td>
<td>Thesis Research</td>
<td>1-12</td>
<td>All</td>
<td></td>
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<tr>
<td>EENG 899</td>
<td>Doctoral Level Special Study</td>
<td>1-12</td>
<td>All</td>
<td></td>
</tr>
<tr>
<td>EENG 999</td>
<td>Dissertation Research</td>
<td>1-12</td>
<td>All</td>
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</tbody>
</table>

### EENG 777: Advanced Micro Electro Mechanical Systems (MEMS)
This course will provide the student an in-depth experience in design and modeling of classical and advanced MEMS and optical MEMS devices. Classical MEMS devices, designed and fabricated in the prerequisite companion course EENG 636 will be fabricated and tested in a three hour weekly lab. The experimental results will be compared to numerical results obtained from finite element models and analytical models. This class will also include a course project where an advanced MEMS design is optimized through finite element modeling and simulation.

### EENG 779: Nanotechnology
This course covers selected topics in nanometer-scale technology relevant to Air Force and DoD systems. The focus is on topics related to nanoelectronic materials, devices, and systems including sub-micrometer silicon-based integrated circuits, molecular electronics, quantum-effects in materials and devices, and nanoelectromechanical systems. Other topics include monolayer crystal growth, nanometer synthesis, fabrication, and assembly techniques, quantum dots, nanomagnetics, carbon nanotubes, and nano-biological devices, tags/labels, and sensors. The course also includes discussions of specialized laboratory measurement techniques including atomic-force microscopy and scanning tunneling microscopy. The class includes a course project and a weekly three-hour laboratory wherein students perform modeling and simulation studies of nanometer-scale materials and devices, and fabricate and test selected nanoelectronic materials and devices.

### EENG 780: Statistical Image Processing
This course covers topics related to image reconstruction from incomplete data and advanced image registration problems. Models for both linear shift variant imaging systems and non-linear imaging systems will be introduced. Statistical descriptions of various kinds of image data will be covered so that estimation theory can be applied to practical imaging systems. Emphasis will be placed on understanding key elements of astronomical, coherent and hyper-spectral imaging problems.

### EENG 795: Advanced Topics in VLSI Systems
This course is a combination of a testing laboratory and advanced topics class. The design projects which the student completed in EENG 695 will be tested both functionally and parametrically. The student will gain experience in both probing the circuit directly and using automated test equipment. The student will also have the opportunity to explore advanced topics in VLSI system design in a seminar format. Such topics may include analog circuit design, gallium arsenide circuit design, computer-aided design theory, and new VLSI architectural concepts.

### EENG 799: Thesis Research
The thesis topic is normally selected during EENG 698, Research Seminar, from a wide variety of subjects of current interest to various Air Force and DoD organizations. The thesis is performed under the supervision of a faculty member who serves as the student’s thesis advisor and chairman of his thesis committee. The results of the research are presented in a formal written thesis. An oral presentation and defense of the research is also required. A master's degree candidate must enroll in EENG 799 for a total of 12 credit hours while working on his master's thesis. Ordinarily this course extends over the last three quarters of a student's program, with the student enrolling for 4 credit hours each quarter. The letter grade for the entire 12 hours of thesis is awarded in the final thesis quarter. A grade of in-progress (IP) or unsatisfactory (U) is awarded for the other quarters.

### EENG 899: Doctoral Level Special Study
Directed study for doctoral students on a special topic which is not normally covered in a regularly scheduled course or as part of dissertation research. Topic, format, and requirements of the course are determined by the faculty member directing the study. Requires submission of Special Studies Form and syllabus to the department for registration.

### EENG 999: Dissertation Research
This course supports doctoral research under the direction of a faculty research advisor from the Department of Electrical and Computer Engineering.
Course Descriptions

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>Terms Offered</th>
<th>Prerequisite</th>
</tr>
</thead>
<tbody>
<tr>
<td>OENG 645</td>
<td>Wave Optics I</td>
<td>4</td>
<td>Spring</td>
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<tr>
<td></td>
<td><strong>Prerequisite:</strong> EENG-672 and either OENG-644 or EENG-527</td>
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<td></td>
<td>This course introduces the student to light propagation through Earth's atmosphere using theoretical and simulation approaches. Topics covered include solving Maxwell's equations in a random medium, key atmospheric statistical parameters such as the mutual coherence function, and simulating light propagation in both vacuum and atmospheric turbulence.</td>
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<tr>
<td>OENG 699</td>
<td>Master's Level Special Study</td>
<td>1-12</td>
<td>All</td>
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<td></td>
<td><strong>Prerequisite:</strong></td>
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<td></td>
<td>Directed study at an intermediate graduate level on a special topic which is not normally covered in a regularly scheduled course or as part of dissertation research. Topic, format, and requirements of the course are determined by the faculty member directing the study. Requires submission of Special Studies Form and syllabus to the department for registration.</td>
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<tr>
<td>OENG 899</td>
<td>Doctoral Level Special Study</td>
<td>1-12</td>
<td>All</td>
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<td><strong>Prerequisite:</strong></td>
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<td></td>
<td>Directed study for doctoral students on a special topic which is not normally covered in a regularly scheduled course or as part of dissertation research. Topic, format, and requirements of the course are determined by the faculty member directing the study. Requires submission of Special Studies Form and syllabus to the department for registration.</td>
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<tr>
<td>TENG 799</td>
<td>Thesis Completion</td>
<td>12</td>
<td>All</td>
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<td><strong>Prerequisite:</strong></td>
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<td>Thesis Completion course for graduating students to be taken during the last quarter of study. Registration in TENG 799 for 12 non-billable credit hours is required for all master's students whose research advisors are in the Department of Electrical and Computer Engineering. The grade assigned to this course is the official thesis grade.</td>
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<tr>
<td>BIOL 597</td>
<td>Biological Weapons Effects and Technology</td>
<td>4</td>
<td>Summer</td>
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<td></td>
<td><strong>Prerequisite:</strong></td>
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<td>The malicious use of microorganisms and threats of further acts of war or of terrorism drive this course. A review of fundamental microbial biology and organisms known to have biowarfare applications will be followed by coverage of current advances in biotechnology and the potential for offensive or defensive applications. Finally, current technologies for detection and response to microbial agents will be reviewed.</td>
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<tr>
<td>CHEM 581</td>
<td>Introduction to Nuclear Fuel Cycles</td>
<td>4</td>
<td>Winter</td>
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<td></td>
<td><strong>Prerequisite:</strong></td>
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<td>NENG-651</td>
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<td>Introduction to nuclear fuel cycles with emphasis on engineering techniques important to produce materials for nuclear weapons. Topics relevant to nuclear nonproliferation will be introduced including uranium and plutonium chemistry relevant to milling, mining and refining; isotope enrichment; fuel element fabrication; reactor operation; fuel separation; and reprocessing. Nuclides possibly released during these processes will be considered.</td>
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<tr>
<td>CHEM 597</td>
<td>Chemical Weapons: Materials, Effects and Technology</td>
<td>4</td>
<td>Fall</td>
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<td></td>
<td><strong>Prerequisite:</strong></td>
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<td>The potential use of chemical agents as weapons of war or as weapons of terror motivates this course. The chemistry and physiochemical properties of chemical agents important to their production, employment, and effects will be presented. Technology relevant to personnel protection will be reviewed.</td>
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<tr>
<td>CHEM 675</td>
<td>Upper Atmospheric Chemistry</td>
<td>4</td>
<td>Spring</td>
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<td><strong>Prerequisite:</strong></td>
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<td>PHYS-519</td>
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<td>This course focuses on the physical and chemical characteristics of the upper atmosphere of which the ionosphere is a vital and integral part of this region. The principle ionization sources are photoionization and energetic particle collisions with ambient atoms and molecules. A variety of processes that operate in the upper atmosphere will be identified and related to input and output parameters by detailed mathematical and physical descriptions of the processes. This course should bridge the gap between elementary studies in the fields of physics and research literature in upper atmosphere physics and chemistry.</td>
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<tr>
<td>CHEM 720</td>
<td>Kinetics of Fast Reactions</td>
<td>4</td>
<td>Spring</td>
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<td><strong>Prerequisite:</strong></td>
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<td>Advanced level investigation of the rates and mechanism of chemical reactions and energy transfer. Theoretical methods of Slater and RRKM are presented for the calculations of rate coefficients from fundamental properties. Current experimental methods used to study the kinetics of jet engines, rockets, lasers, plasmas, and the Earth's atmosphere are discussed.</td>
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<tr>
<td>CHEM 840</td>
<td>Advanced Chemical Kinetics</td>
<td>4</td>
<td>Spring</td>
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<td></td>
<td><strong>Prerequisite:</strong></td>
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<td>CHEM-720 or CHEM-825 or permission of instructor</td>
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<td></td>
<td>A seminar course covering the theoretical aspects of chemical kinetics; calculation of rate constants from consideration of the fundamental properties of atoms and molecules; analysis of classical methods, such as Slater or RRKM, and introduction to quantum and statistical solutions involving the Liouville equation.</td>
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</tbody>
</table>
Course Descriptions

CHEM 850 Molecular Orbital Theory 4
Prerequisite: PHYS-655
A study of modern variational methods to calculate electronic structure and properties of molecules. Topics include molecular orbitals and molecular orbital symmetry, mathematical methods for solving the wave equation for molecules, HF-SCF, LCAO, MCSCF, CI, perturbation methods, and density functional methods.

CWMD 596 Physiological Effects of CBRN 4
Terms Offered: Fall
Prerequisite: A general knowledge of physiology and toxicology is critical to understanding the myriad of health effects that can occur from exposure(s) to chemical, biological, radiological, and/or nuclear agents. This course will cover the physiological effects of each of the agent classes. Human anatomy and physiology are inherent topics in the instruction. The course provides a foundation in the human health effects of CBRN agents, which will ultimately result in better informed decision-making concerning CBRN threat assessments and response and recovery operations.

CWMD 699 Master's Level Special Study 1-12
Terms Offered: All
Prerequisite: Directed study at an intermediate graduate level on a special topic which is not normally covered in a regularly scheduled course or as part of thesis research. Topic, format, and course requirements are determined by the faculty member directing the study. Requires submission of Special Studies Form and syllabus to the department for registration.

CWMD 791 Non-Proliferation of WMD Agents and Technologies 4
Terms Offered: Winter
Prerequisite: This course examines the problem of global proliferation through a multidisciplinary approach. This course provides an understanding of the technology necessary to produce weapons of mass destruction, as well as the means of delivering these weapons. The effects of chemical weapons and biological weapons are studied. Combating proliferation with an emphasis on U.S. Government legal obligations, treaty requirements, and DoD capabilities is considered. Detection of WMD and protection from their effects is examined. Finally, this knowledge is combined with a working knowledge of the current status of international proliferation to assess future trends.

CWMD 799 Thesis Research 1-12
Terms Offered: All
Prerequisite: This course is an in-depth study of a research topic selected from a wide variety of problems of current interest to the Air Force, with the results presented in a formal thesis and defense. Ordinarily, this course extends over several quarters, and no credit is given until the end of the last quarter. An oral presentation and defense of the research are required.

MATL 525 Thermodynamics and Kinetics of Materials 4
Terms Offered: Spring
Prerequisite: Applications of thermodynamics and kinetics relevant to materials science and engineering are presented. Concepts treated include free energy of phases, phase diagrams, metastability, and applications to problems in solids and thin films. Thermodynamics is applied to pure materials, solid solutions, phase equilibria, interfaces and defects. Kinetics topics include diffusion in solids, nucleation kinetics, composition-invariant solid/solid interface migration, and kinetics of surface deposition.

MATL 560 Electronic, Magnetic and Optical Properties of Materials 4
Terms Offered: Fall
Prerequisite: Introduction to the theory and engineering applications, magnetic, and optical materials. Atomic bonding, crystal structure, crystal defects, lattice properties, diffussion, electrical properties of materials, metals, dielectrics, semi-conductors, magnetic properties of materials, ferroelectrics, superconductors, polymers, ceramics and the growth and processing of materials are covered. Use of such materials in solid state devices, hard and soft magnets, super-conductors, and optical devices are treated.

MATL 598 Materials and Processes Seminar 1
Terms Offered: Fall
Prerequisite: Current technologies, applications, and research issues in the materials and processes are presented by subject matter experts and active researchers in the field.

MATL 620 Chemistry of Materials 4
Terms Offered: Fall and Winter
Prerequisite: A study of the electrochemistry, inorganic chemistry, organic chemistry, polymer chemistry and solid-state chemistry relevant to synthesis processing of materials. Computational methods of predicting and correlating materials structure with properties of alternative materials will be introduced. This course introduces the student to chemistry of materials and chemical processes which produce significant quantities of toxic chemicals. Emphasis will be placed on chemistry of materials and processes important in current and future aerospace manufacture and maintenance. This course provides background for understanding pollution prevention.

MATL 672 Optical Properties of Materials 4
Terms Offered: Summer
Prerequisite: PHYS-670
Study of the various optical phenomena in materials; topics will be selected from absorption, reflection and emission processes, luminescence, dispersion theory, optical materials, polymers, wave propagation in anisotropic media, and nonlinear properties of materials. Application will be made to the material requirements of optical devices such as lasers, detectors, etc.
Course Descriptions

MATL 680  Materials Characterization 4
Terms Offered  Winter
Prerequisite:
This course provides an integrated view of materials characterization as a process requiring the application of many methods. This course will focus on several representative methods, including methods based on photons (IR, visible, UV, X-ray), on electrons, and on atoms/ions/neutrons. Acoustic, microwave and mechanical test methods will be introduced. Advanced understanding of the interactions between the material and the sensor or probe used in the characterization will be stressed.

MATL 681  Scanning Electron Microscopy and Microanalysis 4
Terms Offered  Spring
Prerequisite:

MATL 685  Materials Selection and Processing 4
Terms Offered  Spring
Prerequisite:
This course provides an introduction to the principles and techniques that are used in selection, fabrication, and processing of bulk, thin film and nanoscale materials for applications in electronic and structural systems, including risk and cost assessments. A selected group of fabrication methods will be emphasized. Techniques and underlying principles for synthesis and assembly of materials with one or more micro- to nanoscale dimensions will be presented.

MATL 699  Master’s Level Special Study 1-12
Terms Offered  All
Prerequisite:
Directed study at an intermediate graduate level on a special topic which is not normally covered in a regularly scheduled course or as part of thesis research. Topic, format, and course requirements are determined by the faculty member directing the study. Requires submission of Special Studies Form and syllabus to the department for registration.

MATL 799  Thesis Research 1-12
Terms Offered  All
Prerequisite:
This course is an in-depth study of a research topic selected from a wide variety of problems of current interest to the Air Force, with the results presented in a formal thesis and defense. Ordinarily, this course extends over several quarters, and no credit is given until the end of the last quarter. An oral presentation and defense of the research are required.

MATL 899  Doctoral Level Special Study 1-12
Terms Offered  All
Prerequisite:
Directed study for doctoral students on a special topic which is not normally covered in a regularly scheduled course or as part of dissertation research. Topic, format, and requirements of the course are determined by the faculty member directing the study. Requires submission of Special Studies Form and syllabus to the department for registration.

METG 610  Radiative Transfer 4
Terms Offered  Spring
Prerequisite:
This course covers topics in radiative transfer for visible, infrared, and acoustic energy including emission, absorption, scattering, and atmospheric refraction. Application of the theory will be examined in operational models, such as Electro-Optical Tactical Decision Aid, Integrated Refractive Effects Prediction System, and Radio Physical Optics.

METG 611  Atmospheric and Space Environmental Effects on Electromagnetic Propagation 4
Terms Offered  Spring
Prerequisite:
Investigates the propagation properties of laser, radar, optical, and IR systems in the atmosphere and near-earth space environment. Weather and environmental effects on ground- based, airborne and spaceborne platforms are considered. Topics include signal processing to characterize both discrete and distributed targets, and inversion methods to retrieve atmospheric parameters. Focus is on the UV to microwave portion of the spectrum.

METG 612  Cloud Physics 4
Terms Offered  Winter
Prerequisite:
Covers the theories of cloud formation, precipitation, and atmospheric electricity. Particular emphasis will be placed on lightning formation, detection, and its effects. Convective clouds and mesoscale storm systems will be discussed in detail to include the general structure, scale, and vertical motions within these storms. A computer-based project will be included to help visualize the formation of clouds and the moisture in them.

METG 620  Advanced Atmospheric Dynamics 4
Terms Offered  Winter
Prerequisite:
This course covers geophysical fluid dynamics including the development of the fundamental equations governing atmospheric motion, basic approximations, simplified flows, and physical interpretation of the corresponding theory. It also includes circulation theory, vorticity, planetary boundary layer, quasi-geostrophic, ageostrophic and linear theories and introductory numerical modeling concepts.
<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
<th>Credits</th>
<th>Terms Offered</th>
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<tbody>
<tr>
<td>METG 634</td>
<td>General Circulation and Tropical Meteorology</td>
<td>4</td>
<td>Winter</td>
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<tr>
<td>METG 640</td>
<td>Applied Climatology</td>
<td>4</td>
<td>Summer</td>
</tr>
<tr>
<td>METG 642</td>
<td>Radar Meteorology</td>
<td>4</td>
<td>Summer</td>
</tr>
<tr>
<td>METG 644</td>
<td>Satellite Meteorology</td>
<td>4</td>
<td>Spring</td>
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<tr>
<td>METG 650</td>
<td>Numerical Weather Prediction (NWP) for Scientists and Engineers</td>
<td>4</td>
<td>Spring</td>
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<tr>
<td>METG 655</td>
<td>Fine Scale, Specialized and Probabilistic NWP</td>
<td>4</td>
<td>Summer</td>
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<tr>
<td>METG 660</td>
<td>Operational Assessments in Atmospheric Science Laboratory</td>
<td>4</td>
<td>Winter</td>
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<tr>
<td>METG 799</td>
<td>Thesis Research</td>
<td>1-12</td>
<td>All</td>
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<tr>
<td>NENG 500</td>
<td>Nuclear Weapons Strategy and Policy</td>
<td>4</td>
<td>Fall, Winter, and Spring</td>
</tr>
</tbody>
</table>

**Course Descriptions**

**METG 634 General Circulation and Tropical Meteorology**

Prerequisite: 
This course extends atmospheric dynamics to the tropics where large scale circulations dominate. Phenomena discussed will include cumulus convection, meso-scale convection systems, tropical waves and disturbances, as well as 30-50 day, and semi-annual oscillations: el Nino, la Nina, Madden-Julian and the Inter-Tropical Convergence Zone.

**Terms Offered:** Winter

**Prerequisite:** METG-634

**METG 640 Applied Climatology**

Prerequisite: 
This course introduces the student to the field and application of climatology and its vast databases. The Earth's complex climate system, and contributing elements of climate change will be discussed while students learn military applications and the limitations of supporting operations.

**Terms Offered:** Summer

**Prerequisite:** METG-634

**METG 642 Radar Meteorology**

Prerequisite: 
This course provides students with a background on the theory of remote sensing using weather radar. Emphasis will be given to current interpretation techniques, and recent technology advancements to interrogate phenomena such as precipitation type and intensity, lightning onset, turbulence, wind shear, meso-scale convective complexes, and various severe weather scenarios.

**Terms Offered:** Summer

**Prerequisite:** METG-612

**METG 644 Satellite Meteorology**

Prerequisite: 
This course will provide students with a broad foundation on the history, theory, data, and application of meteorological satellites/sensors, so that they will be able to interpret and fully utilize these data for operational and/or research applications and understand their capabilities and limitations. It includes techniques, research, and operational applications related to satellite-based remote sensing of the atmosphere and their applications in numerical weather prediction.

**Terms Offered:** Spring

**Prerequisite:** METG-620

**METG 650 Numerical Weather Prediction (NWP) for Scientists and Engineers**

Prerequisite: 
This course provides students with a background in available dynamic, microphysical and climate models with a rigorous treatment of numerical modeling techniques, physical parameterizations and data assimilation. This course provides tools for future research using transport, dispersion, and fallout techniques, as well as numerical weather prediction and long range climate modeling.

**Terms Offered:** Spring

**Prerequisite:** METG-620

**METG 655 Fine Scale, Specialized and Probabilistic NWP**

Prerequisite: 
Building on the basis of METG 650, this course delves further into Numerical Weather Prediction (NWP) models to better understand fine and meso-scale modeling as well as the latest state of ensembles. Topics discussed include current model capabilities, limitations and operational applications.

**Terms Offered:** Summer

**Prerequisite:** METG-612, METG-644 and METG-650

**METG 660 Operational Assessments in Atmospheric Science Laboratory**

Prerequisite: 
In this course, students will study the current operational aspects of USAF environmental forecasting and observing. Additionally, students will attempt to solve a current or future DoD operational environment related problems through the use of remote sensors. Students will learn about the required inputs for each model, and evaluate the output. The course also discusses instrumentation and models used to observe and characterize the environment. Finally, students will be exposed to experiments that illustrate how environmental conditions can ultimately impact daily operations.

**Terms Offered:** Winter

**Prerequisite:** METG-612, METG-644 and METG-650

**METG 799 Thesis Research**

Prerequisite: 
An in-depth study of a research topic selected from a variety of problems of current interest to the Air Force, with the results presented in a formal thesis written under the supervision of a departmental professor. Ordinarily this course extends over several quarters and no credit is given until the end of the last quarter. An oral presentation and defense of the research is required.

**Terms Offered:** All

**Prerequisite:**

**NENG 500 Nuclear Weapons Strategy and Policy**

Prerequisite: 
This course provides students with a professional understanding of the historical and current US nuclear policy and the implementation of that policy by the Department of Defense and the Air Force. The course starts with analysis of the current Nuclear Posture Review and then reviews the historical development of nuclear weapons policy and strategy. The course then provides a functional and critical understanding of how national and Air Force policy is implemented through current force structures, nuclear surety, and weapons employment. The course also incorporates current debates and case studies.

**Terms Offered:** Fall, Winter, and Spring
### Course Descriptions

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Terms Offered</th>
<th>Credits</th>
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</thead>
<tbody>
<tr>
<td>NENG 525A</td>
<td>Nuclear Weapon EM Effects</td>
<td>Fall</td>
<td>4</td>
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<tr>
<td>Terms Offered:</td>
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<tr>
<td><strong>Prerequisite:</strong></td>
<td>This is a fundamental graduate course that addresses applications of electromagnetic (EM) phenomena related to nuclear weapons. The key focus of the course is an understanding of the electromagnetic pulse (EMP) resulting from a nuclear weapon detonation and key defensive and offensive applications. Course coverage includes: an assessment of the EMP threat, EM concepts used by the defense industry, nuclear weapon effects on EM wave propagation, EMP source and attributes associated with its development, EM coupling, testing methods, and hardening strategies. It is assumed that that students do not have an EM background nor nuclear weapon effects experience. As such, this course will have a broad scope, and reading and working the exercises will be key to fully comprehending the course content and being apply the material.</td>
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</table>

| NENG 585 | Introduction to Modern Fortran With Applications in Computational Nuclear Engineering | Fall                   | 4       |
| Terms Offered: |                                                                 |                        |         |
| **Prerequisite:** | Modern Fortran programming techniques are presented and practiced using example problems from the nuclear engineering curriculum. The objectives include: to develop knowledge of the structure and syntax of Fortran-95, to develop skill in programming and in effective use of the provided development environment, and to practice writing, debugging, and validating portable Fortran programs. Relevant ANSI/ANSI standards are presented. Programming exercises focus on numerical computations needed to solve problems encountered in the AFIT nuclear engineering curriculum. Modern programming approaches, including operator overloading, data abstraction, encapsulation, objects, are introduced using Fortran-95 user-declared types and modules. |                     |         |

| NENG 591 | Nuclear Weapons and Proliferation                                     | Fall Winter and Summer | 4       |
| Terms Offered: |                                                                 |                        |         |
| **Prerequisite:** | This course examines the elements and technology involved in building a nuclear weapons capability, including producing or obtaining nuclear fuel; assembling a weapon; fusing and firing; testing, storage, surety, and delivery; and how a proliferator might clandestinely complete the steps. The course covers elements of the United States nuclear weapon program, from fuel production to the maintenance of a nuclear arsenal at an unclassified level. |                     |         |

| NENG 596 | Nuclear Weapons Effects                                               | Fall Spring and Summer | 4       |
| Terms Offered: |                                                                 |                        |         |
| **Prerequisite:** | This course provides an understanding of the unique effects of nuclear weapon detonations: blast, thermal, radiation, electromagnetic, and fallout. Each effect is treated by examining its generation, transmission, and mechanisms of interaction with the environment. The course covers the physical origin of each effect, the manner in which these effects impact targets, and how these effects can shape a battle space both tactically and strategically. The course also covers survivability/vulnerability issues at the unclassified level. |                     |         |

| NENG 601 | Research Apprenticeship                                               | Winter                 | 4       |
| Terms Offered: |                                                                 |                        |         |
| **Prerequisite:** | Students will work on special problems related to individual professors research programs. These special problems will range from pedagogical problems intended to bring the student up to the state of knowledge to problems which are a part of the immediate goals of the program. The problems may be computational, experimental or theoretical. This will vary from professor to professor. |                     |         |

| NENG 605 | Physics of Nuclear Explosives                                          | Winter                 | 4       |
| Terms Offered: |                                                                 |                        |         |
| **Prerequisite:** | Elementary theory of fission and fusion explosive devices is taught. Diffusion theory is developed to examine the space-time variation of neutrons in fission devices. Criticality, yield and disassembly mechanisms are included. Methods of statistical physics including Maxwell-Boltzmann and Planck distributions are employed. In fusion systems, reaction rate production, radiation-loss balance and yield calculations are examined. Size, mass, density and temperature ranges for fusion burning are developed. Some Secret (RD) material is included. |                     |         |

| NENG 612 | Nuclear Engineering Laboratory                                         | Summer                 | 4       |
| Terms Offered: |                                                                 |                        |         |
| **Prerequisite:** | Experimental techniques in nuclear engineering. Typical projects include the analysis of environmental radiation from natural and man-made sources, and of stable components of airborne particulates. General techniques include gamma-ray spectroscopy, coincidence methods, activation with fast and thermal neutrons, X-ray fluorescence. Special techniques include Mossbauer spectroscopy and Rutherford scattering of protons. Individual and group project approach is used. Students must set criteria, decide what to measure, how to measure it and analyze results. |                     |         |

| NENG 612L | Nuclear Engineering Lab                                               | Summer                 | 0       |
| Terms Offered: |                                                                 |                        |         |
| **Prerequisite:** | Lab associated with NENG-612                                         |                     |         |
# Course Descriptions

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Terms Offered</th>
<th>Credits</th>
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<tbody>
<tr>
<td>NENG 620</td>
<td>Nuclear Reactor Theory and Engineering</td>
<td>Winter</td>
<td>4</td>
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<tr>
<td></td>
<td><strong>Prerequisite:</strong> NENG-651 and MATH-508</td>
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<tr>
<td></td>
<td>This course presents nuclear reactor theory, building</td>
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<td></td>
<td>upon the coverage of nuclear physics (reactions,</td>
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<td></td>
<td>radiations, fission, etc.) from NENG 651 and the</td>
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<td></td>
<td>coverage of neutron diffusion, prompt fast criticality</td>
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<td></td>
<td>and prompt kinetics from NENG 605. Delayed and thermal</td>
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<td></td>
<td>neutrons are incorporated into the treatment of</td>
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<td>criticality and kinetics. Reactor dynamics are</td>
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<td>examined, including aspects of reactor core and</td>
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<td>system design, which provide reactivity feedback for</td>
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<td>reactor control. Nuclear reactor engineering topics</td>
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<td>include thermal management, energy conversion,</td>
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<td>radiation shielding, and mechanical and structural</td>
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<td></td>
<td>aspects of reactor and system design. This course</td>
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<td>provides a broadened exposure to applications of</td>
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<td>nuclear science, and provides the necessary</td>
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<td>foundation for the study of space nuclear power and of</td>
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<td>the nuclear fuel cycle.</td>
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<td>NENG 625</td>
<td>Electromagnetic Pulse Effects</td>
<td>Summer</td>
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<td></td>
<td><strong>Prerequisite:</strong> PHYS-531 NENG-605</td>
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<td></td>
<td>Source, propagation, and interaction of the nuclear</td>
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<td>weapon generated electromagnetic pulse. Source</td>
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<td>generation is developed for high altitude burst,</td>
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<td>surface burst and system generated situations.</td>
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<td>Propagation of the radiated signal is developed from</td>
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<td>classical electromagnetism (solution of Maxwell's</td>
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<td>equations) for free space and extended to the</td>
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<td>atmosphere. EMP interaction is examined using antenna</td>
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<td>theory. Energy coupling from the wave is developed.</td>
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<td>Methods of shielding are considered.</td>
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<td>NENG 630</td>
<td>Radiation Health Physics</td>
<td>Spring</td>
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<td></td>
<td><strong>Prerequisite:</strong> NENG-651</td>
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<td>This course in radiation health physics provides the</td>
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<td>foundation for understanding the biological effects of</td>
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<td>ionizing radiation and for protecting individuals and</td>
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<td>population groups. The content depends in part on the</td>
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<td>students' backgrounds and curricular goals. Topics may</td>
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<td></td>
<td>include: physical measurements and properties of</td>
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<td>different types of radiation and radioactive</td>
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<td>materials, quantitative relationships between</td>
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<td>radiation exposure and biological damage, movement of</td>
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<td>radioactivity through the environment, and design of</td>
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<td>radiologically safe equipment, processes, and</td>
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<td>environments with the intent on assessing the</td>
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<td>radiological impact on humans. In some offerings of</td>
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<td>the course, the effects of non-ionizing radiation may</td>
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<td>be included. This course will be useful to bio-</td>
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<td>environmental engineers, environmental managers,</td>
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<td>radiation safety officers, nuclear research officers,</td>
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<td>or medical personnel who will have responsibility for</td>
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<td>managing radiation safety programs, managing</td>
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<td>environmental activities of military installations</td>
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<td>which have nuclear sources (hospitals, PMEL, or nuclear</td>
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<td>weapons) or who must interact in their</td>
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<td>environmental management jobs with the</td>
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<td>Department of Energy.</td>
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<tr>
<td>NENG 631</td>
<td>Prompt Effects of Nuclear Weapons</td>
<td>Spring</td>
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<td><strong>Prerequisite:</strong> NENG-605</td>
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<td>Topics include source, transmission, and mechanisms</td>
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<td>of interaction of x-ray, blast, thermal, neutron, and</td>
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<td>prompt gamma radiation. X-ray interactions include</td>
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<td>shock generation and propagation. The conservation</td>
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<td>equations of fluid dynamics are used to describe</td>
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<td>shocks. These same equations are applied to blasts in</td>
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<td>air and underwater shock. Shock &quot;jump conditions&quot; and</td>
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<td>scaling laws are derived and applied. Thermal</td>
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<td>transmission is examined. The heat transfer equation</td>
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<td>is used to study thermal interaction. Buildup factors</td>
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<td>and fits of transport calculations are employed to</td>
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<td>study neutron and gamma transmission. Various neutron</td>
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<td>and gamma interaction phenomena are studied. In the</td>
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<td>case of each effect, systems response is examined,</td>
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<td>hardening techniques are surveyed, and design trade-</td>
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<td>offs are discussed. Some secret (RD) material is</td>
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<td>discussed.</td>
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<td>NENG 635</td>
<td>Residual Effects of Nuclear Weapons</td>
<td>Spring and</td>
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<td><strong>Prerequisite:</strong> NENG-605</td>
<td>Summer</td>
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<td>Environmental radioactivity from natural, nuclear</td>
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<td>industry and weapon fallout is treated. The emphasis</td>
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<td>is on weapon fallout, both local and global. Methods of</td>
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<td>fallout modeling are included for both ground dose and</td>
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<td>airborne crew dose. Health physics fundamentals</td>
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<td>including mechanisms of biological response calculation</td>
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<td>of dose, body burdens and maximum permissible</td>
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<td>concentrations are also included. Seismic detection of</td>
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<td>nuclear explosions and worldwide detection systems are</td>
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<td>examined.</td>
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<tr>
<td>NENG 650</td>
<td>Nuclear Instrumentation</td>
<td>Winter</td>
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<td><strong>Prerequisite:</strong> NENG-651</td>
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<td>Radiation detectors and detection systems;</td>
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<td>characteristics, applications, and principles of</td>
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<td>operation of gas-filled detectors, scintillation</td>
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<td>detectors, semiconductor detectors; applications and</td>
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<td>principles of electronic components such as single and</td>
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<td>multi-channel analyzers, pulse amplifiers,</td>
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<td>discriminators, scalers, etc.</td>
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<td>NENG 650L</td>
<td>Nuclear Instrumentation Lab</td>
<td>Winter</td>
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<td><strong>Lab associated with NENG 650</strong></td>
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<tr>
<td>NENG 651</td>
<td>Nuclear Physics</td>
<td>Fall and</td>
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<td><strong>Prerequisite:</strong></td>
<td>Summer</td>
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<td></td>
<td>A basic graduate level treatment of nuclear physics with</td>
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<td>emphasis on interaction of radiation with matter,</td>
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<td>nuclear reactions and radioactive decay processes.</td>
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<td>Essential ideas of nuclear structure, stability of</td>
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<td>nuclei and quantum characterization of nuclear energy</td>
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<td>levels are covered. A practical understanding and</td>
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<td>interpretation of nuclear data tabulations to serve the</td>
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<td>needs of the nuclear engineer are stressed.</td>
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Course Descriptions

**NENG 660 Radiation Effects on Electronics**  
**Terms Offered:** Spring  
**Prerequisite:** NENG-650 and NENG-660  
This course covers the range of damage and effects that gamma rays, neutrons and charged particles can have on modern electronic devices. Emphasis will be on the effects and possible measures for protection. Temporary and permanent damage will be investigated. Topics to be discussed include: bulk effects, latch-up, charge trapping and single event upsets.

**NENG 664 Radiation Effects on Electronics Laboratory**  
**Terms Offered:** Summer  
**Prerequisite:** NENG-650 and NENG-660  
Experimental procedures used in radiation effects testing. Typical projects will include ionizing and non-ionizing radiation dosimetry, optical and electrical measurements, and irradiation of devices. The course will cover practical dosimetry, device modeling, characterization, development of a test plan, modeling device changes, irradiation of devices, and interpreting data. Special techniques include: calibrating a PIN diode dosimeter, foil activation dosimetry, device irradiation, and development of systems and controls. Students must establish test criteria, model effects, develop system controls and interpret data.

**NENG 680 Nuclear Forensics**  
**Terms Offered:** Spring  
**Prerequisite:** NENG-650 and NENG-681  
This course provides education in technical nuclear forensics at the graduate level to AFIT master's level students. This course is not intended to be a survey, but instead provide a knowledge base sufficient that upon successful completion students can contribute to nuclear forensic data analysis and experiments in a substantive way. In order to discuss technical thresholds and tool limitations quantitatively, portions of this course are held at the Secret Level.

**NENG 681 The Nuclear Fuel Cycles**  
**Terms Offered:** Fall  
**Prerequisite:** Nuclear Fuel Cycles. This course covers the nuclear fuel cycles with emphasis on engineering techniques important to produce materials for nuclear weapons. Uranium and plutonium chemistry relevant to milling, mining and refining; isotope enrichment; fuel element fabrication; reactor operation; fuel separation; and fuel reprocessing are all covered. Topics relevant to nuclear nonproliferation, especially regarding physical and material requirements for reactor operations and key signatures related to materials processing, will be included.

**NENG 685 Computational Methods for Neutral Particle Transport**  
**Terms Offered:** Fall  
**Prerequisite:**  
This course covers the principal methods used for deterministically solving the Boltzmann transport equation for neutral particles (neutrons and photons). This course presents the fundamental mathematical and computational methods using discretizations in space, energy, and angle. Iterative methods for the efficient solution of transport problems are explored and analyzed. Monte Carlo and Discrete Ordinance methods are explicitly developed and applied to shielding and criticality problems of interest. The course will include both code development and use of exiting codes for solving criticality and shielding problems of interest in nuclear engineering.

**NENG 699 Master's Level Special Study**  
**Terms Offered:** All  
**Prerequisite:**  
Directed study at an intermediate graduate level on a special topic which is not normally covered in a regularly scheduled course or as part of thesis research. Topic, format, and course requirements are determined by the faculty member directing the study.

**NENG 705 Methods of Radiation Transport**  
**Terms Offered:** Spring  
**Prerequisite:** MATH-504 and NENG-605  
The transport of X-rays, gamma rays and neutrons is examined by analysis and numerical solution of the Boltzmann transport equation. Theoretical analysis includes discussion of various approximations to the transport equation, such as particle streaming and one-speed transport theory. Numerical methods of radiation transport such as the P(n) and S(n) methods, are derived and then used by the students to solve nontrivial transport problems.

**NENG 720 Nuclear Reactor Systems**  
**Terms Offered:** Winter  
**Prerequisite:** NENG-631 and NENG-635  
A survey of current systems from a design point of view. An advanced course in that the prerequisites involve similar theory, both statics and kinetics, for explosive systems, some heat transfer, and a study of reactor effluents. The same theory and methods are applied to nuclear chain reactors in this course. Large civilian power production reactors, small military power reactors, and space nuclear systems are examined. Safety, cost, and performance are included.

**NENG 721 Space Nuclear Power Systems**  
**Terms Offered:** Spring and Summer  
**Prerequisite:** NENG-631  
Current and future nuclear power systems such as radioisotope thermal generators, solid core, fluidized bed and gas core reactors are analyzed. Converter and heat rejection theory is studied and integrated with nuclear heat sources. One of the outstanding research issues for advanced nuclear space power systems assigned as a group design project.
**Course Descriptions**

**NENG 725** Monte Carlo Methods of Radiation Transport

**Terms Offered**: Spring

**Prerequisite**: NENG 705

Monte Carlo calculation techniques are introduced and developed. The technique is applied to problems of X-ray, neutron and gamma transport from and in nuclear explosives. Monte Carlo techniques are contrasted with and compared to Boltzmann equation solutions considered in NENG 705.

**NENG 751** Nuclear Physics II

**Terms Offered**: Fall

**Prerequisite**: NENG-651

This course will be an advanced study of nuclear phenomena based upon quantum mechanics. It assumes knowledge of nuclear phenomena at the level of the course NENG 651, Nuclear Physics, and non-relativistic quantum physics at the undergraduate level. This course will investigate current models of the nucleus, nuclear reactions, and the sources and interactions of photons, electrons, charged particles, and neutrons. Students will apply knowledge of nuclear physics to problems of interest to the Air Force and Department of Defense.

**NENG 785** Topics in Computational Nuclear Engineering

**Terms Offered**: Fall

**Prerequisite**: MATH-674 or NENG-685

Advanced numerical problem solving techniques are examined in the context of problems encountered in nuclear engineering and/or nuclear weapons effects. State of the art numerical methods are adapted to the problems examined in the course. Numerical experiments are used to augment analysis in evaluating the stability, conditioning, accuracy, and efficiency of the resulting algorithms.

**NENG 791** Non-Proliferation of Nuclear Weapons and Technologies

**Terms Offered**: Winter

**Prerequisite**: NENG-635

This course examines the problem of global proliferation through a multidisciplinary approach. This course provides an understanding of the technology necessary to produce weapons of mass destruction as well as the means of delivering these weapons. The effects of chemical and biological weapons (with specific emphasis on the differences between them and nuclear weapons) are studied. Combating proliferation with an emphasis on U.S. Government legal obligations, treaty requirements, and DOD capabilities is considered. Detection of WMD and protection from their effects is examined. Finally, this knowledge is combined with a working knowledge of the current status of international proliferation to assess future trends.

**NENG 799** Thesis Research

**Terms Offered**: All

**Prerequisite**: A research problem is selected from a wide variety of problems of current interest to DoD and the results are presented in a formal thesis. The student works under the supervision of a department professor; however, the burden of analysis and solution falls upon the student. Ordinarily, this course extends over several quarters and no credit is given until the end of the last quarter. An oral presentation and defense of the project is required.

**NENG 816** Advanced Topics in Neutral Particle Transport

**Terms Offered**: Winter

**Prerequisite**: NENG-705

Problems in neutron, gamma ray and x-ray transport are formulated and solved. Emphasis is on numerical methods of solution of the Boltzmann equation. Topics introduced in NENG 705 are expanded and extended. Current topics from the literature are examined.

**NENG 830** Advanced Nuclear Weapons Effects

**Terms Offered**: Summer

**Prerequisite**: NENG-631 and NENG-635

Examines in depth selected problems in neutron, gamma, x-ray, thermal and electromagnetic radiation and in shock, debris, blackout and Argus effects. Treats problems both experimentally and theoretically on the basis of the most recent literature and information available.

**NENG 880** Advanced Nuclear Forensics

**Terms Offered**: Spring

**Prerequisite**: Take NENG-605 NENG-631 NENG-635 CHEM-681 NENG-650

This advanced PhD topics course covers nuclear tech

**NENG 899** Doctoral Level Special Studies

**Terms Offered**: All

**Prerequisite**: Directed study for doctoral students on a special topic which is not normally covered in a regularly scheduled course or as part of dissertation research. Topic, format, and requirements of the course are determined by the faculty member directing the study. Requires submission of Special Studies Form and syllabus to the department for registration.

**NENG 999** Dissertation Research

**Terms Offered**: All

**Prerequisite**: This course consists of dissertation research conducted in nuclear engineering, including both the research itself and the preparation and defense of the dissertation. Selection of the research advisor and topic, formation of the research committee, supervision of the research, presentation and defense of the dissertation, and so on, are conducted in accordance with the Doctoral Council Policy Letters.
Course Descriptions

OENG 530 Fundamentals of Remote Sensing Data Exploitations & Sensor Technology 4
Terms Offered: All
Prerequisite: This course lays the groundwork for solving GEOINT (Geospatial Intelligence) remote sensing problems, with emphasis on infrared sensor technology. Both the signature and metric aspects of GEOINT will be considered. Topics include source characteristics, radiometry, atmospheric and propagation effects, optics, detectors, and elementary signal/image processing. Students should have a background in algebra and basic physics.

OENG 616 Electro-Optical Systems 4
Terms Offered: Summer
Prerequisite: OENG-650
A laboratory and lecture course that introduces laboratory techniques for the measurement of optical observables (emissions or reflections of optical radiation from aerospace vehicles). The weekly two-hour-long lecture period is used to discuss the design of experiments, safe and practical laboratory techniques, and the communication (in written and oral form) of experimental results. The experiments are in the areas of spectroradiometry, optical cross section measurement, TV sensors, and IR sensors.

OENG 616L Electro-Optical Systems Lab 0
Terms Offered: Winter and Spring
Prerequisite: Lab associated with OENG 616

OENG 620 Laser Engineering 4
Terms Offered: Spring
Prerequisite: PHYS-640 and PHYS-556 or PHYS-655
Treats the basic operation and components of the laser with emphasis on the knowledge required to use the laser as an optical system component. Covers laser media, resonator, pump and waste heat removal as well as types of lasers available. Both CW and pulsed lasers will be treated. Stress will be placed on the laser output beam and the device parameters which affect that beam.

OENG 644 Linear Systems and Fourier Optics 4
Terms Offered: Winter and Spring
Prerequisite: PHYS-640
This course covers the linear systems approach to modeling optical wavefront propagation, diffraction, and imaging. Introductory material includes analysis tools and two-dimensional Fourier transforms. The majority of the course is devoted to using these tools to solve problems in optics imaging, and optical information processing.

OENG 647 Hyperspectral Remote Sensing 4
Terms Offered: Summer
Prerequisite: PHYS-640 and OENG-650
This course provides a thorough treatment of the primary components of the field of Hyperspectral remote sensing, including the underlying spectral signature characteristics of natural and man-made materials, the radiative transfer to remote sensors, the design of imaging spectrometers, and the data processing methods employed. The goal is to prepare the student to model the observed spectral radiance for several remote sensing scenarios, analyze the performance of Hyperspectral imaging systems, and implement standard Hyperspectral classification and detection algorithms.

OENG 650 Optical Radiometry and Detection 4
Terms Offered: Winter
Prerequisite: PHYS-640
Develops the solid state and semiconductor technology necessary for an understanding of optical detection. Specific application will be made to photomissive, photconductive and photodiode detectors. In order to describe the detection of radiation, the language of radiation measurement must be studied. Thus, radiometry is included as an integral part of this course.

OENG 651 Optical Diagnostics 4
Terms Offered: Summer
Prerequisite: OENG-620 and PHYS-542
An advanced laboratory and lecture course in optical diagnostic techniques. The lecture phase of this course treats radiometry, optical sources, spectroscopic techniques, detector physics and performance, error analysis and laser safety. The laboratory experiments emphasize the design of optical systems for the purpose of analyzing physical phenomena. Typical experiments include: diagnostics of CW and pulsed laser systems, spectroscopic analysis of the luminescence from solids and plasmas, interferometric measurements, holography, and calorimetry.

OENG 651L Optical Diagnostics Lab 0
Terms Offered: Summer
Prerequisite: Lab associated with OENG-651

OENG 660 Introduction to Non-Linear Optical Devices 4
Terms Offered: Winter and Spring
Prerequisite: PHYS-640
This course is designed to develop those areas of electromagnetic wave interaction with matter necessary for an understanding of nonlinear optical devices. Plane wave propagation in anisotropic media, commonly called "crystal optics" is stressed. Passive optical devices, such as wave plates, polarizers and compensators, are designed. Parametric processes are introduced and applications such as amplitude and frequency modulation, second harmonic generation, and parametric oscillation are considered.
## Course Descriptions

<table>
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<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
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<th>Prerequisite</th>
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<tbody>
<tr>
<td>OENG 681</td>
<td>Digital Image Processing</td>
<td>4</td>
<td>Spring</td>
<td>PHYS-640</td>
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<td>The principle objectives of this course are to develop the concepts and techniques of digital image processing and lay a foundation that can be used as the basis for research in this field. Topics covered include the characteristics of digital images, image transforms, image enhancement, image restoration, image segmentation, and image representation and description.</td>
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| OENG 699    | Master's Level Special Study                     | 1-12    | All           |              |
|             | Directed study at an intermediate graduate level on a special topic which is not normally covered in a regularly scheduled course or as part of thesis research. Topic, format, and course requirements are determined by the faculty member directing the study. Requires submission of Special Studies Form and syllabus to the department for registration. |

| OENG 720    | Laser Devices and Applications                   | 4       | Winter        | OENG-620     |
|             | Treats specific laser systems of importance to the commercial world and Air Force in particular. The course stresses current laser technology and engineering analysis of specific systems. Topics covered typically include operations characteristics, such as power and energy output, their scalability, spectral and temporal characteristics, and beam quality and the factors limiting the performance. Where appropriate, design issues associated with specific systems are also discussed. In addition to the laser systems commercially available, laser systems appropriate for the Air Force and other military applications, such as laser ranging, target designation, imaging, electro-optic countermeasure, and laser weapons, are discussed. |

| OENG 740    | Optical System Design                            | 4       | As Needed     | PHYS-640     |
|             | This course is designed to introduce the basic principles of computer-aided optical system design. Topics include basic principles of optical ray tracing (both geometric and analytic), chromatic aberrations, third-order Seidel aberrations, techniques for reducing these aberrations, current computer optical design programs, Gaussian beams, and modulation and scanning techniques. The course concludes with a design project of an optical system using a state-of-the-art computer optical design code. |

| OENG 775    | Introduction to Photonic Devices                 | 4       | Winter        |              |
|             | Provides an introduction to photonic components and devices, focusing on their basic principles of operation and applications. This course covers the basic components that are used in photonic devices: dielectric waveguides; semiconductor lasers, including distributed feedback and quantum well lasers; semiconductor detectors; acousto-optic modulators; and fiber optics. Specific photonic devices are covered, including directional couplers, phase modulators, intensity modulators, photonic switches, bistable optical devices, and self-electro-optic-effect devices. |

| OENG 780    | Infrared Technology                              | 4       | Spring        | OENG-650     |
|             | This course presents the principles and technology required for the design and analysis of electro-optic systems, with emphasis on those systems operating in the infrared, and considers the overall problem of the reduction of optical observables by studying the aircraft infrared signature scenario. Sources of radiation, propagation through the atmosphere, detection of radiation, and reduction of infrared signature are all discussed. |

| OENG 799    | Thesis Research                                  | 1-12    | All           |              |
|             | This course is an in-depth study of a research topic selected from a wide variety of problems of current interest to the Air Force, with the results presented in a formal thesis and defense. Ordinarily, this course extends over several quarters, and no credit is given until the end of the last quarter. An oral presentation and defense of research are required. |

| OENG 899    | Doctoral Level Special Study                     | 1-12    | All           |              |
|             | Directed study for doctoral students on a special topic which is not normally covered in a regularly scheduled course or as part of dissertation research. Topic, format, and requirements of the course are determined by the faculty member directing the study. Requires submission of Special Studies Form and syllabus to the department for registration. |

| OENG 999    | Dissertation Research                            | 1-12    | All           |              |
|             | This course consists of dissertation research conducted in optical sciences and engineering, including both the research itself and the preparation and defense of the dissertation. Selection of both the research advisor and topic, formation of the research committee, supervision of the research, presentation and defense of the dissertation, and so on, are conducted in accordance with the Doctoral Council Policy letters. |
### Course Descriptions

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<tr>
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<tbody>
<tr>
<td>PHYS 519</td>
<td>The Space Environment</td>
<td>4</td>
<td>Fall and Summer</td>
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<td><strong>Prerequisite:</strong></td>
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<td>The near-earth space environment is that in which artificial satellites and astronauts must operate. This course is concerned with the general conditions encountered in the Earth's atmosphere, the ionosphere, and the magnetosphere, and specific effects studied are spacecraft thermal equilibrium, spacecraft charging, and space-to-ground communications. Other topics include atmospheric chemistry, radiation belts and solar activity.</td>
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<tr>
<td>PHYS 521</td>
<td>Space Surveillance</td>
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<td>Fall and Winter</td>
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<td><strong>Prerequisite:</strong></td>
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<td>This course covers the fundamental physics necessary for an understanding of remote sensors with an emphasis on visible light and infrared systems. Beginning with the sources of electromagnetic radiation, the following aspects of the problem are treated phenomenologically; the interaction of light with matter, atmospheric absorption and scattering, radiometry, optical systems, spectral and spatial resolution and imaging, and electro-optical detectors. Where appropriate, examples are chosen from current Air Force technology.</td>
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<tr>
<td>PHYS 531</td>
<td>Electromagnetism</td>
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<td>Summer</td>
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<td><strong>Prerequisite:</strong></td>
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<td>An intermediate level course stressing basic principles of electromagnetic field theory. Treats electrostatics, Maxwell's equations and electrodynamics. Course emphasis is on propagation of electromagnetic waves through the atmosphere and interaction of electromagnetic waves with matter, e.g., electronic systems.</td>
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<tr>
<td>PHYS 542</td>
<td>Optics Laboratory Course</td>
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<td>Spring</td>
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<td><strong>Prerequisite:</strong></td>
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<td>A fundamental laboratory course with experiments in coherence, diffraction, lenses, interference, polarization and lasers. Lectures will introduce selected topics in laboratory practice such as error calculation, radiometry, spec-trometry, coherence, and detectors.</td>
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<tr>
<td>PHYS 542L</td>
<td>Lab for Optics Laboratory Course</td>
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<td><strong>Prerequisite:</strong></td>
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<td>Lab associated with PHYS 542</td>
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<tr>
<td>PHYS 556</td>
<td>Introduction to Quantum Physics</td>
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<td>Summer</td>
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<td><strong>Prerequisite:</strong></td>
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<td>Basic mathematical and conceptual principles of quantum physics. Includes black body radiation, photoelectric effect, Rutherford scattering, Bohr theory of the atom, wave-particle duality, Schrodinger wave equation and applications, one electron atom, atomic spectra, X-rays, periodic table, statistical physics, and statistical distribution functions.</td>
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<td>PHYS 570</td>
<td>Physics of Solid State Devices</td>
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<td><strong>Prerequisite:</strong></td>
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<td>PHYS-556 or Permission of Instructor</td>
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<td>Basic solid state physics for the non-physicist who needs an understanding of solid state devices. Topics include quantum theory, quantum statistics, crystal structure and binding, reciprocal lattice, crystal lattice dynamics, free electron theory, energy band theory, and semiconductors.</td>
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<tr>
<td>PHYS 598</td>
<td>Engineering Physics Seminar</td>
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<td>Spring</td>
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<td><strong>Prerequisite:</strong></td>
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<td>This seminar, offered once a week for the first four quarters, is designed primarily to assist engineering physics and electro-optics students in the pursuit of their careers as R&amp;D officers. The focus is on specific AF needs and programs in areas related to their studies and the structure and organization of the R&amp;D community within the AF. This series is also used to present possible areas for thesis work, problem-solving techniques, as well as the necessary background for writing and defending the final thesis document.</td>
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<td>PHYS 600</td>
<td>Dynamics</td>
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<td>Spring</td>
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<td><strong>Prerequisite:</strong></td>
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<td>Treatment of theoretical mechanics at the advanced level. Develops Lagrangian and Hamiltonian formulations of dynamics from variational principles. Applications include central force problems, rigid body motion by matrix transformations, and coupled oscillators.</td>
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<tr>
<td>PHYS 601</td>
<td>Electrodynamics I</td>
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<td>Fall</td>
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<td><strong>Prerequisite:</strong></td>
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<td>A course in classical electromagnetic radiation. Treats wave propagation in space and in material media, reflection and refraction, and radiating systems.</td>
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<tr>
<td>PHYS 620</td>
<td>Directed Energy Effects</td>
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<td>Fall and Summer</td>
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<td><strong>Prerequisite:</strong></td>
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<td>The effectiveness of directed energy systems is analyzed and assessed. Laser and high power microwave missions are presented; target vulnerabilities are then analyzed and translated into system requirements. Laser-target interactions will include thermal soak, ablation, vaporization, impulsive damage and plasma formation. Microwave interactions with a variety of targets will also be addressed and related to the full range of desired effects.</td>
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<tbody>
<tr>
<td>PHYS 624</td>
<td>High Power Microwave Systems</td>
<td>4</td>
<td>As Needed</td>
<td>PHYS-531 or PHYS-601</td>
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<td>A modular approach to the design and characterization of a high power microwave weapon system is adopted. The course objective is to provide an understanding of the system components and the attributes of the weapon system. The weapon system is viewed as consisting of five modules: prime power and power conditioning Equipment, a microwave source, structures to couple the source to the propagation media, propagation media, and the target. The physical principles associated with a module, module characteristics, and the influence and constraints of each module on total system requirements and effectiveness are identified and discussed.</td>
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<tr>
<td>PHYS 635</td>
<td>Thermal Physics</td>
<td>4</td>
<td>Winter</td>
<td>PHYS-556 or PHYS-655</td>
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<td>Treats statistical mechanics and thermodynamics. Topics include statistical methods, statistical thermodynamics with applications, ensemble theory, Maxwell-Boltzmann, Fermi-Dirac, and Bose-Einstein statistics with applications.</td>
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<td>PHYS 640</td>
<td>Optics</td>
<td>4</td>
<td>Fall</td>
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<td>Introduction to modern optics, with a treatment of both geometrical and physical optics. Geometrical topics include reflection and refraction, lenses, mirrors, stops, ray tracing, telescopes, and optical instruments. Wave phenomena treated will include interference, optical testing, polarization, and Fraunhofer and Fresnel diffraction.</td>
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<tr>
<td>PHYS 650</td>
<td>Kinetic Theory of Plasmas</td>
<td>4</td>
<td>Spring</td>
<td>PHYS-531 or PHYS-601</td>
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<td>Study of the basic concepts and definitions of plasma physics and the parameters that characterize plasma behavior. Includes applications of the Boltzman equation and kinetic theory to such basic plasma phenomena as Beybe shielding, plasma waves, magnetic confinement, and Ionospheric physics.</td>
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<td>PHYS 655</td>
<td>Quantum Mechanics I</td>
<td>4</td>
<td>Fall</td>
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<td>An introduction to the Schroedinger approach to quantum mechanics. Presentation and analysis of experimental background, postulatory basis and perturbation methods. Application of theory to linear oscillator, free particle, hydrogen atom, hydrogen molecule, tunnel effect is presented.</td>
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<tr>
<td>PHYS 661</td>
<td>Atomic and Molecular Spectroscopy</td>
<td>4</td>
<td>Winter</td>
<td>PHYS-655</td>
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<td>Treats selected topics in atomic and molecular physics. Includes atomic spectroscopy, rotation, vibration and electronic transitions in diatomic and triatomic molecules, line shape, line broadening, and interaction of radiation fields with matter, particularly in lasers.</td>
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<tbody>
<tr>
<td>PHYS 670</td>
<td>Introduction to Solid State Physics</td>
<td>4</td>
<td>Spring</td>
<td>PHYS-635 and PHYS-655</td>
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<td>Study of fundamental concepts in solid state physics. Topics include crystal structure and binding, x-ray diffraction and reciprocal lattice, lattice vibrations and phonons, free electron Fermi gas, transport properties of metals, quantum theory of electrons and energy bands, semiconductors and semiconductor devices.</td>
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<tr>
<td>PHYS 686</td>
<td>Computational Methods for Atmospheric And Space Sciences</td>
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<td>Fall</td>
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<td>Develops fundamental computational techniques, while emphasizing modern programming practices, with a focus on terrestrial and space weather applications. Topics include numerical integration, linear and nonlinear ODEs, finite difference discretization of PDEs and data assimilation.</td>
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<tr>
<td>PHYS 699</td>
<td>Master's Level Special Study</td>
<td>1-12</td>
<td>All</td>
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<td>Directed study at an intermediate graduate level on a special topic which is not normally covered in a regularly scheduled course or as part of thesis research. Topic, format, and course requirements are determined by the faculty member directing the study. Requires submission of Special Studies Form and syllabus to the department for registration.</td>
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<tr>
<td>PHYS 730</td>
<td>Electrodynamics II</td>
<td>4</td>
<td>Fall</td>
<td>PHYS-601</td>
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<td>A continuation of PHYS 601 into areas appropriate for the study of charged particle beams and electromagnetic pulse effects. Treats relativistic particle dynamics, bremsstrahlung and waves in a magneto-ionic medium.</td>
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<td>PHYS 735</td>
<td>Statistical Physics</td>
<td>4</td>
<td>Winter</td>
<td>PHYS-635</td>
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<td>Development of tools for the description of macroscopic systems based on microscopic insights. The physics of critical phenomena including superconductivity in the Landau-Ginzburg theory, mean field theories, renormalization group, cluster expansion and path integral approaches, and Monte Carlo techniques are developed. Elements of non-equilibrium statistical mechanics including Onsager's theorem and the method of maximum entropy are also introduced.</td>
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<tbody>
<tr>
<td>PHYS 740</td>
<td>Optics II</td>
<td>Winter</td>
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<td></td>
<td><strong>Prerequisite:</strong> PHYS-601 and PHYS-640</td>
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<td>This course is designed to give a more rigorous</td>
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<td>mathematical treatment of optics principles. The</td>
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<td>properties of light propagation through practical</td>
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<td>optical components and systems, as well as free</td>
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<td>space, are described both in terms of geometric</td>
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<td>optics and physical optics languages. In</td>
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<td>particular, wave front aberrations and their</td>
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<td>implications on image quality and focal intensity</td>
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<td>are discussed in depth. Topics covered include</td>
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<td>matrix method in geometric optics and Gaussian</td>
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<td>beam optics, Jones matrix treatment of</td>
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<td>polarization, optics of the solids</td>
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<td>(crystal optics), coherence theory, and diffraction</td>
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<td>theory of aberration.</td>
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<tr>
<td>PHYS 755</td>
<td>Quantum Mechanics II</td>
<td>Fall</td>
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<td><strong>Prerequisite:</strong> PHYS-655</td>
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<td>Intermediate quantum mechanics: develops the</td>
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<td>formal mathematical basis and postulates of</td>
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<td>quantum mechanics. Examines topics in</td>
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<td>measurement theory, two level systems,</td>
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<td>scattering, spin and quantum dynamics. Applications in atomic and nuclear physics are developed.</td>
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<tr>
<td>PHYS 756</td>
<td>Quantum Mechanics III</td>
<td>As Needed</td>
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<td><strong>Prerequisite:</strong> PHYS-755</td>
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<td>Advanced quantum mechanics: examines topics of</td>
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<td>in-variance and symmetries, systems of</td>
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<td>identical particles, time independent and</td>
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<td>dependent perturbation theory, and relativistic</td>
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<td>quantum theory of the Klein-Gordon and Dirac</td>
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<td>equations. Application topics in lasers, solid</td>
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<td>state and plasma physics are developed.</td>
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<tr>
<td>PHYS 757</td>
<td>Quantum Computing</td>
<td>Summer</td>
<td>4</td>
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<td><strong>Prerequisite:</strong> PHYS-655</td>
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<td>The foundational elements of quantum computing</td>
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<td>and quantum information will be developed with a</td>
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<td>focus on the theoretical description of quantum</td>
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<td></td>
<td>bits (qubits) and the entanglement of qubits</td>
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<td></td>
<td>required for quantum computation and quantum</td>
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<td></td>
<td>information technologies. Several quantum</td>
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<td></td>
<td>algorithms will be discussed including the</td>
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<td></td>
<td>elementary Deutsch algorithm and the more</td>
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<td></td>
<td>important quantum Fourier transform algorithm.</td>
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<td>The course will conclude with a discussion of</td>
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<td></td>
<td>various physical realizations that have been</td>
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<td></td>
<td>proposed or employed to construct an actual</td>
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<td></td>
<td>quantum computer.</td>
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<tr>
<td>PHYS 770</td>
<td>Solid State Physics I</td>
<td>As Needed</td>
<td>4</td>
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<tr>
<td></td>
<td><strong>Prerequisite:</strong> PHYS-670 and PHYS-755</td>
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<tr>
<td></td>
<td>First course in a sequence of courses covering</td>
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<td></td>
<td>topics in solid state physics at an advanced</td>
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<td></td>
<td>level. Topics include free electron theory,</td>
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<td></td>
<td>crystal structure, x-ray diffraction, reciprocal</td>
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<td>lattice, electron dynamics, energy band</td>
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<td></td>
<td>calculations, transport theory, Fermi surfaces,</td>
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<td>band structure of metals, electronic</td>
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<td></td>
<td>scattering and cohesive energy.</td>
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<tr>
<td>PHYS 771</td>
<td>Solid State Physics II</td>
<td>As Needed</td>
<td>4</td>
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<tr>
<td></td>
<td><strong>Prerequisite:</strong> PHYS-770</td>
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<td></td>
<td>Second course in a sequence of courses covering</td>
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<td></td>
<td>solid state physics at an advanced level. Topics</td>
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<td></td>
<td>include lattice dynamics, phonons, anharmonic</td>
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<td>effects, dielectric properties, semiconductor</td>
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<tr>
<td></td>
<td>properties, defects, magnetism, and superconductivity.</td>
<td></td>
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<tr>
<td>PHYS 772</td>
<td>Solid State Physics III (Advanced Topics in</td>
<td>As Needed</td>
<td>4</td>
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<td></td>
<td>Solid State Physics)</td>
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<td></td>
<td><strong>Prerequisite:</strong> PHYS-771</td>
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<td></td>
<td>An in-depth study of advanced topics in solid</td>
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<td></td>
<td>state physics. Special emphasis will be given to</td>
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<td></td>
<td>the topics covering the optical properties and</td>
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<td>optical processes in semiconductors, dealing</td>
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<td></td>
<td>with the interactions among photons, electrons,</td>
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<td></td>
<td>holes, and impurities in semiconductor crystals.</td>
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<td></td>
<td>Topics include energy states, radiative and non-radiative transitions, emissions, and absorptions in semiconductors, processes and p-n junctions, and photovoltaic effects on semiconductors.</td>
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<tr>
<td>PHYS 775</td>
<td>Ionospheric Physics and Chemistry</td>
<td>Summer</td>
<td>4</td>
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<tr>
<td></td>
<td><strong>Prerequisite:</strong> CHEM-675, PHYS-635 and PHYS-650</td>
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<td></td>
<td>Formation and chemical properties of the ionosphere. Topics include ionization mechanisms, conductivity, energy loss mechanisms, electromagnetic wave propagation.</td>
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<tr>
<td>PHYS 776</td>
<td>Structure and Dynamics of the Magnetosphere</td>
<td>Summer</td>
<td>4</td>
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<td></td>
<td><strong>Prerequisite:</strong> PHYS-650</td>
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<td></td>
<td>Physics of solar wind, formation of the</td>
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<td></td>
<td>magnetosphere, and properties of the</td>
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<td></td>
<td>magnetosphere. Topics include solar wind flow,</td>
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<td></td>
<td>solar wind-earth magnetic field interaction,</td>
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<td>magnetosphere plasma wave interactions, Van</td>
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<td>Allen belts, and auroral phenomena.</td>
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<tr>
<td>PHYS 777</td>
<td>The Solar Atmosphere</td>
<td>Spring</td>
<td>4</td>
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<tr>
<td></td>
<td><strong>Prerequisite:</strong> PHYS-635 and PHYS-650</td>
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<td></td>
<td>This course deals with the source of the Earth's</td>
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<td>space weather, the sun. In particular, the student</td>
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<td>will study the outer solar regions, including the</td>
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<td>&quot;quiet&quot; photosphere, the chromosphere, the</td>
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<td>corona, and solar wind. The course heavily</td>
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<td>emphasizes both descriptions of instrumentation</td>
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<td>and data used to observe solar conditions and</td>
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<td>the &quot;active&quot; sun, which perturbs the Earth's</td>
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<td>environment, and it is intended to provide the</td>
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<td></td>
<td>space environment student with a quantitative</td>
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<td>description of solar events that impact the</td>
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<td>forecaster's mission. Class discussion will focus</td>
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<td>on sunspot activity, flares, prominence, coronal</td>
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<td>mass ejections, coronal holes, and other</td>
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<td>pertinent observables that indicate active</td>
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<td>conditions on the sun's surface.</td>
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<td>PHYS 780</td>
<td>Group Theory and Quantum Mechanics</td>
<td>As Needed</td>
<td>4</td>
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<td></td>
<td><strong>Prerequisite:</strong> PHYS-755</td>
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<td></td>
<td>Treats abstract theory of groups and the theory</td>
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<td>of group representations in sufficient detail to</td>
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<td>aid in understanding current theories of the</td>
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<td>structure of atoms, molecules and solids.</td>
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</table>
# Course Descriptions

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Terms Offered</th>
<th>Credit Hours</th>
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</thead>
<tbody>
<tr>
<td>PHYS 781</td>
<td>Laser Spectroscopy</td>
<td>Summer</td>
<td>4</td>
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<tr>
<td>Prerequisite:</td>
<td>PHYS-661 AND OENG-620</td>
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<td>A first course in laser spectroscopy designed to provide the student with the fundamental principles underlying modern spectroscopic methods utilizing lasers. Topical coverage includes the discussion of elements of radiation physics relevant to laser spectroscopy, characteristics of lasers as a spectroscopic tool, and spectroscopic instrumentation including various detection techniques. These topics are followed by an overview of selected experimental techniques such as laser induced fluorescence, laser Raman, and two photon absorption spectroscopy.</td>
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<tr>
<td>PHYS 791</td>
<td>Operational Assessments in Atmospheric and Space Sciences</td>
<td>Winter</td>
<td>4</td>
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<tr>
<td>Prerequisite:</td>
<td>PHYS-775</td>
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<td>In this course, students will study the current operational aspects of USAF space and terrestrial environmental forecasting and observing. Additionally, students will then attempt to solve a current or future DoD operational environment-related problem through a class design study. Possible examples include: improving satellite-anomaly analysis procedures; writing satellite-anomaly case studies; validating forecasting rules; comparison of operational models.</td>
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<tr>
<td>PHYS 792</td>
<td>Space Weather Laboratory</td>
<td>Winter</td>
<td>4</td>
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<tr>
<td>Prerequisite:</td>
<td>PHYS-775, PHYS-776, PHYS-777</td>
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<td></td>
<td>This laboratory course introduces the student to the space weather computer instrumentation and models used to provide operational space weather support to DoD, including solar wind, magnetospheric, ionospheric, and thermospheric models. Students will learn about the required inputs for each model, gain experience running the codes, and evaluate the output. The course also discusses instrumentation used to observe the space environment. Students will study the current operational aspects of USAF space environmental forecasting and observing. Finally, students will be exposed to experiments that illustrate how space weather affects operations.</td>
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<tr>
<td>PHYS 792L</td>
<td>Space Weather Laboratory</td>
<td>Winter</td>
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<tr>
<td>Prerequisite:</td>
<td>PHYS-775, PHYS-776, PHYS-777</td>
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<td></td>
<td>This laboratory course introduces the student to the space weather computer instrumentation and models used to provide operational space weather support to DoD, including solar wind, magnetospheric, ionospheric, and thermospheric models. Students will learn about the required inputs for each model, gain experience running the codes, and evaluate the output. The course also discusses instrumentation used to observe the space environment. Students will study the current operational aspects of USAF space environmental forecasting and observing. Finally, students will be exposed to experiments that illustrate how space weather affects operations.</td>
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<tr>
<td>PHYS 798</td>
<td>Departmental Seminar</td>
<td>All</td>
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<td>Prerequisite:</td>
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<td>This seminar is offered once a week during the academic quarters for all students in Doctoral and Master's programs in the Department of Engineering Physics. This seminar is intended to provide the student with information on a wide range of topics from current scientific research to practical engineering design. Where possible, the focus is on specific Air Force needs and programs in areas related to their studies and the structure and organization of the R&amp;D community within the Air Force.</td>
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<tr>
<td>PHYS 799</td>
<td>Thesis Research</td>
<td>All</td>
<td>1-12</td>
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<td>Prerequisite:</td>
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<td>An in-depth study of a research topic selected from a wide variety of problems of current interest to the Air Force, with the results presented in a formal thesis written under the supervision of a departmental professor. Ordinarily this course extends over several quarters and no credit is given until the end of the last quarter. An oral presentation and defense of the research is required.</td>
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<tr>
<td>PHYS 845</td>
<td>Quantum Optics</td>
<td>All</td>
<td>4</td>
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<tr>
<td>Prerequisite:</td>
<td>PHYS-730 and PHYS-755</td>
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<td>A modern introduction to light and its interaction with quantum mechanical systems. Treats the photon concept and the fundamental physics which underlie modern optical phenomena such as self-induced transparency, photon-echo, coherent pulse propagation, Lamb's theory of the laser and superradiance.</td>
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<tr>
<td>PHYS 880</td>
<td>Positron Physics and Chemistry</td>
<td>As Needed</td>
<td>4</td>
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<tr>
<td>Prerequisite:</td>
<td>CHEM-780, CHEM-850 or PHYS-755 or Permission of Instructor</td>
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<td></td>
<td>Advanced treatment of physics and chemistry of positrons and positronium. Topics include: 1) physical chemistry of positrons, 2) compounds and chemistry of positrons and positronium, 3) experimental techniques in positron spectroscopy, 4) positron porimetry, materials applications, and 5) quantum computational methods to model positron chemistry.</td>
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<tr>
<td>PHYS 899</td>
<td>Doctoral Level Special Study</td>
<td>All</td>
<td>1-12</td>
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<td>Prerequisite:</td>
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<td>Directed study for doctoral students on a special topic which is not normally covered in a regularly scheduled course or as part of dissertation research. Topic, format, and requirements of the course are determined by the faculty member directing the study. Requires submission of Special Studies Form and syllabus to the department for registration.</td>
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</table>
Course Descriptions

PHYS 999 Dissertation Research 1-12
Terms Offered All
Prerequisite:
This course consists of dissertation research conducted in applied or engineering physics, including both the research itself and the preparation and defense of the dissertation. Selection of the research advisor and topic, formation of the research committee, supervision of the research, presentation, and defense of the dissertation, and so on, are conducted in accordance with the Doctoral Council Policy letters.

TENP 799 Thesis Completion 12
Terms Offered All
Prerequisite:
The Thesis Completion course for graduating students is to be taken during the last quarter of study. Registration in TENP 799 for 12 non-billable credit hours is required for all master's students whose research advisors are in the Department of Engineering Physics. The grade assigned to this course is the official thesis grade.

Mathematics and Statistics (ENC)

MATH 291 Calculus for Engineering Managers 4
Terms Offered Fall and Summer
Prerequisite:
Preparatory course in which the student reviews and studies mathematical prerequisites required for the core courses in graduate management programs. This course establishes competence with standard material in differential and integral calculus, including multivariable calculus.

MATH 302 Elementary Differential Equations 4
Terms Offered Summer
Prerequisite:
This course is an introduction to ordinary differential equations. Topics include linear first-order differential equations, linear second-order homogeneous differential equations with constant coefficients, the method of undetermined coefficients for nonhomogeneous second-order equations, the method of variation of parameters for non-homogeneous second-order equations, power series solutions of nonconstant coefficient differential equations, an introduction to eigenvalues and eigenvectors for matrices, systems of first-order linear equations, reduction of linear differential equations to a first-order system, and solution of linear differential equations using Laplace transforms.

MATH 504 Differential Equations of Mathematical Physics 4
Terms Offered Fall
Prerequisite:
This course builds proficiency with series solutions for ordinary differential equations having variable, complex coefficients. It provides specific information on Bessel and Legendre functions, Laguerre and Hermite polynomials. Other special functions of mathematics are introduced including gamma and beta functions. The course covers the needed topics in complex variables such as analytic functions, singularities, power series expansions, contour integration and residue theory.

MATH 508 Applied Numerical Methods 4
Terms Offered Winter and Spring
Prerequisite:

MATH 509 Mathematical Methods in the Physical Sciences 4
Terms Offered All
Prerequisite:
This course covers basic topics in linear algebra and the calculus of several variables. Topics from linear algebra include matrix algebra, solutions of systems of linear equations, real vector spaces, and linear transformations between real vector spaces. Topics from several variable calculus include partial differentiation, directional derivatives, functional transformations and Jacobians, maxima and minima, and integration in two and three variables.

MATH 511 Methods of Applied Mathematics I 4
Terms Offered Fall Winter and Summer
Prerequisite:

MATH 513 Methods of Applied Mathematics II 4
Terms Offered Winter
Prerequisite: MATH-511

MATH 521 Applied Linear Algebra 4
Terms Offered Fall and Spring
Prerequisite:
Algebra of matrices, the theory of finite-dimensional vector spaces, and basic results concerning eigenvalues and eigenvectors with particular attention to topics that arise in applications.
### Course Descriptions

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>Terms Offered</th>
<th>Prerequisite:</th>
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</thead>
<tbody>
<tr>
<td>MATH 523</td>
<td>Numerical Analysis and Linear Algebra</td>
<td>4</td>
<td>Fall</td>
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<td><strong>Prerequisite:</strong></td>
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<td>This course presents the basic concepts necessary</td>
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<td>for the qualitative and quantitative analysis of</td>
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<td>mathematical systems. The goal is to understand</td>
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<td>the underlying mathematical concepts as well as</td>
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<td>be able to explain the numerical issues when</td>
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<td>faced with a computational technique. Topics</td>
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<td>include vector spaces, systems of linear</td>
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<td>equations, norms, eigenvalues, and numerical</td>
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<td></td>
<td>iterative methods.</td>
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<td>MATH 600</td>
<td>Mathematical Analysis</td>
<td>4</td>
<td>Fall and Spring</td>
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<td><strong>Prerequisite:</strong></td>
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<td>This course provides the transition from</td>
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<td>elementary calculus to advanced courses (6XX, 7XX,</td>
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<td>8XX) which require mathematical analysis with</td>
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<td>rigor. Topics include basic notions of set</td>
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<td>theory, point set topology, limits and</td>
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<td>continuity, derivatives, functions of bounded</td>
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<td>variation, Riemann-Stieltjes Integration,</td>
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<td>uniform convergence of sequences and series of</td>
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<td>functions and their consequences and Lebesgue</td>
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<td>measure and integration theory.</td>
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<td>MATH 601</td>
<td>Complex Analysis</td>
<td>4</td>
<td>Summer</td>
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<td><strong>Prerequisite:</strong></td>
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<td>Introduction to the theory of complex variables,</td>
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<td>analytic functions, elementary functions and</td>
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<td>their geometry, integrals, power series,</td>
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<td>residues and poles; conformal mapping;</td>
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<td></td>
<td>applications.</td>
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<td>MATH 602</td>
<td>Modern Applied Mathematics I</td>
<td>4</td>
<td>Fall</td>
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<td><strong>Prerequisite:</strong></td>
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<td></td>
<td>Introduction to the foundations and applications</td>
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<td>of modern applied mathematics for students of</td>
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<td>applied science. Topics include distribution</td>
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<td>theory and Green's functions applied to one-</td>
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<td></td>
<td>dimensional boundary value problems, classical</td>
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<td>and weak solutions, alternative theorems,</td>
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<td></td>
<td>functions and transformations, Banach and</td>
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<td></td>
<td>Hilbert spaces, linear functionals, basic</td>
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<td>properties of linear and metric spaces</td>
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<td>including topology, continuity,</td>
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<td>differentiability, convergence of sequences and</td>
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<td>series of functions.</td>
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<tr>
<td>MATH 604</td>
<td>Modern Applied Mathematics II</td>
<td>4</td>
<td>Winter</td>
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<td><strong>Prerequisite:</strong></td>
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<td>This is a course in applied functional analysis.</td>
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<td>Topics include linear operator theory and</td>
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<td>applications to (approximate) solutions of</td>
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<td>boundary value problems of applied science,</td>
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<td>closed operators, the inverse operator,</td>
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<td>adjoint and compact operators, spectrum,</td>
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<td>contraction mappings, Fredholm integral</td>
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<td></td>
<td>equations.</td>
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<tr>
<td>MATH 605</td>
<td>Nonlinear Differential Equations</td>
<td>4</td>
<td>Spring</td>
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<td><strong>Prerequisite:</strong></td>
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<td>Topics include linear systems with an</td>
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<td>introduction to phase space analysis, existence</td>
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<td>theory, stability of linear and almost linear</td>
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<td>systems. Lyapunov's second method, applications</td>
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<td>to nonlinear problems and optimal control</td>
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<td>theory, bifurcation theory and chaos.</td>
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<tr>
<td>MATH 607</td>
<td>Calculus of Variations</td>
<td>4</td>
<td>Winter</td>
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<td><strong>Prerequisite:</strong></td>
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<td>MATH-600 or MATH-602</td>
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<td>Topics include a study of functionals, fixed</td>
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<td>and variable end point problems, canonical</td>
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<td>forms of the Euler equations and related topics,</td>
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<td>sufficient conditions for a weak extremum,</td>
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<td>fields, sufficient conditions for a strong</td>
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<td>extremum, variational problems involving</td>
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<td>multiple integrals, direct variational</td>
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<td>methods and applications.</td>
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<tr>
<td>MATH 611</td>
<td>Introduction to Partial Differential Equations</td>
<td>4</td>
<td>Winter</td>
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<td><strong>Prerequisite:</strong></td>
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<td>MATH-600 or MATH-602</td>
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<td></td>
<td>Introduction to the fundamental concepts of</td>
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<td>partial differential equations and applications</td>
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<td>emphasizing the use of these basic concepts.</td>
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<td>Topics considered include classification,</td>
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<td>reduction to canonical form, existence of</td>
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<td>solutions, variational principles, methods of</td>
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<td>obtaining solutions of the basic types of</td>
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<td>equations using analytical methods.</td>
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<td>Some numerical methods are presented.</td>
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<tr>
<td>MATH 621</td>
<td>Linear Algebra</td>
<td>4</td>
<td>Fall and Spring</td>
<td>MATH-600 or MATH-602</td>
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<td><strong>Prerequisite:</strong></td>
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<td>Basic algebraic properties of vector spaces and</td>
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<td>matrices, including dimension and bases,</td>
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<td>linear transformations, determinants,</td>
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<td>similarity and congruence, solutions of linear</td>
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<td>systems of equations, generalized inverses,</td>
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<td>singular value decompositions, Jordan normal</td>
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<td>form, norms and inner products.</td>
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<tr>
<td>MATH 631</td>
<td>Algebraic Structures</td>
<td>4</td>
<td>Winter</td>
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<td><strong>Prerequisite:</strong></td>
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<td>An introduction to the algebra of semigroups,</td>
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<td>monoids, groups, rings, integral domains,</td>
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<td>fields and categories. Emphasis is placed on</td>
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<td>gaining a fundamental understanding of these</td>
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<td>basic algebraic structures so that the</td>
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<td>successful student will be able to apply the</td>
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<td>material in familiar and unfamiliar settings.</td>
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<td>MATH 633</td>
<td>Graph Theory</td>
<td>4</td>
<td>Spring</td>
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<td><strong>Prerequisite:</strong></td>
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<td>An introduction to the theory and application</td>
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<td>of graphs. Topics include introductory concepts</td>
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<td>and definitions, digraphs, connected and</td>
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<td>disconnected graphs, graph traversals,</td>
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<td>connection problems, trees, planar and</td>
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<td>nonplanar graphs, Eulerian and Hamiltonian</td>
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<td>graphs, coloring problems, graph isomorphisms,</td>
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<td>multigraphs.</td>
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<td>MATH 672</td>
<td>Numerical Linear Algebra</td>
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<td>Winter</td>
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<td><strong>Prerequisite:</strong></td>
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<td>Vector and matrix norms, condition number,</td>
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<td>sensitivity analysis. Matrix decompositions</td>
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<td>including LU, QR and Cholesky, Direct and</td>
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<td>iterative methods for solving systems of linear</td>
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<td>equations. Iterative methods for the eigenvalue</td>
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<td>problem. Least squares, singular value</td>
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<td>decomposition, orthogonal projections,</td>
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<td>generalized eigenvalue problem.</td>
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</table>
### Course Descriptions

**MATH 674**  
**Introduction to Numerical Analysis**  
**Terms Offered:** Spring  
**Prerequisite:**  
Roots of nonlinear equations, interpolation and approximation of functions, techniques for numerical integration and differentiation, techniques for solving ordinary differential equations, error estimates and convergence analyses for each topic.

**MATH 676**  
**Numerical Analysis for Partial Differential Equations**  
**Terms Offered:** Fall  
**Prerequisite:**  

**MATH 699**  
**Master's Level Special Study**  
**Terms Offered:** As Needed  
**Prerequisite:**  
Directed study at an intermediate graduate level on a special topic which is not normally covered in a regularly scheduled course or as part of thesis research. Topic, format, and course requirements are determined by the faculty member directing the study. Requires submission of Special Studies Form and syllabus to the department for registration.

**MATH 705**  
**Linear Functional Analysis**  
**Terms Offered:** Spring  
**Prerequisite:**  
Introduction to metric spaces and normed linear spaces, operators and functionals on a Banach space, dual space; concrete representations and applications in Hilbert space, Hahn-Banach theorem, Open Mapping theorem, Banach-Steinhaus theorem, Close Graph theorem, and topics in spectral theory.

**MATH 799**  
**Thesis Research**  
**Terms Offered:** All  
**Prerequisite:**  
The topic for an independent study is selected from a wide variety of problems usually of current interest to the Air Force. The results of the study are reported in a thesis written under the supervision of a departmental faculty member and are presented in a formal oral report. Ordinarily this study extends over four quarters and no credit is given until the end of the last quarter.

**MATH 831**  
**Mathematical Optimization and Control**  
**Terms Offered:** Fall  
**Prerequisite:**  
Modern Banach space formulation of optimization and control problems; calculus in Banach spaces; Gateaux and Frechet derivatives; optimization of functions. The geometric approach to optimal estimation in a Hilbert space; the global and local theory of constrained optimization in a Banach space; iterative methods of optimization.

**MATH 899**  
**Doctoral Level Special Study**  
**Terms Offered:** As Needed  
**Prerequisite:**  
Directed study for doctoral students on a special topic which is not normally covered in a regularly scheduled course or as part of dissertation research. Topic, format, and requirements of the course are determined by the faculty member directing the study. Requires submission of Special Studies Form and syllabus to the department for registration.

**STAT 521**  
**Applied Statistical Data Analysis**  
**Terms Offered:** Spring  
**Prerequisite:**  
This course provides statistical tools for the analysis of data in the decision-making process. The course covers descriptive statistics, probability theory, and statistical inference. Concepts discussed include methods on how to specify what data is wanted, collect data, extract information from existing sources of data, test the validity of key concepts, estimate problem parameters, and relate one decision variable to another (ANOVA and regression).

**STAT 525**  
**Applied Statistics for Managers I**  
**Terms Offered:** Fall  
**Prerequisite:**  
This course covers descriptive statistics, probability theory and statistical inference. Descriptive statistics covers both numerical and graphical techniques to illustrate data. Probability theory covers the theoretical underpinnings of both discrete and continuous random variables. Statistical inference includes topics such as the central limit theorem, confidence interval and hypothesis testing (one sample and two), and nonparametric techniques.

**STAT 535**  
**Applied Statistics for Managers II**  
**Terms Offered:** Winter  
**Prerequisite:**  
STAT-525  
Statistical methods needed to gather, interpret and apply data in the decision-making process are presented. Concepts discussed include methods on how to: specify what data is wanted, collect data, extract information from existing sources of data, test the validity of key concepts, make intelligent estimates of major problem parameters, and relate one decision variable to another (ANOVA and regression).

**STAT 535L**  
**Applied Statistics for Managers II Lab**  
**Terms Offered:** Winter  
**Prerequisite:**  
STAT-525  
Lab associated with STAT 535
### Course Descriptions

**STAT 583**  
**Introduction to Probability and Statistics**  
4 credits  
**Terms Offered:**  
Fall, Winter, and Summer  
**Prerequisite:**  
Basic concepts of probability and statistics with applications are covered. Topics include: Permutations and combinations; random variables; probability distributions; estimation and confidence intervals; hypothesis testing.

**STAT 586**  
**Probability Theory for Communication and Control**  
4 credits  
**Terms Offered:**  
Fall  
**Prerequisite:**  
Selected topics from probability theory are introduced as a basis for applications in the analysis and design of modern communication and control systems. Topics include the concepts of sample spaces, random variables, random vectors, probability densities, probability distributions, discrete and continuous distributions, expectation and moments, characteristic functions, transformations of random variables and vectors, multivariate normal distribution.

**STAT 587**  
**Applied Probability and Statistical Analysis**  
4 credits  
**Terms Offered:**  
Fall  
**Prerequisite:**  
This course presents the basic concepts of probability and statistics. Emphasized topics are basic probability axioms and laws, discrete and continuous random variables, joint probability distributions, expectations, conditional probability, the central limit theorem, sampling theory, estimation and hypothesis testing.

**STAT 601**  
**Theory of Probability**  
4 credits  
**Terms Offered:**  
Fall  
**Prerequisite:**  
STAT-583 and either MATH-509 or MATH-511  
Topics include an introduction to probability theory, distributions and expectations of random variables, moment-generating functions, joint distribution of functions of several random variables, transformations of random variables, conditional expectation and conditional density functions, order statistics, and limit theorems.

**STAT 602**  
**Mathematical Statistics**  
4 credits  
**Terms Offered:**  
Winter  
**Prerequisite:**  
STAT-601  
This course provides the student with a solid foundation in the basic concepts of mathematical statistics. Topics include tests of hypotheses, point and interval estimation, sufficient statistics, uniform minimum variance unbiased estimates, Cramer-Rao inequality, and convergence theorems.

**STAT 641**  
**Analysis of Variance**  
3 credits  
**Terms Offered:**  
Spring  
**Prerequisite:**  
STAT-602, STAT-696 and either MATH-521 or MATH-621  
This course introduces classical analysis of variance (ANOVA) techniques which includes one-way, two-way, and three-way ANOVA. Additionally, an introduction to design of experiments will be presented (i.e., full/fractional factorial, split-plot, and incomplete-block designs).

**STAT 641L**  
**Analysis of Variance Lab**  
1 credit  
**Terms Offered:**  
Spring  
**Prerequisite:**  
Lab associated with STAT 641.

**STAT 642**  
**Computational Statistics**  
4 credits  
**Terms Offered:**  
Spring  
**Prerequisite:**  
STAT-602  
A detailed examination of essential statistical computing skills needed for research and applications. Students will use software tools to develop algorithms for solving a variety of statistical problems using resampling and simulation techniques such as the bootstrap, Monte Carlo methods and Markov chain methods for approximating probability distributions.

**STAT 643**  
**Nonparametric Statistics**  
4 credits  
**Terms Offered:**  
Winter  
**Prerequisite:**  
This course teaches the fundamental techniques and concepts used in modern nonparametric analysis. Topics include nonparametric tests, confidence intervals, density estimation, regression, resampling methods, smoothing and classification.

**STAT 644**  
**Categorical Data Analysis**  
4 credits  
**Terms Offered:**  
Winter  
**Prerequisite:**  
STAT-696 and either STAT-583 or STAT-602  
Introduction to the theory and methods used in the modeling and analysis of categorical response variables. Topics include contingency tables, logistic and log-linear models, measures of association and agreement, and standard classification methods such as discriminant analysis, clustering and regression trees.

**STAT 645**  
**Bayesian Inference**  
4 credits  
**Terms Offered:**  
Spring  
**Prerequisite:**  
STAT-602  
This course introduces the philosophical and computational aspects of Bayesian statistics. Specific topics are choice of priors, posterior analysis, prediction, and computational methods such as Markov chain Monte Carlo (MCMC).
## Course Descriptions

<table>
<thead>
<tr>
<th>Code</th>
<th>Course Title</th>
<th>Terms Offered</th>
<th>Credits</th>
<th>Prerequisite(s)</th>
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<tbody>
<tr>
<td>STAT 687</td>
<td>Mathematics of Reliability Theory I</td>
<td>Summer</td>
<td>4</td>
<td>Prerequisite: STAT-602 Reliability models, reliability estimation, exponential and Weibull models, sequential life testing, sequential testing and design, goodness-of-fit tests, accelerated testing, reliability growth models.</td>
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<tr>
<td>STAT 694</td>
<td>Design of Experiments</td>
<td>Summer</td>
<td>4</td>
<td>Prerequisite: STAT-696 or MATH-521 This course gives an introduction to the linear statistical model and its associated forms of inference with special emphasis on analysis of variance models. The classical experimental design models are analyzed with emphasis on fractional factorial designs and their application to engineering problems. The successful student will be able to pose a research question in statistical terms and design an experiment to answer that question including determination of Expected Mean Square (EMS) and F-tests.</td>
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<tr>
<td>STAT 696</td>
<td>Applied General Linear Models</td>
<td>Fall</td>
<td>4</td>
<td>Prerequisite: STAT-583 Theory and application of the general linear statistical models. Population distribution and parameters are tested using regression and analysis of variance in the context of the general linear model. Topics covered include general regression and correlation analysis, basic analysis of variance, and multifactor analysis of variance.</td>
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<tr>
<td>STAT 696L</td>
<td>Applied General Linear Models Lab</td>
<td>Fall</td>
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<td>Prerequisite: Lab associated with STAT 696.</td>
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<tr>
<td>STAT 699</td>
<td>Master's Level Special Study</td>
<td>As Needed</td>
<td>1-12</td>
<td>Prerequisite: Directed study at an intermediate graduate level on a special topic which is not normally covered in a regularly scheduled course or as part of thesis research. Topic, format, and course requirements are determined by the faculty member directing the study. Requires submission of Special Studies Form and syllabus to the department for registration.</td>
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<tr>
<td>STAT 701</td>
<td>Advanced Probability</td>
<td>Summer</td>
<td>4</td>
<td>Prerequisite: MATH-600 and STAT-601 This course provides a measure-theoretic foundation for probability theory. Sigma-fields, measurable spaces and functions will be used to define the elements of probability theory: probability measures and events, random variables, conditional probability and expectation, independence, and modes of convergence. Further topics include characteristic functions, stochastic integration, convergence theorems, martingales, and Brownian motion.</td>
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<tr>
<td>STAT 702</td>
<td>Advanced Inference</td>
<td>Spring</td>
<td>4</td>
<td>Prerequisite: STAT-602 This course covers advanced topics in statistical inference. Topics include types of convergence, various limit theorems, aspects of point estimation, asymptotic confidence intervals and hypothesis testing, decision theory and risk optimality.</td>
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<tr>
<td>STAT 703</td>
<td>Theory of Linear Models</td>
<td>Winter</td>
<td>4</td>
<td>Prerequisite: STAT-602 and STAT-696 This course provides a rigorous treatment of the theory of linear models. Topics include best linear unbiased estimator, minimum variance unbiased estimate, sampling distribution of estimates, normal equations, testing hypothesis of linear parametric functions, tests for generalized linear models, multifactor analysis of variance, k-way analysis of variance, polynomial regression, estimation and testing in general Gauss-Markov models.</td>
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<tr>
<td>STAT 799</td>
<td>Thesis Research</td>
<td>All</td>
<td>1-12</td>
<td>Prerequisite: The topic for an independent study is selected from a wide variety of problems usually of current interest to the Air Force. The results of the study are reported in a thesis written under the supervision of a departmental faculty member and are presented in a formal oral report. Ordinarily this study extends over four quarters and no credit is given until the end of the last quarter.</td>
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<tr>
<td>STAT 899</td>
<td>Doctoral Level Special Study</td>
<td>As Needed</td>
<td>1-12</td>
<td>Prerequisite: Directed study for doctoral students on a special topic which is not normally covered in a regularly scheduled course or as part of dissertation research. Topic, format, and requirements of the course are determined by the faculty member directing the study. Requires submission of Special Studies Form and syllabus to the department for registration.</td>
</tr>
</tbody>
</table>
Course Descriptions

STAT 999 Dissertation Research 1-12
Terms Offered All
Prerequisite:
Dissertation research conducted in probability or statistics, including both the research itself and the preparation and defense of the prospectus and dissertation. Selection of the research advisor and topic, formation of the research committee, supervision of the research, presentation and defense of the dissertation, and so on, are conducted in accordance with the Doctoral Council Policy letters.

TENC 799 Thesis Completion 12
Terms Offered All
Prerequisite:
Thesis Completion course for graduating students to be taken during the last quarter of study. Registration in TENC 799 for 12 non-billable credit hours is required for all master's students whose research advisors are in the Department of Mathematics and Statistics. The grade assigned to this course is the official thesis grade.

Operational Sciences (ENS)

LOGM 520 Managerial Economics 4
Terms Offered Winter
Prerequisite:
Basic microeconomic principles such as supply and demand, elasticity, short-run and long-run shifts in resources allocation, diminishing returns, economies of scale, and pricing are covered. There is a general introduction to economics and economic reasoning, including the application of economic theory to the firm. Also covered are various tools of analysis helpful to decision makers, including demand, production, and cost estimation using regression analysis, forecasting, capital budgeting, and risk analysis. The nature of economic incentives concerning consumers, workers, and business are studied.

LOGM 525 Statistics for Mobility Managers 4
Terms Offered Summer
Prerequisite:
This course is designed as an introductory statistics course for graduate students in the Masters of Mobility Operations program offered at the Air Mobility Warfare Center. As such, it is to be taught from a managerial, rather than a mathematical perspective. Basic statistical concepts will be taught, including probability, distributions, hypothesis testing, and problem solving. Statistical techniques to be covered include both descriptive and inferential statistics, such as frequency distributions, histograms, regression analysis, chi-square, ANOVA, and nonparametric analysis. Emphasis is on the selection and analysis of statistical output, rather than manual computation, through the utilization of the software that is integrated with the text material.
REMARKS: This course is open only to students in the Ft Dix Air Mobility Program.

LOGM 542 Management of Logistics Organizations 4
Terms Offered Winter
Prerequisite:
This is a survey course covering the behavior of individuals and groups as it pertains to logistics organizations and the Air Force. Topics include, but are not limited to, decision theory and biases, motivation, cognition, individual differences, teams, and culture.

LOGM 545 Introduction to Management and Organizations 3
Terms Offered Winter and Spring
Prerequisite:
This is a survey course covering the behavior of individuals and groups as it pertains to organizations and the Air Force. Topics include, but are not limited to, decision theory and biases, motivation, cognition, individual differences, teams, and culture.

LOGM 565 Strategic Sourcing 3
Terms Offered Winter and Spring
Prerequisite:
This course provides an introduction to and an overview of the strategic sourcing process including topics such as supplier selection, supplier evaluation, negotiation, contract management, supplier development, e-procurement, buyer-supplier relationships, strategic cost management, and purchasing law and ethics.

LOGM 566 Strategic Sourcing 4
Terms Offered Winter and Spring
Prerequisite:
This course provides an introduction to and an overview of the strategic sourcing process including topics such as supplier selection, supplier evaluation, negotiation, contract management, supplier development, e-procurement, buyer-supplier relationships, strategic cost management, and purchasing law and ethics.

LOGM 567 Lean Operations Management 4
Terms Offered As Needed
Prerequisite:
Creating, sustaining, and employing military capability is the purpose of military leadership and management. Operations management theory outlines how organizations perform the systematic direction and control of the processes that transform inputs into finished goods and services. In the past decades, the concept on leanness has emerged as a management philosophy that can facilitate increased productivity while simultaneously reducing costs and improving service to the customer/warfighter. This course presents basic operations management concepts as well as the lean principles with a focus on how lean changes traditional operations management.

LOGM 568 Introduction to Supply Chain Management 3
Terms Offered Winter Spring and Summer
Prerequisite:
This class provides an introduction to and overview of supply chain management concepts and practices with an emphasis on the areas related to logistics (a sub-area of supply chain management). Supply chain management and its supporting activities of strategic planning, purchasing, operations management, and logistics represent one of the cornerstones of competitive strategy for most organizations, including the Department of Defense. This course introduces the concepts and tools that will enhance the student's understanding of supply chain management and their ability to effectively manage various supply chain operations.
## Course Descriptions

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>Terms Offered</th>
<th>Prerequisite</th>
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<tbody>
<tr>
<td>LOGM 569</td>
<td>Maintenance and Production Management</td>
<td>4</td>
<td>Fall</td>
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<td></td>
<td><strong>Prerequisite:</strong> This course explores operations management functions as applied to an Air Force environment. The course familiarizes the student with a variety of operations management techniques which are being applied in maintenance as well as a variety of other operations management settings. Course topics include productivity, facility layout, location, capacity planning, quality control, scheduling, project management, queuing theory, inventory management, forecasting, and current operations management innovations.</td>
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<tr>
<td>LOGM 601</td>
<td>Principles and Methods of Research</td>
<td>4</td>
<td>Fall and Spring</td>
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<td><strong>Prerequisite:</strong> The course provides information on how to conduct an appropriate review of literature to identify gaps and opportunities surrounding the problem area, and to identify and to evaluate approaches for data collection and analysis leading to valid inference about the topic into answerable research and investigation questions leading to a formal research proposal. The broadest scope of qualitative and quantitative research methods is discussed. Application of appropriate research designs and analysis tools are course outcomes.</td>
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<tr>
<td>LOGM 569</td>
<td>Maintenance and Production Management</td>
<td>4</td>
<td>Fall</td>
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<td><strong>Prerequisite:</strong> Well managed and designed operations are a key pillar to the success of any organization. In this course, we will explore how to analyze, manage, and design efficient operations that support the organization's strategic goals. Topics will include process analysis, inventory management, process design, queuing theory, quality control and lean manufacturing. An emphasis will be placed on critical thinking. A major theme of this course is that variability negatively affects operations and that operations management is essentially a battle against variability.</td>
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<tr>
<td>LOGM 570</td>
<td>Principles of Inventory Management</td>
<td>4</td>
<td>Spring</td>
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<td><strong>Prerequisite:</strong> This course develops fundamental understanding of the design and operation of inventory management systems. Specifically, this course provides students with a broad survey of methods and issues concerning inventory systems such as (1) the logistics pipeline with emphasis on the DoD, (2) demand data and forecasting methods, (3) consumable and repairable item inventory models, (4) information theory, and (5) management implications.</td>
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<tr>
<td>LOGM 590</td>
<td>Computer Simulation for Managers</td>
<td>4</td>
<td>Spring</td>
<td>MATH-291, STAT-525, and STAT-535</td>
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<td><strong>Prerequisite:</strong> The course concentrates on the concept of designing a model, running experiments with that model, and analyzing the results. The course's main emphasis is on the proper use of simulation techniques to model systems and answer logistics questions. Course work focuses on the use of the computer to enhance the decision-making capabilities of the logistics manager. This course provides the student with a working knowledge of discrete-event computer simulation as a decision-making tool.</td>
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<tr>
<td>LOGM 590L</td>
<td>Computer Simulation for Managers Lab</td>
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<td>Spring</td>
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<td></td>
<td><strong>Prerequisite:</strong> Lab associated with LOGM-590</td>
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<tr>
<td>LOGM 612</td>
<td>Repair Network and Sustainment Management</td>
<td>4</td>
<td>Summer</td>
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<td><strong>Prerequisite:</strong> In this course students will learn how to manage the sustainment of assets within a large enterprise. The topics covered will include (1) multi-echelon supply chain management, (2) service supply chain management, (3) operations at various levels of repair (e.g., depot, intermediate, and backshop), (4) repair network design and (5) special topics in sustainment.</td>
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<tr>
<td>LOGM 613</td>
<td>Transportation Policy and Strategic Mobility</td>
<td>3</td>
<td>Fall and Spring</td>
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<td><strong>Prerequisite:</strong> Focuses on a study of the complex national and defense transportation policy frameworks that guide the constant development of our transportation systems. Examines how transportation policy impacts, and is, in turn impacted by policies formulated to address other national issues. Particular emphasis is placed on the study of the effects of national policies on the defense transportation system. Policy analysis models are presented and discussed.</td>
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<tr>
<td>LOGM 617</td>
<td>Transportation Systems and Strategic Mobility</td>
<td>4</td>
<td>Fall Winter and Summer</td>
<td>MATH-291, STAT-525, and STAT-535</td>
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<td><strong>Prerequisite:</strong> Examines each transportation mode for similarities and differences. Ownership of the modes is also detailed, along with cost and service characteristics. Each mode is then examined for its particular contribution to the defense transportation system. The mission, organization, resources and financing arrangements of the three transportation operation agencies of the defense transportation system are examined. Problems associated with strategic mobility are emphasized.</td>
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</table>
Course Descriptions

**LOGM 617  Transportation Systems and Strategic Mobility**

Terms Offered: Fall Winter and Summer

Prerequisite:
Examines each transportation mode for similarities and differences. Ownership of the modes is also detailed, along with cost and service characteristics. Each mode is then examined for its particular contribution to the defense transportation system. The mission, organization, resources and financing arrangements of the three transportation operation agencies of the defense transportation system are examined. Problems associated with strategic mobility are emphasized.

**LOGM 619  Transportation Policy and Strategic Mobility**

Terms Offered: Fall and Spring

Prerequisite:
Focuses on a study of the complex national and defense transportation policy frameworks that guide the constant development of our transportation systems. Examines how transportation policy impacts, and is, in turn impacted by policies formulated to address other national issues. Particular emphasis is placed on the study of the effects of national policies on the defense transportation system. Policy analysis models are presented and discussed.

**LOGM 620  Activity Based Costing/Management**

Terms Offered: Summer

Prerequisite:
The course is designed to give the students knowledge of Activity Based Costing (ABC), why traditional accounting practices do not support managerial decision-making, and techniques to perform ABC. Activity Based Management will be introduced to enable the student to utilize the output from ABC. The development and application of non-financial metrics will be covered. Students will be introduced to the Theory of Constraints, and Balanced Scorecard will be covered. Examples from DoD and the commercial sector will be used to illustrate the application of ABC.

**LOGM 621  Air Transportation Management**

Terms Offered: Winter

Prerequisite: LOGM-617
This course focuses on the air operations/air management aspect of the transportation network. As such, the students are expected to develop an understanding of both civilian and military air cargo and air passenger network operations. Topics covered will include: Airline/Air Cargo forecasting and management, principles of air scheduling, and the interaction between the civilian and military air transportation systems. Similarities and differences between these two systems will be covered extensively. The reliance of the DoD on civilian air transportation will be emphasized.

**LOGM 622  Transportation Systems and Strategic Mobility**

Terms Offered: Fall Winter and Summer

Prerequisite:
Examines each transportation mode for similarities and differences. Ownership of the modes is also detailed, along with cost and service characteristics. Each mode is then examined for its particular contribution to the defense transportation system. The mission, organization, resources and financing arrangements of the three transportation operation agencies of the defense transportation system are examined. Problems associated with strategic mobility are emphasized.

**LOGM 626  Supply Chain Management Capstone**

Terms Offered: Spring and Summer

Prerequisite:
This is a program capstone course that concentrates on the relationship of key business processes within the firm and across the network of firms that comprise the supply chain, in any organization. Key emphasis is on the senior leader and manager perspective of managing a complex organization and supply chain, developing various leadership strategies to execute the objective, being able to map key supplier/customer relationships, and ensuring personnel develop and utilize proper metrics to gauge performance of the organization. A capstone project and case study culminate the learning.

**LOGM 627  Supply Chain Management**

Terms Offered: Fall Winter and Spring

Prerequisite:
This course concentrates on the cross-functional integration of key business processes within the firm and across the network of firms that comprise the supply chain in both commercial and DoD organizations. Emphasis is on managing the complexity of the supply chain, developing supply chain strategies, selecting metrics and mapping supply chain networks. The concept of business partnerships will also be explored. A capstone project provides students with hands-on experience in managing the integration of functional skills, such as planning, forecasting, inventory management and distribution.
## Course Descriptions

### LOGM 630 Forecasting Management

Terms Offered: Fall 4

#### Prerequisite: STAT-525 and STAT-535

Since the DoD community collects much of its data as a natural time series, this course is concerned with the application of time series analysis theory in describing and forecasting logistics performance. This course covers analysis of time series data patterns, introduction of major forecasting techniques, measuring the effectiveness of these techniques, and implementing time series analysis theory in describing and forecasting logistics performance. Statistical developments will be brief with an intent to survey a wide variety of concepts. Forecasting methods covered include: moving average; exponential smoothing; regression; econometric; and Box-Jenkins.

### LOGM 630 Forecasting Management

Terms Offered: Fall 3

#### Prerequisite: STAT-525 and STAT-535

Since the DoD community collects much of its data as a natural time series, this course is concerned with the application of time series analysis theory in describing and forecasting logistics performance. This course covers analysis of time series data patterns, introduction of major forecasting techniques, measuring the effectiveness of these techniques, and implementing time series analysis theory in describing and forecasting logistics performance. Statistical developments will be brief with an intent to survey a wide variety of concepts. Forecasting methods covered include: moving average; exponential smoothing; regression; econometric; and Box-Jenkins.

### LOGM 631 Scheduling: Theory and Application

Terms Offered: Summer 3

#### Prerequisite: MATH-291, STAT-525 and STAT-535

This course is an introduction to scheduling theory with applications in manufacturing and services. The course is of primary interest to officers in the maintenance career field who often encounter production scheduling problems in an industrial setting as well as workforce scheduling problems. Manufacturing applications include machine scheduling, job shop scheduling, scheduling of flexible assembly systems, and planning and scheduling in supply chains. Services applications include reservations and timetabling, tournament scheduling, planning and scheduling in transportation, and workforce scheduling. The course is quantitative in nature but will also address management implications.

### LOGM 631 Scheduling: Theory and Application

Terms Offered: Summer 4

#### Prerequisite: MATH-291, STAT-525 and STAT-535

This course is an introduction to scheduling theory with applications in manufacturing and services. The course is of primary interest to officers in the maintenance career field who often encounter production scheduling problems in an industrial setting as well as workforce scheduling problems. Manufacturing applications include machine scheduling, job shop scheduling, scheduling of flexible assembly systems, and planning and scheduling in supply chains. Services applications include reservations and timetabling, tournament scheduling, planning and scheduling in transportation, and workforce scheduling. The course is quantitative in nature but will also address management implications.

### LOGM 634 Reliability, Maintainability and Supportability

Terms Offered: Fall and Winter 3

#### Prerequisite: LOGM-525 or 4 Credits of STAT 500 level or higher

Creating and sustaining military capability is the purpose of military leadership and management. Reliability and maintainability (R&M) are component characteristics which define the ability of a product to perform its specified functions throughout its operational life. Component R&M of the military system are primary determinants of military capability. This course teaches fundamental R&M and product warranty concepts. Additionally, probability theory is discussed and employed as a tool to quantitatively define these concepts. Topics discussed include the measures which quantitatively define component R&M, the relationships between reliability, maintainability, availability, and the prediction of R&M measures.

### LOGM 634 Reliability, Maintainability and Supportability

Terms Offered: Fall and Winter 4

#### Prerequisite: LOGM-525 or 4 Credits of STAT 500 level or higher

Creating and sustaining military capability is the purpose of military leadership and management. Reliability and maintainability (R&M) are component characteristics which define the ability of a product to perform its specified functions throughout its operational life. Component R&M of the military system are primary determinants of military capability. This course teaches fundamental R&M and product warranty concepts. Additionally, probability theory is discussed and employed as a tool to quantitatively define these concepts. Topics discussed include the measures which quantitatively define component R&M, the relationships between reliability, maintainability, availability, and the prediction of R&M measures.

### LOGM 636 Service Operations Management

Terms Offered: Winter 3

#### Prerequisite: LOGM-568

The body of knowledge pertaining to the management of operations has evolved largely in the context of manufacturing. However, the majority of operations in both the commercial and defense sectors are more properly classified as services, whose outputs are less tangible. This course draws on production management techniques to enhance the effectiveness of managers of service operations. Topics covered include characteristics of services, establishing customer service levels, designing service delivery systems, measuring system performance, the psychology of waiting lines, and scheduling personnel and capacity.
# Course Descriptions

<table>
<thead>
<tr>
<th>LOGM 639</th>
<th>Reliability, Maintainability and Supportability</th>
<th>3</th>
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</thead>
<tbody>
<tr>
<td><strong>Terms Offered</strong></td>
<td>Fall and Winter</td>
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</tr>
<tr>
<td><strong>Prerequisite:</strong></td>
<td>LOGM-525 or 4 Credits of STAT 500 level or higher</td>
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</tbody>
</table>

Creating and sustaining military capability is the purpose of military leadership and management. Reliability and maintainability (R&M) are component characteristics which define the ability of a product to perform its specified functions throughout its operational life. Component R&M of the military system are primary determinants of military capability. This course teaches fundamental R&M and product warranty concepts. Additionally, probability theory is discussed and employed as a tool to quantitatively define these concepts. Topics discussed include the measures which quantitatively define component R&M, the relationships between reliability, maintainability, and availability, and the prediction of R&M measures.

<table>
<thead>
<tr>
<th>LOGM 644</th>
<th>Current Topics in Logistics</th>
<th>3</th>
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<tbody>
<tr>
<td><strong>Terms Offered</strong></td>
<td>Summer</td>
<td></td>
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<tr>
<td><strong>Prerequisite:</strong></td>
<td>This course is a seminar-based investigation into current and emerging topics which originate in, or affect, logistics thought or action. The purpose of this course is to provide knowledge depth to students on critical issues most likely to affect the logistics field in the coming years. The main source of these issues will be recent academic and trade publications. Following individual, in-depth critiques of these works, class members will discuss topics in an open discussion format. Students will be challenged to take and defend their positions on a variety of issues relevant to the field of logistics. A final project will allow each student to more deeply explore an area of special interest within the field of logistics.</td>
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<tr>
<th>LOGM 644</th>
<th>Current Topics in Logistics</th>
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<tbody>
<tr>
<td><strong>Terms Offered</strong></td>
<td>Summer</td>
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<tr>
<td><strong>Prerequisite:</strong></td>
<td>This course is a seminar-based investigation into current and emerging topics which originate in, or affect, logistics thought or action. The purpose of this course is to provide knowledge depth to students on critical issues most likely to affect the logistics field in the coming years. The main source of these issues will be recent academic and trade publications. Following individual, in-depth critiques of these works, class members will discuss topics in an open discussion format. Students will be challenged to take and defend their positions on a variety of issues relevant to the field of logistics. A final project will allow each student to more deeply explore an area of special interest within the field of logistics.</td>
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<tr>
<th>LOGM 650</th>
<th>Seminar in Space Logistics</th>
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<tr>
<td><strong>Terms Offered</strong></td>
<td>Fall</td>
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<tr>
<td><strong>Prerequisite:</strong></td>
<td>This course will address, in a seminar format, the activities associated with supporting all aspects of military and civilian space operations. Topics to be covered include: logistical support for spacecraft, satellites, stations, facilities, or other entities on earth orbits, or on orbits/trajectories associated with or situated on other celestial bodies. Discussion will address planning for total life cycle support, continued support of operation and maintenance, and current issues in space logistics operations and support.</td>
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<table>
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<tr>
<th>LOGM 651</th>
<th>Seminar in Petroleum Management</th>
<th>3</th>
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<tbody>
<tr>
<td><strong>Terms Offered</strong></td>
<td>Summer</td>
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<tr>
<td><strong>Prerequisite:</strong></td>
<td>This course will provide an overview of the primary aspects of petroleum management within the Department of Defense. Major topics to be covered include: product procurement, transportation modal selection, storage and inventory management, quality assurance, distribution, and joint operations. Additional areas include alternative fuels, environmental concerns, and interfaces with key Department of Defense organizations.</td>
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<tr>
<th>LOGM 655</th>
<th>Text Mining</th>
<th>3</th>
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<tr>
<td><strong>Terms Offered</strong></td>
<td>Fall</td>
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<tr>
<td><strong>Prerequisite:</strong></td>
<td>Text mining is the organization, classification, labeling and extraction of information from text sources. In these days of more information readily available through the internet, analysts and decision makers find themselves overloaded with data. Text mining is an application which can help analysts glean necessary information either for general understanding about a corpus of text documents, or for putting text into a form useful for the application of alternative analysis techniques. This course will introduce students to this rapidly growing field and equip them with some of its basic principles and tools as well as its general mindset. Students will learn concepts, techniques and tools they need to deal with text mining practice in a joint military context.</td>
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<tr>
<th>LOGM 660</th>
<th>Strategy for Logistics</th>
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<tr>
<td><strong>Terms Offered</strong></td>
<td>Fall</td>
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<tr>
<td><strong>Prerequisite:</strong></td>
<td>This course focuses on the strategy process and its specific application to the logistics discipline. It covers the strategy formulation, implementation, and evaluation process at the enterprise level to include discussions of the top level decisions and their long-term impact on the organization. The course will apply those concepts to the major decision factors involving infrastructure and organizational issues in logistics enterprises and business units.</td>
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<th>LOGM 660</th>
<th>Strategy for Logistics</th>
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<tr>
<td><strong>Terms Offered</strong></td>
<td>Fall</td>
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<tr>
<td><strong>Prerequisite:</strong></td>
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## Course Descriptions

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<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Terms Offered</th>
<th>Credits</th>
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<tbody>
<tr>
<td>LOGM 668</td>
<td>Special Topics in Nuclear Deterrence</td>
<td>Summer</td>
<td>4</td>
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<td><strong>Prerequisite:</strong></td>
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<td>We will examine the theory of nuclear deterrence through guided readings, seminar discussions, and research on four core topics. (1) NUCLEAR DETERRENCE: What is the proper balance between credibility and stability? How much is enough? Can rogue states and terrorists be deterred? (2) ARMS CONTROL AND COUNTERPROLIFERATION: How should the U.S. respond to states pursuing nuclear weapons? Does the Nonproliferation Treaty continue to hold value? Should the U.S. ratify the Comprehensive Test Ban Treaty? (3) NUCLEAR ENTERPRISE: What is the current &quot;health&quot; of the nuclear stockpile?</td>
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<tr>
<td>LOGM 675</td>
<td>Logistics Management Colloquium</td>
<td>All</td>
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<td><strong>Prerequisite:</strong></td>
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<td>This course introduces students to current issues, concerns, and practices of logistics management through a series of presentations by key logistics personnel during the graduate program.</td>
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<tr>
<td>LOGM 682</td>
<td>Applied Business Analytics</td>
<td>Summer</td>
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<td><strong>Prerequisite:</strong></td>
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<td>This course provides an applied introduction to the field of business analytics, which has been defined as the extensive use of data, statistical and quantitative analysis, exploratory and predictive models, and fact-based management to drive decisions and actions. In this course you will experience an intensive, hands-on introduction to applied business analytics with the R programming language. You will learn and apply the fundamental skills required to acquire, munge, transform, manipulate, visualize, and analyze data in a computing environment that fosters reproducibility.</td>
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<tr>
<td>LOGM 685</td>
<td>Performance Measurement and Benchmarking Using Data Envelopment Analysis</td>
<td>Fall</td>
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<td><strong>Prerequisite:</strong></td>
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<td>This course includes topics for measuring the performance of various organizations, processes, individuals, machines and other entities using data envelopment analysis (DEA). The major requirement of this course is completing a research project on a topic relevant to the U.S. Air Force and/or DoD.</td>
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<tr>
<td>LOGM 699</td>
<td>Master's Level Special Studies</td>
<td>All</td>
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<td><strong>Prerequisite:</strong></td>
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<td>Special topics of study for masters students in Logistics and Supply Chain Management under the direction of a member of the Logistics faculty.</td>
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<tr>
<td>LOGM 701</td>
<td>Advanced Research Methods</td>
<td>Winter</td>
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<td><strong>Prerequisite:</strong></td>
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<td>This advanced research methods course provides a PhD-level introduction to academic research and theory with a specific focus on concepts necessary to properly write and defend a research proposal.</td>
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<tr>
<td>LOGM 768</td>
<td>Advanced Topics in Logistics</td>
<td>Fall</td>
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<td><strong>Prerequisite:</strong></td>
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<td>This course is intended for students planning advanced study and research in the areas of logistics and supply chain management. A continuation of material covered in LOGM 627, the course covers in more detail the theoretical properties of product support and physical distribution systems found in defense and commercial sector contexts. Course topics are drawn from the current literature.</td>
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<tr>
<td>LOGM 770</td>
<td>Advanced Inventory Theory</td>
<td>Fall</td>
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<td><strong>Prerequisite:</strong></td>
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<td>This course develops advanced concepts in the design and operation of inventory management systems. Specifically, this course will examine various research methods to study advanced inventory theories. Students will investigate inventory theoretic issues such as demand data, forecasting of inventory requirements, dependent and independent inventory modeling, and select topics as determined by the professor. The emphasis is on both analytic development and data analysis.</td>
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<tr>
<td>LOGM 791</td>
<td>Research Project for Mobility Managers</td>
<td>All</td>
<td>1-7</td>
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<td><strong>Prerequisite:</strong></td>
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<td>A research topic is selected from mobility problems of interest to USAF and DoD. This topic is thoroughly investigated by the student, and the findings, recommendations, and conclusions are presented as a graduate research paper under the supervision of an AFIT faculty member.</td>
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<tr>
<td>LOGM 799</td>
<td>Thesis Research</td>
<td>All</td>
<td>1-12</td>
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<td><strong>Prerequisite:</strong></td>
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<td>A research topic is selected from those problems of interest to USAF and DoD. The topic is thoroughly investigated by the student and the findings, recommendations, and conclusions are presented in a formal thesis under the supervision of a departmental professor.</td>
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<tr>
<td>LOGM 899</td>
<td>Doctoral Level Special Studies</td>
<td>All</td>
<td>1-12</td>
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<td><strong>Prerequisite:</strong></td>
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<tr>
<td></td>
<td>Special topics of study for doctoral students in Logistics under the direction of a member of the Logistics faculty.</td>
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Course Descriptions

LOGM 999 Dissertation Research 1-12
Terms Offered All
Prerequisite:
Dissertation research conducted in Logistics; including, but not limited to, selection of research advisor and topic, formation of research committee, supervision of the research, presentation and defense of the dissertation in accordance with Doctoral Council policy letters.

OPER 498 Research Methods 1
Terms Offered Spring
Prerequisite:
This course is designed to provide the student with an understanding of the research process and department research expectations. Topics include problem definition, use of secondary sources, research design and communication of results. Students prepare and present a research proposal.

OPER 500 Operational Sciences Seminar 0
Terms Offered All
Prerequisite:
This seminar acquaints students with the application of operations research to Air Force and DoD issues and with faculty research interests. This course also provides a forum for lectures by distinguished visitors.

OPER 501 Quantitative Decision Making 3
Terms Offered Fall
Prerequisite:
This is an introductory course in management science applications for the logistics, systems, acquisition and transportation manager. Emphasis is on understanding and applying the techniques to managerial problem solving and decision making. Major topics include linear programming, decision theory, networks, and queueing theory.

OPER 501L Quantitative Decision Making Lab 0
Terms Offered Fall
Prerequisite:
Lab associated with OPER-501

OPER 505 Business Analytics 4
Terms Offered Fall
Prerequisite:
This is an introductory course in operations research/management science. Major topics include Linear Optimization, Descriptive Data Mining, Linear Regression, Monte Carlo Simulation, and Decision Analysis. Emphasis is on understanding understanding and applying the techniques to managerial problem solving and decision making. Students will be expected to demonstrate their ability to identify applications, formulate appropriate models, and obtain and interpret analytical results. Microsoft Excel with add-in utilities is the primary analytical tool.

OPER 510 Introduction to Mathematical Programming 4
Terms Offered Fall
Prerequisite:
In this breadth-oriented course, students learn the art and science of formulating mathematical programs and are exposed to classical problems in linear programming, nonlinear programming, integer programming, and dynamic programming. Selected solution methods and their theoretical underpinnings for each realm are introduced and motivated, as well as the use of commercial solvers and interpretation of results. Concepts such as duality and optimality conditions will be given a limited treatment, primarily to understand how to better utilize and tailor settings for commercial software.

OPER 540 Stochastic Modeling and Analysis I 4
Terms Offered Winter
Prerequisite: STAT-583 or STAT-587 or Approval of Instructor
This course applies the fundamental probability theory to develop standard approaches to stochastic modeling in operations research. Specific topics include conditional probability and expectation, the Poisson process and exponential distribution, discrete-time Markov chains, and continuous-time Markov chains. The various models are discussed in the context of military applications.

OPER 542 Decision Analysis Using Value Focused Thinking 4
Terms Offered Winter
Prerequisite: STAT-583 or STAT-587
This course presents a logical, systematic procedure for applying Multiobjective Decision Analysis (MODA) to complex, real world decision problems. Emphasis is placed evenly across the socio-technical process to applying value focused thinking to create value for decision makers facing difficult decisions. Topics to be covered include: identifying & structuring objectives, selecting appropriate attributes to measure achievement of objectives, developing value functions that accurately reflect decision-maker preference structures, and analysis techniques for obtaining insight from the developed model. Techniques for applying Decision Analysis in practice are introduced.
Course Descriptions

OPER 543 Decision Analysis 4
Terms Offered Winter
Prerequisite: STAT-583 or STAT-587 or Approval of Instructor
This course presents a logical, systematic procedure for transforming complex decision problems into simpler, more manageable decision problems by a sequence of transparent steps. A theoretical foundation is developed, including: structuring a decision problem w/decision trees & decision diagrams, treating uncertainty using probability as a measure of belief, treating risk attitude using von Neumann-Morgenstern expected utility theory, & examining the value of information. Techniques for applying Decision Analysis in practice are introduced. Focuses on decision problems with a single value measure.

OPER 544 Operational Decision Support Systems 2
Terms Offered Summer
Prerequisite: OPER-543, OPER-561 and OPER-610 or Approval of Instructor
This course blends techniques from the fields of operations research, management sciences, artificial intelligence and information systems to create decision support systems primarily using Excel, including Excel VBA and specialized add-ins for analysis. This course will integrate the use of spreadsheets with operations research topics such as decision analysis, Monte-Carlo simulation and optimization models.

OPER 544L Operational Decision Support Systems Lab 1
Terms Offered Winter
Prerequisite: This course is a 1 credit lab taught in conjunction with OPER 544 lecture.

OPER 561 Discrete-Event Simulation 4
Terms Offered Spring
Prerequisite: STAT-583 and STAT-587 or Approval of Instructor
This is an introductory course on the use of computer simulation modeling to analyze complex military systems. The focus of the course is on the development of discrete-event simulation models and the analysis of simulation model input and output. A modern simulation language is taught to provide a modeling framework and the means for implementing a computerized model. Basic concepts important to simulation studies such as random number and random variate generation, model verification and validation, and output analysis are discussed. Examples are oriented toward DoD operational systems.

OPER 601 Operations Research Seminar 0
Terms Offered All
Prerequisite: This course is designed to provide students, primarily those in the doctoral program with information relating to the state-of-the-art within the Operations Research field. Prominent speakers in the field will be invited and used whenever possible. This course may also be used by the faculty to present recent developments in their research and by doctoral candidates to present progress reports on their dissertation research.

OPER 610 Linear Programming 3
Terms Offered Winter
Prerequisite: OPER-510 and MATH-523 or Approval of Instructor
In this depth-oriented course, students learn the theoretical concepts that motivate and enable key exterior and interior solution methods for linear programming as a basis for future studies. While refining mathematical programming skills, they learn to implement these solution methods with emphasis on key concepts: identifying an initial feasible solution, iterating to assure a convergent sequence of improving feasible solutions, and identifying an optimal or epsilon-optimal solution. Selected methods are enhanced by a rigorous understanding and application of duality theory.

OPER 612 Nonlinear Programming 3
Terms Offered Fall
Prerequisite: OPER-610 or Approval of Instructor
This course is a detailed study of nonlinear programming techniques. The differential calculus and Karush-Kuhn-Tucker results for constrained optimization are presented, including convexity, local and global optima, and saddle point conditions. A thorough treatment of duality theory and Lagrangian duality constitutes a major portion of the course, and serves to unify several key points. Various classes and types of techniques for solving nonlinear programs are presented, including geometric programming. Modern derivative-free optimization methods are also introduced.

OPER 612 Nonlinear Programming 4
Terms Offered Fall
Prerequisite: OPER-610 or Approval of Instructor
This course is a detailed study of nonlinear programming techniques. The differential calculus and Karush-Kuhn-Tucker results for constrained optimization are presented, including convexity, local and global optima, and saddle point conditions. A thorough treatment of duality theory and Lagrangian duality constitutes a major portion of the course, and serves to unify several key points. Various classes and types of techniques for solving nonlinear programs are presented, including geometric programming. Modern derivative-free optimization methods are also introduced.

OPER 613 Integer Programming 3
Terms Offered Summer
Prerequisite: OPER-510 or Approval of Instructor
Integer programming is the class of mathematical programming models that requires some or all of the variables to assume discrete or integer values. This course covers modeling, theoretical developments, and the principal solution procedures associated with the subject. At the completion of the course, the student should be able to recognize when integer programming is appropriate, set up a model for solution by an available algorithm, solve the model, interpret the solution, and understand the theoretical basis for the solution procedure.
Course Descriptions

OPER 614 Dynamic Programming 3
Terms Offered Fall
Prerequisite: OPER-510 and OPER-504 or OPER-540 or Approval of Instructor
This course addresses the theory and practice of dynamic programming, i.e., optimal sequential decision making over time. The course will stress intuition, the mathematical foundations being for the most part elementary. Applications will be considered in capital investment, transportation, and production and inventory control.

OPER 615 Large Scale Systems Optimization 3
Terms Offered Winter
Prerequisite: OPER-610 or Approval of Instructor
Large scale systems optimization takes advantage of the structure of large problems to develop efficient algorithms for their solution. Many large problems can only be solved by taking advantage of these special structures. The course examines the relationship between special structures and the algorithms which take advantage of them. Topics include interior point methods, Dantzig-Wolfe decomposition, column generation, Bender's decomposition, generalized upper bounding, and Lagrangian relaxation. Several examples of large problems will be examined, including scheduling a delivery fleet.

OPER 617 Networks 3
Terms Offered Spring
Prerequisite: OPER-610 or Approval of Instructor
This course is an introduction into the study of networks. Topics include basic graph terminology, formulation of problems involving graphs, maximum flow, shortest path, minimum cost flow, minimum spanning tree, and network design. The algorithms and their corresponding computational complexity are discussed, motivated by a wide variety of applications including routing and inventory management.

OPER 621 Multicriteria Optimization 3
Terms Offered Winter
Prerequisite: OPER-501 or OPER-510, or Approval of Instructor
This course exposes students to a variety of solution methods for multicriteria optimization problems with an emphasis on theory and applications. Topics covered include efficient points, goal programming, weighted sum and scalarization techniques, multiobjective linear programming, multiobjective combinatorial optimization, and multiobjective versions of well known easy and hard optimization problems.

OPER 623 Heuristic Search Methods 3
Terms Offered Spring
Prerequisite: OPER-501 or OPER-510, or Approval of Instructor
Introduction and application of modern search methods for solving complex optimization problems. Topics include genetic algorithms, simulated annealing, tabu search, hybrid combinations, and adaptive techniques.

OPER 626 Scheduling Theory 3
Terms Offered Summer
Prerequisite: OPER-510
This course covers the introduction and application of heuristic solution procedure approaches for solving complex problems. Topics include fundamental heuristic methods such as greedy, and local search as well as meta-heuristic methods such as genetic algorithms, simulated annealing, tabu search and ant colony search.
Course Descriptions

**OPER 638 Cost and Risk Analyses** 4
Terms Offered: Fall
Prerequisite: OPER-540, OPER-542, and STAT-583 or STAT-587

This course develops the theory of cost and risk analysis. The effects of time on economic and monetary evaluation are studied, and risk and its impact on decision making are investigated. Specific cost topics include an overview of defense requirements, acquisition, and budgeting systems, inflation indices and time-value of money, cost estimation techniques for development, procurement, and operating and support phases. The risk topics include engineering risk and risk approaches used within the Air Force, operational risk management, utility and prospect theory, adversarial risk and game theory.

**OPER 641 Stochastic Modeling and Analysis II** 3
Terms Offered: Spring
Prerequisite: OPER 540 or Approval of Instructor

This course develops advanced concepts in the modeling and analysis of complex stochastic systems. Specific topics include generalizations of the Poisson process, renewal theory, regenerative processes, Markov-renewal theory, and Markov-regenerative processes. The course also introduces martingale, Brownian motion, and other diffusion processes.

**OPER 642 Decision Analysis Under Uncertainty and Risk** 3
Terms Offered: Spring
Prerequisite: #MULTIVALUE

This course builds upon the Multiobjective Decision Model (MODA) by including uncertainty and risk into the problem formulation. Emphasis is placed evenly across the socio-technical process to create value for decision makers facing difficult decisions. Topics covered include: structuring a decision problem with decision trees & decision diagrams, treating uncertainty using probability as a measure of belief, treating risk attitude using von Neumann-Morgenstern expected utility theory, applying Monte Carlo simulation to uncertainty, and examining the value of information. Particular emphasis is placed on understanding the relationships between preference statements, value functions, and value trade-offs.

**OPER 643 Multiobjective Decision Analysis** 3
Terms Offered: Spring
Prerequisite: #MULTIVALUE

This course examines the multiattribute value problem. Topics covered include: identifying and structuring objectives, selecting appropriate attributes to measure achievement of objectives, developing value functions that accurately reflect decision-maker preference structures, and analysis techniques for obtaining insight from the developed model. Particular emphasis is placed on understanding the relationship between preference statements, value functions, and value trade-offs.

**OPER 645 Risk Modeling and Analysis** 4
Terms Offered: Summer
Prerequisite: OPER-540 or Approval of Instructor

This is a course on the theory and practice of risk analysis. Specific topics include quantitative risk assessment, multi-objective risk assessment, multi-objective risk analysis, Bayesian networks, game theory, actuarial risk, and fault tree analysis. Military and industrial applications are discussed.

**OPER 646A Operational Reliability** 3
Terms Offered: Fall
Prerequisite: STAT-583 and STAT-587

Reliability and maintainability (R&M) are characteristics which define the ability of a system to perform its specified functions throughout its operational life. R&M of the military system are primary determinants of military capability. This course introduces fundamental mathematical concepts and applications for modeling reliability, providing reliability estimates, and establishing optimal maintenance policies. Additionally, probability theory is discussed and employed as a tool to quantitatively define these concepts. Topics discussed include the measures which quantitatively define system and component R&M, the relationships between reliability, maintainability, and availability, prediction of R&M measures, accelerated testing, and reliability growth models.

**OPER 647 Queueing System Analysis** 3
Terms Offered: Fall
Prerequisite: OPER-540 or Approval of Instructor

This course begins with an overview of stochastic modeling and transforms methods. These techniques are then employed in equilibrium analysis of simple Markov and embedded Markov queueing systems. Results are extended to address more advanced modeling concepts such as priority customers, bulk arrivals or service, generalized distributions of interarrival or service times, and networks of queues. Potential applications are discussed, including performance evaluation and optimization of communication systems, transportation networks, computer systems, and other resource-constrained operations.

**OPER 660 Statistical Aspects of Simulation: Input Analysis** 3
Terms Offered: Summer
Prerequisite: OPER-561 or Approval of Instructor

This course provides an indepth treatment of a number of important issues in the Statistical Aspects of Simulation. The emphasis in this course is on input modeling. Topics include random number generation, random variate modeling and generation, the structure of simulation programs, and model validation.
**Course Descriptions**

**OPER 661  Statistical Aspects of Simulation: Output Analysis**

**Terms Offered**: Fall

**Prerequisite**: OPER-561 or Approval of Instructor

This course provides an in-depth treatment of a number of important issues in the Statistical Aspects of Simulation. The emphasis in this course is on output modeling. Topics include the analysis of terminating and steady state simulation output as well as variance reduction techniques. It is intended to provide a rigorous treatment of current issues within the simulation literature.

**OPER 671  Combat Modeling**

**Terms Offered**: Summer

**Prerequisite**: OPER-561 or Approval of Instructor

The purpose of this course is to expose students to combat modeling by examining air operations from an application oriented point of view to include mission planning. Basic combat processes are discussed along with general methods for how they are modeled to include aggregated approaches such as Lanchester equations. The Advanced Framework for Simulation, Integration, and Modeling (AFISM) is introduced and used to develop and modify scenarios for analysis as part of the course requirements.

**OPER 674  Joint Mobility Modeling**

**Terms Offered**: Winter

**Prerequisite**: OPER-561 or Approval of Instructor

The purpose of this course is to present mobility modeling from an application oriented, large-scale point of view. Models currently in use for DoD analysis are examined. Particular attention will be given to the air mobility problem and its relation to land and sea mobility. Both strategic and theater mobility are explored.

**OPER 676  Information Operations Research**

**Terms Offered**: Summer

**Prerequisite**: OPER-561 or Approval of Instructor

This course is designed to increase the awareness and integration of the relationship between Information Operations (IO) and Operations Research. The focus will be on the tools, techniques, theories, and models currently in use for IO analysis. Particular attention will be paid to current IO modeling issues. This course is open to U.S. military students only.

**OPER 679  Empirical Modeling**

**Terms Offered**: Spring

**Prerequisite**: STAT-583 or STAT-587, or Approval of Instructor

Analysis of experimental and observational data from engineering systems. Focus on empirical model building using observation data for characterization, estimation, inference and prediction.

**OPER 681  Statistical Process Control**

**Terms Offered**: Fall

**Prerequisite**: STAT-583 or STAT-587, or Approval of Instructor

This course provides an in-depth treatment of the fundamental concepts and methods of modern statistical process control. The primary focus will be on the use of control charts for monitoring the process mean and variance. Other topics include process capability analysis, the modern role of acceptance sampling, and the use of such statistical techniques within the context of total quality management.

**OPER 682  Operational Data Science With R**

**Terms Offered**: Summer

**Prerequisite**: #MULTIVALE

Data Science is the study of the generalizable extraction of knowledge from data. Being a data scientist requires an integrated skill set spanning operations research, statistics, and computer science along with a good understanding of crafting a problem formulation for effective solutions. This course will introduce students to this rapidly growing field and equip them with some of its basic principles and tools as well as its general mindset. Students will learn concepts, techniques and tools they need to deal with various facets of data science practice in an Air Force context.

**OPER 683  Response Surface Methodology**

**Terms Offered**: Fall

**Prerequisite**: #MULTIVALE

This is a course on advanced experimental design. Topics include process improvement with steepest ascent, design optimality criteria, designs for fitting response surfaces, analysis of non-linear response functions, and designs subject to randomization restrictions. State-of-the-art experimental design and analysis methods are included as special topics.

**OPER 684  Quantitative Forecasting Techniques**

**Terms Offered**: Winter

**Prerequisite**: STAT-583 or STAT-587, or Approval of Instructor

This is a course in applied techniques to predict discrete time-series phenomena. The emphasis is on understanding and applying forecasting tools in analysis and management settings. Both classical smoothing methods and the Box-Jenkins methodology for model identification, estimation, and prediction are presented. Time series data are modeled and predictions made with interactive computer software.

**OPER 685  Applied Multivariate Analysis I**

**Terms Offered**: Fall and Spring

**Prerequisite**: STAT-583, STAT-587 or Approval of Instructor

This course is oriented toward the computer-assisted analysis of multidimensional data. The course will present statistical techniques such as multiple regression, principal components analysis, canonical correlation, factor analysis, cluster analysis, discriminant analysis, and neural networks. Emphasis will be on practical application to data sets using computerized statistical packages.
Course Descriptions

OPER 688 Operational Experimentation 3
Terms Offered Summer
Prerequisite: OPER-679 or STAT-696 or Approval of Instructor
Introduction to designing experiments for operational testing and evaluation. This is an applied course intended for operations analysts who perform experiments or serve as advisors to experimentation. A statistical approach to the design and analysis of experiments is provided as a means to efficiently study and comprehend the underlying process or system being evaluated. Insight gained leads to improved system performance and quality.

OPER 689 Advanced Statistical Methods for Test 3
Terms Offered Winter
Prerequisite: OPER-679 and OPER-688
This course builds upon the material in the prerequisite course providing advanced coverage in time series modeling, generalized linear models, and advanced experimental design. Examples and projects are focused on problems from the test and evaluation enterprise.

OPER 695 Issues in Defense Analysis 3
Terms Offered Winter
Prerequisite:
This course discusses the role of analyses in defense, national and international security decisions. The course focuses on the analyst’s role in providing structure to complex issues and developing analytically-sound insights to support defense leaders. Specific topics include determining decisions’ values, timeliness, measures of merit, modeling resolution, technique selection, data availability, accuracy, gaining insights, and communicating analytic results. Students examine historical and contemporary case studies to demonstrate the contributions and limitations of analysis in the decision-making process. Additional topics include analytical pitfalls, along with issues of bias, advocacy, and ethics in defense analysis.

OPER 699 Master’s Level Special Study 1-12
Terms Offered All
Prerequisite:
Directed study at an intermediate graduate level on a special topic which is not normally covered in a regularly scheduled course or as part of thesis research. Topic, format, and requirements of the course are determined by the faculty member directing the study. Requires submission of Special Studies Form and syllabus to the department for registration.

OPER 710 Advanced Linear Programming and Extensions 3
Terms Offered Summer
Prerequisite: OPER-610
This course will explore the theoretical properties of the general linear program (LP), developing results concerning extreme points, the existence of extreme point solutions, interior point methods for LP, computational complexity, fractional programming, and current developments in LP.

OPER 712 Advanced Math Programming 3
Terms Offered Fall and Spring
Prerequisite: OPER-612
This course is intended for students planning advanced study and research in the areas of mathematical programming and optimization. A continuation of material covered in OPER 612, the course covers in more detail the theoretical and topological properties of the general nonlinear programming problem. Other topics are drawn from the current literature.

OPER 713 Advanced Integer Programming 3
Terms Offered Fall
Prerequisite: OPER-613
Integer programming is the class of mathematical programming models that requires some or all of the variables to assume discrete or integer values. This course covers advanced modeling and theoretical developments. The course will focus on polyhedral theory, computational complexity, integer lattices, valid inequalities, and Lagrangian relaxation.

OPER 741 Advanced Stochastic Modeling 3
Terms Offered Fall
Prerequisite: OPER-641 or Approval of Instructor
This course covers the advanced analysis and modeling of stochastic processes. Topics include theoretic probability, Markov processes, renewal theory, martingales, stopping theorems, Brownian motion, and large deviation theory.

OPER 743 Decision Analysis Practice 3
Terms Offered Fall and Winter
Prerequisite: At least two of the following courses: OPER 543, OPER 621, OPER 643, OPER 645, or Approval of Instructor.
This course examines the professional practice of decision and risk analysis. The course provides new material on the selection of decision analysis topics, the interface with the decision makers and technical experts, the advanced use of decision analysis software, and the presentation of results to decision makers. Students have the opportunity to apply their knowledge and risk analysis to a real decision for a real decision maker.

OPER 746 Advanced Topics in Reliability 3
Terms Offered Fall and Winter
Prerequisite: OPER 540
This course develops advanced mathematical concepts for application in the reliability and maintainability areas. Topics include censored reliability data analysis, optimal preventive maintenance policies, warranty analysis, burn-in strategies and other topics of current interest. The emphasis is on both analytic development as well as actual application to data analysis. The course will consider the implications of reliability during the system design phase as well as the system operational phase. Simulation software as well as “solver” software will be utilized in class exercises.
## Course Descriptions

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<th>OPER 782</th>
<th>Data Science Practice</th>
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<tr>
<td>Terms Offered</td>
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<td><strong>Prerequisite:</strong></td>
<td>Data Science is the study of the generalizable extraction of knowledge from data. Being a data scientist requires an integrated skill set spanning operations research, statistics, and computer science along with a good understanding of crafting a problem formulation for effective solutions. This course provides students an opportunity to demonstrate their data science knowledge by developing an operationalized analytic product. In this course students will evaluate a process for frontline operators or an organization and support them by integrating data and algorithms into an operationalized analytic product that helps improve their performance. This analytic product can take the shape of a Shiny application, an R package, or other similar analytic product.</td>
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<th>OPER 785</th>
<th>Applied Multivariate Analysis II: Pattern Recognition</th>
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<tr>
<td>Terms Offered</td>
<td>Winter</td>
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<td><strong>Prerequisite:</strong></td>
<td>OPER-685 or Approval of Instructor</td>
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<td><strong>Terms Offered:</strong></td>
<td>This course is a survey course in pattern recognition. Theory, parameters estimation, linear discriminant functions, multilayer neural networks, and other topics. Real-world applications will be emphasized.</td>
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<tr>
<th>OPER 786</th>
<th>Multivariate Analysis III: Advanced Topics</th>
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<tr>
<td>Terms Offered</td>
<td>Spring</td>
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<td><strong>Prerequisite:</strong></td>
<td>OPER-785 or Approval of Instructor</td>
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<td><strong>Terms Offered:</strong></td>
<td>This course examines a variety of topics in pattern recognition such as Bayesian networks, hidden Markov models, neural feature selection procedures and sensor fusion. Recent research in these areas is explored.</td>
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<th>OPER 791</th>
<th>Research Project for Operational Sciences</th>
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<tr>
<td>Terms Offered</td>
<td>All</td>
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<tr>
<td><strong>Prerequisite:</strong></td>
<td>A research topic is selected from problems of interest to USAF and DoD. This topic is thoroughly investigated by the student, and the findings, recommendations, and conclusions are presented as a graduate research paper under the supervision of an AFIT faculty member. Available only for students enrolled in the Test and Evaluation Certificate Program (TECP) or the Intermediate Developmental Education (IDE) program. This course is offered as the 3 credit hour capstone course (distance learning) for TECP students. It may also be taken in residence for 6-7 credit hours by IDE students.</td>
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<th>OPER 799</th>
<th>Thesis Research</th>
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<tr>
<td>Terms Offered</td>
<td>All</td>
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<tr>
<td><strong>Prerequisite:</strong></td>
<td>A research topic is selected from those problems of interest to USAF and DoD. The topic is thoroughly investigated by the student and the findings, recommendations, and conclusions are presented as a formal thesis under the supervision of a departmental professor. On site research is conducted as required. An oral presentation and defense of research work results are required.</td>
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<th>OPER 899</th>
<th>Doctoral Level Special Studies</th>
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<tr>
<td>Terms Offered</td>
<td>All</td>
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<tr>
<td><strong>Prerequisite:</strong></td>
<td>Special topics of study for doctoral students under the direction of a member of the Department of Operational Sciences faculty.</td>
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<tr>
<th>OPER 999</th>
<th>Dissertation Research</th>
<th>1-12</th>
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<tbody>
<tr>
<td>Terms Offered</td>
<td>All</td>
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<tr>
<td><strong>Prerequisite:</strong></td>
<td>Dissertation research conducted in Operations Research; including, but not limited to, selection of research advisor and topic, formation of research committee, supervision of the research, presentation and defense of the dissertation in accordance with Doctoral Council policy letters.</td>
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<thead>
<tr>
<th>PENS 791</th>
<th>Research Project Completion</th>
<th>1-7</th>
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</thead>
<tbody>
<tr>
<td>Terms Offered</td>
<td>Spring</td>
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<tr>
<td><strong>Prerequisite:</strong></td>
<td>Project completion course. Credit given for completion of research project.</td>
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<tr>
<th>TENS 799</th>
<th>Thesis Completion</th>
<th>12</th>
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<tr>
<td>Terms Offered</td>
<td>All</td>
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<tr>
<td><strong>Prerequisite:</strong></td>
<td>Thesis Completion course for graduating students to be taken during the last quarter of study. Registration in TENS 799 for 12 non-billable credit hours is required for all master's students whose research advisors are in the Department of Operational Sciences. The grade assigned to this course is the official thesis grade.</td>
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### Systems and Engineering Management (ENV)

<table>
<thead>
<tr>
<th>COMM 680</th>
<th>Technical Reports and Theses</th>
<th>3</th>
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<tbody>
<tr>
<td>Terms Offered</td>
<td>Summer</td>
<td></td>
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<tr>
<td><strong>Prerequisite:</strong></td>
<td>Analysis of the communication situation in which engineering reports are generated and of specific expository problems involved. Selecting, organizing, and presenting technical information within local and more general conventions to meet the reader's needs. Style and format in formal engineering (with special emphasis on the MS thesis) and consideration of related problems of grammar, syntax, and mechanics as necessary. Locating and using published technical information. Written assignments to demonstrate competence in organizing the student's thesis whenever possible. Approximately on third of the subject matter is presented as formal oral reports by the students. This course should be taken in the quarter in which the thesis topic is chosen.</td>
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<thead>
<tr>
<th>COST 510</th>
<th>Principles of Cost Estimating</th>
<th>3</th>
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<tbody>
<tr>
<td>Terms Offered</td>
<td>Fall</td>
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<tr>
<td><strong>Prerequisite:</strong></td>
<td>This course introduces the student to the cost analysis profession. The course is designed to develop a realistic perspective on the part of the student concerning the tasks a cost analyst is expected to be able to perform, the techniques and methodologies available to the analyst to accomplish the job, and the environment in which the cost analyst will operate.</td>
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</table>
### Course Descriptions

**COST 520 Advanced Concepts in Cost Estimating**

**Terms Offered:** Winter

**Prerequisite:** COST-510

This course builds upon the foundational topics of cost analysis and estimating from COST 510. The techniques, methodologies, and concepts of acquisition estimating are incorporated through the standardized DoD cost estimating and analysis software suite, Automated Cost Estimating and Integrated Tools (ACEIT). Additional topics relevant to the cost estimator are explored. These topics include: cost management, activity based costing, labor rate derivation, earned value management, O&S estimating, aging system issues, software estimating and source selection processes.

**COST 543 Decision Analysis for Cost Analysis**

**Terms Offered:** Winter

**Prerequisite:** STAT-525

This course presents a logical, systematic procedure for transforming complex decision problems into simpler, more manageable decision problems through a sequence of transparent steps. Both theoretical foundations and analytical tools are explored, to include the following: structuring a decision problem with decision trees & decision diagrams, treating uncertainty using probability as a measure of belief, and examining the value of information. Techniques for applying Decision Analysis in practice are introduced.

**COST 610 Project Risk Analysis**

**Terms Offered:** Spring

**Prerequisite:** STAT-525

This course covers the concept of project risk with an emphasis on formal risk analysis methods. The course exposes students to a variety of approaches for evaluating risk and uncertainty as they apply to a dynamic decision-making environment. Topics include defining risk, DoD risk policy, risk identification, risk handling, qualitative and quantitative risk methods. Both analytical and simulation methods for quantifying cost risk will be discussed. In order to cover simulation methods, the general method of Monte Carlo simulation will be introduced.

**COST 625 Operation and Support Cost Estimating**

**Terms Offered:** Fall

**Prerequisite:** COST-510 and COST-520, or approval of instructor

This course is designed to prepare students to address the unique cost concerns related to system life-cycle costs. The Weapon System Acquisition Reform Act of 2009 identified life-cycle costs as critical concern for the profession. The course examines the nature of the challenges. It explores economic theory to develop a theoretical framework for estimating and controlling costs. And it provides students the opportunity to use specific cost-modeling techniques designed to address operation and support (O&S) cost growth. Key topics include optimal timing of modification projects, managing legacy systems, estimating fuel costs, estimating organic and contract depot maintenance, employing scenario-based risk assessment, assessing readiness impacts, and eliciting subject matter expertise.

**COST 630 Defense Cost Economics**

**Terms Offered:** Winter

**Prerequisite:**

This course is divided into two parts. The first part of the course provides the economic foundation of defense as a public good and establishes the role institutions, bureaucracy, collective action, rent-seeking, and public policy play in the defense realm. This first part of the course establishes the framework in which the cost estimator operates. The second part of the course examines topics of interest to cost estimators and relates these to the economic foundations of the first half. These topics include: portfolio analysis, cost growth, acquisition reform, and commercial derivatives.

**COST 668 Cost Analysis Colloquium**

**Terms Offered:** All

**Prerequisite:**

This course exposes students to current, real-world issues, problems, and practices of the defense cost analysis community as viewed by senior individuals and practitioners in the field. The structure of the colloquium consists of approximately 15 presentations by individuals from the cost analysis community during the course of the graduate program. Each guest speaker typically makes a one hour presentation on a selected topic (e.g., a current independent cost analysis) which is followed by an open discussion to allow as much interaction between the guest speaker and students as possible. The presentations focus on cost estimating management, processes, problems, and action taken to mitigate the problems.

**COST 674 Seminar in Cost Analysis**

**Terms Offered:** Winter

**Prerequisite:** COST-510

This seminar is the capstone in the cost analysis curriculum. Its purpose is to integrate the material covered in the curriculum and to introduce the students to current topics and issues of interest to the cost analysis community. The seminar explores current concepts and applications of cost analysis, the demands of life cycle cost management and analysis, and the role of economic analysis. Other current topics are included as appropriate.

**COST 699 Master's Level Special Study**

**Terms Offered:** All

**Prerequisite:**

Directed study at an intermediate graduate level on a special topic which is not normally covered in a regularly scheduled course or as part of thesis research. Topic, format, and course requirements are determined by the faculty member directing the study. Requires submission of Special Studies Form and syllabus to the department for registration.
## Course Descriptions

### ECON 610 Comparative Economic Analysis

**Terms Offered**: Summer

**Prerequisite**: This course applies economic methodologies to a variety of contemporary issues. The foundational economic principles covered in the course include institutional analysis, public choice, game theory and behavioral economics. Topics for comparative analyses include: capitalist and non-capitalist social formations, the role of the U.S. military in exporting democracy, and other current economic issues such as inequality, trade agreements, public debt, or monetary and fiscal policy.

### ECON 640 Econometrics I

**Terms Offered**: Spring

**Prerequisite**: STAT-525 and STAT-535, STAT-583, or STAT-587. Or have approval of instructor.

This course is designed to explore various econometric modeling techniques. The course begins by studying the classical linear model and the theory behind it to include the underlying assumptions and properties of the ordinary least squares estimators and then moves to building sound econometric models. The course then proceeds to other econometric topics to include limited dependent variable techniques and time-series analysis. Exercises will focus on data preparation, model construction, analysis of results, and technical communication.

### EMGT 500 Engineering Management Research Colloquium

**Terms Offered**: All

**Prerequisite**: This course is offered every quarter and is intended to guide students through the research process and prepare them to conduct graduate-level research. A building block approach is used in which the topics for each quarter align with the research process. Students are progressively introduced to research topics, the principles of organizing and conducting research, and methodological approaches. The literature review, prospectus, and research proposal are also discussed. The course also provides the opportunity to informally present their research to student peers and faculty.

### EMGT 501 Engineering Management Curriculum And Research Options

**Terms Offered**: Fall

**Prerequisite**: This seminar guides the students in selecting a focus sequence and a thesis advisor as part of the Engineering Management Program. All focus sequences will be introduced and discussed, along with relevant electives. Faculty will speak on their research interests and provide ideas on how to choose a research project, milestones to establish, and expectations of the completed research. Selected students from the class matriculating one year earlier will present and discuss their research approaches. This seminar shall be scheduled during the first full academic quarter of the full-time quota students' program.
Course Descriptions

EMGT 502  Engineering Management Research Perspectives  0
Terms Offered  Winter

Prerequisite:
This seminar presents the principles of organizing and conducting research. Students are introduced to scientific literature, the concept of research objectives within the scientific method, and alternative methodological approaches. Thesis construction, development, and timelines are discussed. The seminar serves to help students complete their thesis prospectus and prepare to conduct graduate level research.

EMGT 503  Critical Review of Research Literature  0
Terms Offered  Spring and Summer

Prerequisite:
This seminar provides students with an introduction to research literature in a specific area of engineering and/or environmental management and prepares students for conducting critical reviews of such literature. Several seminar groups are formed, led by faculty members, and defined by more focused research areas. Students will lead discussions within their groups on published research papers. Literature review documentation and thesis proposal requirements will also be discussed.

EMGT 504  Engineering Management Thesis Research Review  0
Terms Offered  Summer

Prerequisite:
This seminar provides students with the opportunity to informally present their thesis research before their student peers and faculty, exercising their abilities to clearly articulate the background, literature, research questions, methodologies, and current status of the work in a concise manner. All students will be exposed to the thesis work of their peers and gain a broader perspective on current research issues and the various methods being employed. For large classes, the seminar is scheduled over two academic quarters and is designated as EMGT 505 in the second quarter.

EMGT 505  Engineering Management Thesis Research Review  0
Terms Offered  Fall

Prerequisite:
This seminar provides students with the opportunity to informally present their thesis research before their student peers and faculty, exercising their abilities to clearly articulate the background, literature, research questions, methodologies, and current status of the work in a concise manner. Each student will receive critical feedback from both students and faculty. All students will be exposed to the thesis work of their peers and gain a broader perspective on current research issues and the various methods being employed. For large classes, this seminar is scheduled over 2 academic quarters and is designated as EMGT 504 in the first quarter and EMGT 505 in the second quarter.

EMGT 550  Engineering Economic Decision Analysis  3
Terms Offered  Summer

Prerequisite:
This course studies the analytical techniques necessary to optimize the economic outcome of technical and managerial decisions. Traditional engineering economic concepts such as basic cost concepts and time value of money are reviewed before presenting more complex concepts including comparison of alternatives, economic analysis, capital budgeting, analysis of risk and uncertainty, and decision models.

EMGT 560  Future Dod Energy Systems Engineering  4
Terms Offered  Fall and Spring

Prerequisite:
This course will focus on the engineering of future energy systems to increase the energy resiliency of Department of Defense (DoD) fixed installations, contingency bases and individual warfighter equipment. The course will provide an in-depth look at energy technologies and provide a systematic approach for their conceptualization, design, analysis, operation, and sustainment. Students will compare the generation and storage of solar, fossil, geothermal, nuclear, hydroelectric, and wind energy systems, and develop analysis skills necessary to determine the best technologies for systems integration when considering technical/economic feasibility and operational impact.

EMGT 611  Topics in Crisis Management  3
Terms Offered  Fall

Prerequisite:
The topics in crisis management course will provide the student with a broad background of this emergent area of research and theory. The course will focus on the frameworks and perspectives developed in the literature to aid practitioners in working in crisis environments. The student will come away from the course with a vocabulary and knowledge set ready to be applied to the specific environments they may encounter after they graduate. The purpose of the course is to teach students to view crises as systems and to understand means and mechanisms by which they can be influenced.

EMGT 612  Crisis Management Systems  3
Terms Offered  Winter

Prerequisite: EMGT-611
The crisis management systems course is divided into three modules. Through this course, students will gain an appreciation and understanding of quantitative tools that can be used to prepare for and manage crises. The knowledge developed in EMGT 611 will be applied to analysis and application in real-world situations to aid the students to function effectively in such situations in the future. Module 1 focuses on natural disasters; using tools such as ArcGIS and R, students will collect data to analyze natural disasters. Module 2 focuses on a system model of crisis management. Students will apply a systems perspective to understand the causes of crises and possible interventions. Module 3 is intended to provide students with an overview of the techniques used in probabilistic risk analysis.
Course Descriptions

EMGT 621 Asset Management I  3
Terms Offered: Winter
Prerequisite:
This course covers a wide variety of topics in infrastructure asset management. Fundamental concepts of asset management such as inventory, assessment, condition state, levels of service, and program development are presented to establish a framework for an asset management system. Infrastructure assets are explored from a variety of perspectives to include a systems perspective, an Air Force Policy perspective, and a national/current events perspective.

EMGT 622 Asset Management II  3
Terms Offered: Spring
Prerequisite: STAT-535 and OPER-501
This course explores infrastructure asset management concepts from a systems engineering perspective. It presents foundational systems principles and techniques as applied in the management of infrastructure systems. Topics to be covered include: systems modeling, system risk, monte carlo simulation, sampling methods, and decision modeling analysis techniques.

EMGT 631 Construction Management I  3
Terms Offered: Winter
Prerequisite:
This course will study inspection methods utilized in the construction industry to oversee major projects. The course presents the material in three main thrust areas to help students develop a better understanding of the inspection process: specific criteria and methods, safety, and contingency construction. The topics to be covered include: site work, asphalt, concrete, steel, masonry, roofing, underground piping, electrical, HVAC and mechanical systems, and OSHA safety.

EMGT 632 Construction Management II  3
Terms Offered: Summer
Prerequisite: EMGT-631
Knowledge of construction inspection, engineering, and materials is a necessity for today's Air Force civil engineers. This class provides information on how vertical and horizontal projects should be inspected to include OSHA regulations and ASTM requirements. Construction engineering analysis provides information on how to calculate structural, mechanical, electrical and hydraulic loadings of vertical and horizontal construction.

EMGT 641 Construction Contracts and Law  3
Terms Offered: Fall
Prerequisite:
This course is intended to provide a practical introduction to the legal topics and issues related to the construction process; it is not intended to train the student as a construction lawyer. This course will present the theories, principles, and established rules students are likely to encounter in the construction industry. Topics include the legal aspects of contract documents, drawings, and specifications; owner-engineer-constructor relationship and responsibilities; bids and contract performance; labor laws; governmental administrative and regulatory agencies; and ethics.

EMGT 642 System Dynamics Analysis  4
Terms Offered: Winter
Prerequisite:
This course describes the methodology used for portraying and analyzing the behavior of holistic systems. It introduces the concepts of 'systems thinking', developing the tools for modeling complicated systems of multiple feedback loops typical of management, social, political, and environmental interactions. The primary objective of the course is to instill a systems thinking approach in the mind set of the student. The examples within the course are chosen for applicability to current engineering management issues. In addition, the student will master a modeling tool to facilitate this approach to problem solving.

EMGT 642L System Dynamics Analysis Lab  0
Terms Offered: All
Prerequisite:
Lab associated with EMGT-642

EMGT 643 Introduction to Geographic Information Systems: a Computing Perspective  4
Terms Offered: Summer
Prerequisite:
This course presents an overview of Geographic Information Systems (GIS). There are two distinct topic areas to be covered in this course: (1) computational and data aspect of GIS and (2) GIS operations and functions. In the first topic area, the technology, theories, models, and representations of GIS data and systems will be presented. The method of delivery will primarily be through lectures and class discussions on weekly assigned readings. For the second topic area, experiential learning will be employed. Experiential learning is emphasized through the weekly laboratories accomplishing online tutorials followed by application exercises. The course is designed to develop student expertise in spatial data management, spatial reasoning, problem definition, and skilled application of ESRI's ArcGIS software.

EMGT 643L Geographic Information Systems and Science Lab  0
Terms Offered: Spring
Prerequisite:
Lab Associated with EMGT-643

EMGT 680 Advanced Project Management With Risk Analysis  4
Terms Offered: Winter
Prerequisite: SENG-610
This course builds on foundational material presented in SENG 610 by presenting more advanced tools, techniques, and models for comprehensive project management and risk management in an integrated project management decision framework. The primary goal of the course is to provide the student with sufficient background knowledge and basic tools to confidently manage a project or contribute effectively as a project team member. This is an advanced graduate course that requires substantial independent work outside the classroom.
Course Descriptions

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
<th>Credits</th>
<th>Terms Offered</th>
<th>Prerequisite</th>
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<tbody>
<tr>
<td>EMGT 699</td>
<td>Master's Level Special Study</td>
<td>1-12</td>
<td>All</td>
<td></td>
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<td></td>
<td><strong>Prerequisite:</strong></td>
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<td>Directed study at an intermediate graduate level on a special topic which</td>
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<td>is not normally covered in a regularly scheduled course or as part of thesis</td>
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<td>research. Topic, format, and course requirements are determined by the</td>
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<td>faculty member directing the study. Requires submission of Special Studies</td>
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<td>Form and syllabus to the department for registration.</td>
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<tr>
<td>EMGT 713</td>
<td>Advanced Topics in Crisis Management</td>
<td>3</td>
<td>Spring</td>
<td><strong>Prerequisite:</strong> EMGT-611 and EMGT-612</td>
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<td>Advanced Topics in Crisis Management is a capstone course for the crisis</td>
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<td>management specialty track. Working in small groups, the students will</td>
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<td>devise and execute a crisis management research project of relevance to the</td>
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<td>AF Civil Engineer community. Topic selection is up to the students but</td>
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<td>possible topics could include quantitative natural hazard risk assessments</td>
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<td>for AF installations or modeling AF emergency response performance. Projects</td>
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<td>will apply the principles and techniques learned in EMGT 611 and EMGT 612.</td>
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<tr>
<td>EMGT 721</td>
<td>Constr Optimization &amp; Decision Making</td>
<td>4</td>
<td>Winter and Summer</td>
<td><strong>Prerequisite:</strong> Take EMGT-631, EMGT-632, and STAT-525, or have approval</td>
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<td>of instructor.</td>
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<td>This course explores the latest research developments in optimizing</td>
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<td>construction project decisions during the planning and construction phases,</td>
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<td>including the optimization of bid decisions; contractor and material</td>
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<td>supplier selection; site layout planning; tradeoffs among construction</td>
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<td>time, cost and quality; tradeoffs between site security and construction</td>
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<td>cost; resource allocation and leveling; and building sustainability.</td>
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<td>Decisions and tradeoffs will be explored through instructor-provided</td>
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<td>readings, select peer-reviewed articles, as well as analysis and development</td>
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<td>of optimization models.</td>
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<tr>
<td>EMGT 723</td>
<td>Advanced Topics in Infrastructure Asset Management</td>
<td>3</td>
<td>Summer</td>
<td><strong>Prerequisite:</strong> EMGT-621 and EMGT-622</td>
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<td>This course is an advanced course covering contemporary topics in</td>
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<td>infrastructure asset management. Topics will include the role of</td>
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<td>engineers in the management of federal facilities and infrastructure</td>
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<td>systems, the state of the art in predicting infrastructure decay, critical</td>
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<td>infrastructure protection, infrastructure as socio-technical systems,</td>
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<td>resiliency in infrastructure, and other topics of relevance in the</td>
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<td>infrastructure asset management domain.</td>
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<tr>
<td>EMGT 733</td>
<td>Advanced Topics in Construction Management</td>
<td>3</td>
<td>Fall</td>
<td><strong>Prerequisite:</strong> EMGT-631, EMGT-632 and SENG-610</td>
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<td>Advanced topics in construction management is a capstone course of the</td>
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<td>construction management specialty track. Working in small groups, students</td>
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<td>will devise and execute a construction management research project of</td>
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<td>relevance to the AF civil engineer community. Students will apply the</td>
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<td>principles and techniques learned in EMGT-631, 632, and 641 as they apply</td>
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<td>appropriate quantitative and qualitative techniques to address a real-world</td>
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<td>construction management problem.</td>
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<tr>
<td>EMGT 798</td>
<td>Capstone Project</td>
<td>4</td>
<td>Summer</td>
<td><strong>Prerequisite:</strong></td>
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<td>This course is similar to EMGT 799 but is limited to DL students enrolled</td>
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<td>in the Graduate Engineering Management (GEM) program. The principal purposes</td>
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<td>of the capstone project are to demonstrate the student's ability to integrate</td>
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<td>concepts and techniques acquired through coursework and to demonstrate</td>
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<td>scholarly pursuit of a focused research question, all of which leads to</td>
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<td>enhanced analytical and decision-making skills. The capstone project must</td>
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<td>address a real-world problem in which a topic is selected from a wide variety</td>
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<td>of problems of current interest to the Air Force and/or the Department of</td>
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<td>Defense. The capstone project is an independent effort completed under the</td>
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<td>supervision of departmental faculty. Results are provided in a formal written</td>
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<td>report similar to a thesis.</td>
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<tr>
<td>EMGT 799</td>
<td>Thesis Research</td>
<td>1-12</td>
<td>All</td>
<td><strong>Prerequisite:</strong></td>
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<td>An in-depth study of a research topic selected from variety of problems of</td>
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<td>current interest to the Air Force, with the results presented in a formal</td>
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<tr>
<td>ENGR 648</td>
<td>Physical and Biological Aspects of Aerosols</td>
<td>3</td>
<td>Spring</td>
<td><strong>Prerequisite:</strong></td>
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<td>This course covers an introduction to physical and biological principles of</td>
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<td>aerosols intended primarily for health and safety practitioners and allied</td>
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<td>professions (such as health physics, environmental medicine, and inhalation</td>
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<td>toxicology). Specific areas covered include gas behavior, particle motion</td>
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<td>in air, particle size distributions, aerosol generation, aerosol sampling</td>
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<td>and collection, real-time aerosol monitiorin, aerosol deposition models,</td>
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<td>particle size selective sampling conventions, air purification, and biological</td>
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<td>aerosols.</td>
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<tr>
<td>ENVR 501</td>
<td>GES/GIH Seminar</td>
<td>0</td>
<td>Fall</td>
<td><strong>Prerequisite:</strong></td>
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<td>This course presents the principles of organizing and conducting research</td>
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<td>and will assist students in completing their thesis prospectus. There is a</td>
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<td>significant focus on literature review. Other specific topics: ethics/plagiarism,</td>
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<td>thesis checklist process, and PA approval process. Students from the class</td>
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<td>matriculating one year earlier will present and discuss their research.</td>
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<td>Faculty and guests may also provide lectures detailing current research topics.</td>
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</table>
Course Descriptions

ENVR 502  GES/GIH Seminar 0
Terms Offered  Winter
Prerequisite:
Students will utilize this time to meet with their thesis advisor and research group. Faculty and guests may also provide lectures detailing current research topics.

ENVR 503  GES/GIH Seminar 0
Terms Offered  Spring
Prerequisite:
In this course, students learn how to communicate research results. Students are introduced to the thesis style guide. Other topics include how to prepare and submit papers for publication in technical journals and how to present platform presentations and posters at conferences.

ENVR 504  GES/GIH Seminar 0
Terms Offered  Summer
Prerequisite:
This course provides an opportunity to informally present their thesis research before their thesis peers and faculty, in order to demonstrate effective communication skills and articulate their research to a larger audience. Students will receive critical feedback from both fellow students and faculty. All students will be exposed to the thesis work of their peers and gain a broader perspective on current research issues and the various methods being employed. Faculty and guests may also provide lectures detailing current research topics.

ENVR 505  GES/GIH Seminar 0
Terms Offered  Fall
Prerequisite:
This course provides a conceptual understanding of ecology, including basic concepts and approaches, major elements of American environmental policy, political processes and institutions, public policy tools, and environmental policy analysis.

ENVR 511  Environmental Management and Policy 3
Terms Offered  Winter
Prerequisite:
This course is designed to provide an intensive introduction to the field of environmental management and policy, including basic concepts and approaches, major elements of American environmental policy, political processes and institutions, public policy tools, and environmental policy analysis.

ENVR 532  Air Resources Management 3
Terms Offered  Fall
Prerequisite:
An air pollution survey course to advance the student's knowledge of the sources, emissions, health and environmental effects, dispersion and transport, atmospheric interactions, and federal regulations dealing with air pollution. It includes a discussion of current air pollution topics including ozone depletion, acid rain, and global warming needed for the management of the air resources in our society. Also included is basic design of air pollution control systems.

ENVR 534  Ecology, Limnology, and Natural Resources 3
Terms Offered  Summer
Prerequisite:
This course is to familiarize the student with ecology, limnology, natural resources and general life science principles. A broader understanding of the many interactions of earth's living and non-living systems will facilitate better decision making and land development practices. This class will focus on a conceptual understanding of genetics, species, population and ecosystem ecology, global climate and global issues. Also included will be examination of current topics and ecosystems through an individual extensive review of the ecosystem of choice.

ENVR 535  Solid and Hazardous Waste Management 3
Terms Offered  Winter and Summer
Prerequisite:
This course provides an understanding of the problems of solid waste and hazardous waste management. Collection, storage, treatment, and disposal technologies and regulations will be discussed, with emphasis on sound engineering and economic solutions. Public health and risk communication issues will be addressed, as will the responsibilities of waste generators, transporters, and managers of waste generators, transporters, and managers of waste control facilities such as landfills and incinerators.

ENVR 536  Ecology and Natural Resource Management 3
Terms Offered  Summer
Prerequisite: Take ENVR-511
This is an advanced course in environmental resource management with a focus on the tools and activities that are needed to ensure resource conservation and maintain compliance with appropriate environmental regulations. The course material and lectures will improve the understanding of effective management and sustainable stewardship of natural resources. The course will include a review of environmental laws and case studies.

ENVR 540  Env, Safety, & Oce Health Management 3
Terms Offered  Summer
Prerequisite:
This course provides an overview of Environment, Safety, and Occupational Health (ESOH) management with specific topical applications in Total Exposure Health, review of construction plans, occupational health surveillance strategies and risk management, environmental health risk management from water/solid/industrial pollution, and incident investigations.
Course Descriptions

ENVR 541 Industrial Hygiene Applications I 3
Terms Offered: Fall
Prerequisite: This course provides the anticipation/recognition portions of the "anticipate, recognize, evaluate, control" (AREC) paradigm of classical industrial hygiene. This course provides the student with a background of industrial hygiene history and development, and an overview of all hazard types (chemical, biological, and physical). Topics include: IH history and regulations; exposure limit basis, interpretation, and application; chemical hazards and indoor environmental quality; biological hazards; and physical hazards (noise, thermal stress, ergonomics).

ENVR 543 Industrial Hygiene Applications II 4
Terms Offered: Spring
Prerequisite: ENVR-541
This course provides the evaluation portion of the "anticipate, recognize, evaluate, control" (AREC) paradigm of classical industrial hygiene. Lecture and laboratory sessions focus on evaluation techniques and instruments for chemical, biological, and physical hazards. Topics include: lab-based and direct-reading instrument sampling and analysis of gases, vapors, and aerosols; biological monitoring and evaluation; dermal exposure assessment; noise evaluation; exposure distributions; sampling strategies; and data interpretation.

ENVR 543L Industrial Hygiene Applications II Lab 0
Terms Offered: Spring
Prerequisite: Lab associated with ENVR-543

ENVR 546 Applied Science Studies 4
Terms Offered: Winter
Prerequisite: This course provides an introduction to the applied sciences of human physiology, toxicology, and epidemiology. The physiology of each major organ system, along with the types of toxicological illnesses/injuries that can occur from occupational and environmental exposures will be covered. Epidemiological concepts including disease frequency, association, causation, bias, confounding, along with appropriate study design (e.g., case-control and cohort studies) will also be covered.

ENVR 547 Non-Ionizing and Ionizing Radiation 3
Terms Offered: Summer
Prerequisite: This course covers the health and safety problems involved with the use of ionizing and non-ionizing radiation with an emphasis on identification (detection), control, radiation types, and interactions with matter. Specific areas covered include lasers, microwave radiation, medical and dental x-ray equipment, industrial x-ray, and personnel dosimetry. Radiation safety elements are discussed in detail.

ENVR 548 Industrial Hygiene Applications III 4
Terms Offered: Summer
Prerequisite: ENVR-543
This course completes the "anticipate, recognize, evaluate, control" (AREC) paradigm of classical industrial hygiene by providing control mechanisms competency. Lecture and laboratory sessions acknowledge the control hierarchy (substitution, engineering controls, administrative controls, then personal protective equipment-PPE), but focus on engineering controls. Students will learn industrial ventilation design and hazardous noise controls. Confined spaces, occupational safety, and environmental/safety/occupational health (ESOH) management will also be covered.

ENVR 548L Industrial Hygiene Applications III Lab 0
Terms Offered: Summer
Prerequisite: Lab associated with ENVR-548

ENVR 550 Environmental Systems Engineering 4
Terms Offered: Fall
Prerequisite: This course is intended to provide the student with analytical and mathematical tools that can be used to quantitatively and qualitatively assess the effects of Air Force operations on the environment. In addition, the course provides the student with information regarding basic engineering controls that can be used to minimize the impact of mission operations on the environment. The course discusses the physical, chemical, and biological mechanisms which control the fate and transport of contaminants in the environment. These same mechanisms are discussed with regard to engineering controls which may be implemented to mitigate air, water, and land pollution. A student completing the course should: (1) understand the basic physical, chemical, and biological processes which affect the fate and transport of contaminants in the environment, (2) understand and apply simple mathematical models to describe environmental processes, and (3) know what engineering controls may be used to mitigate air, water, and land pollution as well as understand the physical, chemical, and biological principles upon which these controls are based.

ENVR 556 Sustainable Life Cycle Design 3
Terms Offered: Winter
Prerequisite: This course covers a wide variety of subject areas related to life cycle cost, life cycle assessments and sustainable design concepts. The class covers the use of life cycle assessment tools to help quantify energy and natural resource consumption as well as air, water and solid waste emissions for any product or process. Sustainable design is a broad concept and is approached in this course by going through the major areas that influence the sustainability of a product or process. The major areas covered in this class are pollution prevention legislation, life cycle assessment, life cycle cost, energy sustainability, air and solid waste emissions, global and human health impacts of sustainability and sustainability issues in the military.
## Course Descriptions

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<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>Terms Offered</th>
<th>Prerequisite:</th>
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<tr>
<td>ENVR 575</td>
<td>Applied Environmental Health</td>
<td>3</td>
<td>Fall</td>
<td>ENVR-550</td>
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<td><strong>Prerequisite:</strong></td>
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<td>The class will include coverage of basic environmental health topics/concepts. The format will be periodic lectures from the instructor and presentation/discussion of student/team projects. Topics covered will include basics of public health, intelligence data gathering, toxic industrial chemicals, physical hazards, and global environmental health issues. Contemporary issues pertinent to the deploying military member will be discussed.</td>
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<tr>
<td>ENVR 615</td>
<td>Industrial Hygiene Site Surveys</td>
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<td>Fall</td>
<td>ENVR-550</td>
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<td><strong>Prerequisite:</strong></td>
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<td>This course provides exposure to various industrial workplaces in the local area, in order to better understand the industrial hygiene &quot;anticipate, recognize, evaluate, control&quot; (AREC) paradigm. Students will go on several field trips and will write trip reports to summarize their occupational, environmental, safety, and management observations.</td>
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<td>ENVR 616</td>
<td>Advanced Industrial Hygiene</td>
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<td>Fall</td>
<td>ENVR-548 or permission of the instructor</td>
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<td><strong>Prerequisite:</strong></td>
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<td>This course provides students the opportunity to demonstrate the knowledge and skills to competently and ethically implement and practice applicable scientific, technical, and regulatory aspects of industrial hygiene. This course also serves as a capstone to the GIH program and provides an exhaustive review for those preparing to take the Certified Industrial Hygienist (CIH) exam, offered by the American Board of Industrial Hygiene.</td>
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<td>ENVR 624</td>
<td>Water Chemistry for Environmental Engineers</td>
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<td>Spring</td>
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<td><strong>Prerequisite:</strong></td>
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<td>Application of the principles of equilibrium chemistry to aquatic systems. After a presentation of basic physical/chemical concepts such as conservation of mass and energy, the tendency of a system to change toward a more stable (less reactive) condition, and chemical thermodynamics, these basic concepts are applied to describe acid/base chemistry, liquid/gas and liquid/solid phase equilibria, redox reactions, and reactions of metals in aqueous systems. The course intent is to provide the student with the theoretical tools to analyze natural water systems and solve specific chemical problems related to water treatment and water pollution control technologies.</td>
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<td>ENVR 625</td>
<td>Environmental Microbiology</td>
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<td>Summer</td>
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<td><strong>Prerequisite:</strong></td>
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<td>The principles of biological sciences, as they relate to and impact environmental systems, are described. Microbial systems serve as models to demonstrate the complex interactions between living organisms and the physical/chemical environment. The role of microorganisms and microbial processes in environmental problems, both positive and negative, are investigated. Specific topics include microbial physiology and genetics, aerobic and anaerobic systems, biochemical pathways, nutrient cycles, pathogens and wastewater, and bioremediation of soils and groundwater.</td>
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<td>ENVR 628</td>
<td>Physiology of NBC Weapons Effects</td>
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<td>Winter</td>
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<td><strong>Prerequisite:</strong></td>
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<td>This course analyzes physiological effects of various forms of radiological emissions of various energies as well as the physiological effects (intended and unintended) of chemical weapon agents and their antidotes. Engineering design of shielding for protection of personnel from radiological effects is included as well as the chemical antidote strategy in the field to include dosing, timing, and minimization of unwanted side-effects to keep personnel alive and mission capable as long as possible.</td>
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<td>ENVR 640</td>
<td>Groundwater Hydrology and Contaminant Transport</td>
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<td><strong>Prerequisite:</strong></td>
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<td>Groundwater is a major pathway that serves as a conduit to transport contaminants placed on the land (either intentionally or unintentionally) to environmental and human receptors. This course provides students with an understanding of the occurrence and movement of groundwater in a variety of geologic settings, as well as the fate and transport of contaminants in the groundwater. Also discussed are sampling and site characterization methods, water chemistry, computer modeling of flow and transport, and groundwater restoration technologies.</td>
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<tr>
<td>ENVR 643</td>
<td>Environmental Transport Processes</td>
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<td>Winter</td>
<td>ENVR-550</td>
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<td><strong>Prerequisite:</strong></td>
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<td>Starting with the law of conservation of mass, this course introduces students to the processes that govern the fate and transport of contaminants in the environment. Examples of transport processes relevant to the three main environmental media-air, water, and soil, are presented. Processes such as diffusive mass transport, convection-dispersion (transport with fluid momentum), filtration, and adsorption are discussed, with examples showing how each process affects contaminant fate and transport in several environmental media. A section of the course is devoted to reaction kinetics and reactor modeling. Students completing this course will better understand how containments move about and change in the environment, as well as how transport processes can be engineered to control contamination.</td>
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**Course Descriptions**

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<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Terms Offered</th>
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<tr>
<td>ENVR 645</td>
<td>Water and Wastewater Treatment Design</td>
<td>Summer</td>
<td>4</td>
<td>ENVR-550</td>
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<td>Basic course in fundamentals and design of systems for the treatment of drinking water and wastewater. Topics include: water quality analysis; principles and design of physical, chemical and biological water and wastewater treatment processes; and residuals processing and disposal.</td>
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<tr>
<td>ENVR 646</td>
<td>Water Treatment in Rural and Austere Conditions</td>
<td>Fall</td>
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<td>Take ENVR-645</td>
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<td>This is an advanced course in the analysis and design of systems needed for the treatment of water and wastewater in small communities and austere environments. This course will address the role of new and improved decentralized systems, while also covering the fundamental aspects of decentralized wastewater management, including the design of alternative and innovative systems.</td>
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<tr>
<td>ENVR 648</td>
<td>Phys/Bio Aspects of Aerosols</td>
<td>Spring</td>
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<td>This course covers an introduction to physical and biological principles of aerosols intended primarily for health and safety practitioners and allied professions (such as health physics, environmental medicine, and inhalation toxicology). Specific areas covered include gas behavior, particle motion in air, particle size distributions, aerosol generation, aerosol sampling and collection, real-time aerosol monitoring, aerosol deposition models, particle-size selective sampling conventions, air purification, and biological aerosols.</td>
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<td>ENVR 651</td>
<td>Environmental Risk Analysis</td>
<td>Fall</td>
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<td>The objective of this class is to familiarize the student with the concepts and principles involved with general and environmental risk analysis. This course will cover toxicology concepts, epidemiology, genetics, cancer, animal toxicology studies, exposure assessments, data collection, and computer tools used in risk analysis and risk communication to the public.</td>
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<td>ENVR 658</td>
<td>Indoor Air Quality</td>
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<td>This course focuses on the built environment through theoretical modeling, contaminant review, methodology to measure the indoor air quality, and engineering solutions for improved indoor environments. The course utilizes a mass balance approach to solve transport models for physical, chemical, and biological contaminates. Connections between indoor air quality to outdoor air, building design, energy, and human health will be presented.</td>
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<td>ENVR 661</td>
<td>Environmental Sampling and Analysis</td>
<td>Spring</td>
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<td>This course will cover the basics of environmental sampling and the statistical basics of sampling. Topics to be addressed include normal and lognormal distributions, sampling strategies for statistical considerations, sample preparation, and laboratory instrumentation. Analytical procedures including solids analysis, gas chromatography and spectroscopy will be discussed and demonstrated in the laboratory.</td>
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<tr>
<td>ENVR 661L</td>
<td>Environmental Sampling and Analysis Lab</td>
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<td>Lab associated with ENVR-661</td>
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<tr>
<td>ENVR 699</td>
<td>Master’s Level Special Study</td>
<td>All</td>
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<td>Directed study at an intermediate graduate level on a special topic which is not normally covered in a regularly scheduled course or as part of thesis research. Topic, format, and course requirements are determined by the faculty member directing the study. Requires submission of Special Studies Form and syllabus to the department for registration.</td>
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<td>ENVR 722</td>
<td>Remediation Design and Management</td>
<td>Fall</td>
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<td>This upper-level class investigates the physical, chemical, and biological methods used in remediation of environmental contamination in soils, surface water, and ground waters. Processes to address contamination, including the no-action alternative, containment techniques, and pump-and-treat and in situ technologies, will be reviewed with emphasis on practical applications. Included will be a review of the regulatory requirements that often determine the remediation process. Mechanisms for selection of appropriate treatment technologies will be described.</td>
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<td>ENVR 799</td>
<td>Thesis Research</td>
<td>All</td>
<td>1-12</td>
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<td>An in-depth study of a research topic selected from variety of problems of current interest to the Air Force, with the results presented in a formal thesis written under the supervision of a departmental professor.</td>
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<tr>
<td>ENVR 899</td>
<td>Doctoral Level Special Study</td>
<td>All</td>
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<td>Directed study for doctoral students on a special topic which is not normally covered in a regularly scheduled course or as part of dissertation research. Topic, format, and requirements of the course are determined by the faculty member directing the study. Requires submission of Special Studies Form and syllabus to the department for registration.</td>
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<td>Course Code</td>
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<td>HFEN 560</td>
<td>Introduction to Human Factors</td>
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<td>Winter</td>
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<td><strong>Prerequisite:</strong></td>
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<td>This course examines the study and</td>
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<td>application of humans and the</td>
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<td>system interface, including the</td>
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<td>knowledge of human cognitive/social/</td>
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<td></td>
<td>physical behavior, capabilities, and</td>
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<td>limitations. Topics include</td>
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<td>anthropometrics, sensation-perception,</td>
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<td>decision-making, mental</td>
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<td>workload, situational awareness,</td>
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<td>display/control design, warnings/alerts,</td>
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<td>human error and accident investigation.</td>
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<td>Numerous case studies are used to</td>
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<td>highlight course topics.</td>
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<td>HFEN 610</td>
<td>Human Performance Measurement</td>
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<td>As Needed</td>
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<td><strong>Prerequisite:</strong></td>
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<td>Theories, concepts, and methods for</td>
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<td>measuring and evaluating human</td>
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<td>performance will be discussed with an</td>
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<td>emphasis on facilitating the</td>
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<td>satisfaction. The student will gain</td>
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<td>practice in measuring human</td>
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<td>performance and applying the results</td>
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<td>to suggest and validate system</td>
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<td>design improvements. Influence of</td>
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<td>fatigue, environmental/task</td>
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<td>stressors, and social/team factors will</td>
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<td>HFEN 620</td>
<td>Human Systems Modeling</td>
<td>4</td>
<td>Spring</td>
<td>STAT-583 or STAT-587</td>
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<td><strong>Prerequisite:</strong></td>
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<td>This course introduces students to</td>
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<td>using discrete event simulation to</td>
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<td>model complex human-machine systems.</td>
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<td>Through this course students will</td>
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<td>gain an appreciation of defining systems,</td>
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<td>processes, and workflows using task</td>
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<td>network analysis. This course is intended</td>
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<td>to provide students with the requisite</td>
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<td>knowledge to construct and validate</td>
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<td>discrete event simulations as well as use</td>
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<td>simulation outputs to interpret system</td>
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<td>behavior and evaluate potential solutions</td>
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<td>with respect to impacts on</td>
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<td>system performance, human performance,</td>
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<td>and operator workload.</td>
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<tr>
<td>HFEN 660</td>
<td>Human Factors Engineering</td>
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<td>Winter</td>
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<td><strong>Prerequisite:</strong></td>
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<td>This course examines the application of</td>
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<td>human factors engineering to the</td>
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<td>system interface, including the</td>
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<td>knowledge of human cognitive/social/</td>
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<td>physical behavior, capabilities, and</td>
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<td>limitations. Topics include</td>
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<td>anthropometrics, sensation-perception,</td>
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<td>decision-making, situational awareness,</td>
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<td>display/control design, warnings/alerts,</td>
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<td>automation, human error, and accident</td>
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<td>investigation. Students are</td>
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<td>expected to apply this knowledge</td>
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<td>through design projects.</td>
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<td>Additionally, each student will</td>
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<td>analyze state of the art research within a</td>
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<td>selected topic area of interest in this</td>
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<td>HFEN 663</td>
<td>Human-Computer Interaction</td>
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<td>Summer</td>
<td>HFEN-560</td>
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<td><strong>Prerequisite:</strong></td>
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<td>This course covers the principles of</td>
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<td>human-computer interaction in the</td>
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<td>design and evaluation of useful, usable</td>
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<td>interfaces as well as the social</td>
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<td>consequences of technological innovations.</td>
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<td>Topics include the joint</td>
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<td>performance of tasks by humans and</td>
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<td>machines, the structure of</td>
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<td>communication between human and machines</td>
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<td>(including machine response to changes in</td>
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<td>user state), algorithms and programming of</td>
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<td>the interface itself, engineering concerns</td>
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<td>that arise in the design and construction</td>
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<td>of interfaces, the process of</td>
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<td>specification, design, and</td>
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<td>implementation of interfaces, and</td>
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<td>design tradeoffs.</td>
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<td>HFEN 665</td>
<td>Human-Agent Interaction</td>
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<td>Summer</td>
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<td>This course explores operator interaction</td>
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<td>in human-machine teams to understand</td>
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<td>significant design trade-offs during the</td>
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<td>design of the Human-Agent (H-A) Interface.</td>
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<td>Topics to be covered include: Task</td>
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<td>Allocation, Trust, Interaction Styles,</td>
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<td>Implicit/Explicit Communication, Relevant</td>
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<td>Human Biases, Automation</td>
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<td>Classification/Taxonomies and</td>
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<td>influences of automation limitations.</td>
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<td>Interface design decisions and</td>
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<td>trade-offs will be explored through</td>
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<td>academic articles, as well as analysis and</td>
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<td>development of design options.</td>
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<td>HFEN 670</td>
<td>Human Interaction Technologies</td>
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<td>Robust human-system interaction requires</td>
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<td>information flow between the system and</td>
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<td>technologies available to mediate this</td>
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<td>flow of information, discussing the</td>
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<td>important characteristics and considerations</td>
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<td>for input and output technologies.</td>
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<td>Emphasis will be provided on visual</td>
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<td>information processing and visual display</td>
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<td>design. Human auditory processing and</td>
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<td>various input device technologies will also</td>
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Course Descriptions

**HFEN 699 Master's Level Special Study**

**Terms Offered**: All

**Prerequisite**: Directed study at an intermediate graduate level on a special topic which is not normally covered in a regularly scheduled course or as part of dissertation research. Topic, format, and requirements of the course are determined by the faculty member directing the study. Requires submission of Special Studies Form and syllabus to the department for registration.

**HFEN 899 Doctoral Level Special Study**

**Terms Offered**: All

**Prerequisite**: Directed study for doctoral students on a special topic which is not normally covered in a regularly scheduled course or as part of dissertation research. Topic, format, and requirements of the course are determined by the faculty member directing the study. Requires submission of Special Studies Form and syllabus to the department for registration.

**IMGT 561 Applications of Database Management Systems**

**Terms Offered**: Spring

**Prerequisite**: Data Communications for Managers

This course explores the strategic use of organizational information. It includes a top-down view of how such information is gathered, structured, organized, stored, and used. It addresses both technical and managerial issues of information and its use, with a focus on maximizing the value of information to the organization. It also covers laws and policies related to the strategic management of information.

**IMGT 657 Data Communications for Managers**

**Terms Offered**: Summer

**Prerequisite**: Data Communications for Managers

This course introduces students to the concepts of business process improvement, including the most popular approach to this concept, Business Process Reengineering, by Hammer and Champy. This course will cover the historical reasons that organizations are structured the way they are. The students learn to re-conceptualize the organization in terms of business processes and learn how to use that knowledge to improve organizational effectiveness and efficiency. The students will learn to analyze an organization from this standpoint, and will learn to use these concepts to re-design the organization in ways that lead to doing more with less, and at the same time improving the services provided by the organization's customers.

**IMGT 660 Advanced Topics in Data Management and Analysis**

**Terms Offered**: Summer

**Prerequisite**: Advanced Topics in Data Management and Analysis exposes students to the basics of data science and data analytics for handling massive databases. The course covers concepts related to data management and data mining for big data analytics. Students will learn basic techniques of data analytics, including emerging methods to store and access large, real-time, web distributed data environments (e.g., noSQL, MapReduce, Hadoop, etc) as well as prominent algorithms used to mine data (e.g., clustering and association rule mining) and perform statistical modeling. This course is targeted towards individuals familiar with databases who would like to further understand the concepts and practices of large scale data analytics. The objective of this course is to familiarize students with the fundamental techniques and tools used to design and analyze large volumes of data.

**IMGT 684 Strategic Information Management**

**Terms Offered**: Winter and Summer

**Prerequisite**: Advanced Topics in Data Management and Analysis

This course explores the strategic use of organizational information. It includes a top-down view of how such information is gathered, structured, organized, stored, and used. It addresses both technical and managerial issues of information and its use, with a focus on maximizing the value of information to the organization. It also covers laws and policies related to the strategic management of information.

**IMGT 662 Database Security**

**Terms Offered**: Spring

**Prerequisite**: Information stored in databases is a valuable asset that needs to be protected from damage. Conceptual frameworks for discretionary and mandatory access control data integrity, availability and performance, secure database design, data aggregation, data inference, secure concurrency control, and secure transactions processing are studied. Models for multilevel secure databases for both relational and object-relational databases are analyzed. Practical applications of database security concepts are applied.
Course Descriptions

**IMGT 687 Cyber Systems Security**

**Terms Offered:** Spring

**Prerequisite:**

This course explores the managerial and technological aspects of cyber and systems security (defense and attack) in the Department of Defense (DoD). Information is recognized as a strategic resource vital to military operations and national security objectives. Students will examine relationships and dependencies in support of mission execution, resiliency, and system security inherent in information-based systems and the DoD's networked infrastructure. Students will also explore engineering concepts and considerations for developing secure systems of interest to the DoD. Upon completion the student will understand and be able to apply concepts and methods for managing the security of cyber and information dependent systems, articulating threats in a globally networked environment, and identifying vulnerabilities associated with modern distributed systems and infrastructure. Lastly, the student will practice communicating effectively through written means.

**ORSC 542 Management and Behavior in Organizations**

**Terms Offered:** Fall and Winter

**Prerequisite:**

This course will give the student an in-depth understanding of organizational behavior, organization theory, and management theory. Topics include, but are not limited to, classical and neoclassical organization and management theory, study of organizations, organizational culture, individual behavior, motivation, rewards, organizational behavior, politics, leadership, organizational structure and design, job and organizational design, communication and information in the postmodernist era, decision-making process, and organizational change.

**ORSC 638 Seminar in Contemporary Leadership Theory and Application**

**Terms Offered:** Winter

**Prerequisite:** ORSC-542

This course provides an in-depth introduction to classical and emerging theories of leadership while encouraging students to apply leadership theory to real-world situations. Each of the major leadership theories are addressed, as well as related areas such as the process of influence, bases of power, determinants of leader behavior, and leader facilitation of group problem solving. The concept of leadership will be explored through class discussions based on directed readings as well as the students' personal experiences with leadership, leaders, and organizations.

**ORSC 647 Organizational Policy and Strategic Management**

**Terms Offered:** Summer

**Prerequisite:** ORSC-542 or permission of instructor

This course serves as a basis for the understanding and use of the strategic process within public, governmental, and private organizations. Students are introduced to the history and current theory dealing with the development, execution, and evaluation of strategies and policies to help achieve organizational goals. As part of the strategy process, students are introduced to the concepts of industry and competitor analysis, core competencies, and competitive advantage. In addition to theoretical work, students learn practical methods for implementing and maintaining a viable strategic process within Air Force and DoD organizations. Practical experience is gained through application of theory to specific cases of business problems encountered by actual firms and government organizations. While this course draws heavily on the core concepts and frameworks from strategic management and organizational behavior, we will also deal explicitly with the ways in which ideas based on the study of business organizations need to be adapted to deal with the unique aspects of the DoD/government sector. Thus, a blend of traditional private sector strategic management concepts as well as public policy concepts and applications are addressed in this course.

**PENV 798 Group Design Project Completion**

**Terms Offered:** All

**Prerequisite:**

Project completion course. Credit given for completion of research project.

**QMGT 680 Project Risk Analysis**

**Terms Offered:** All

**Prerequisite:** Any 500 level STAT course

This course covers the concept of project risk with an emphasis on formal risk analysis methods. The course exposes students to a variety of approaches for evaluating risk and uncertainty as they apply to a dynamic decision-making environment. Topics include defining risk, DoD risk policy, risk identification, risk handling, qualitative and quantitative risk methods. Both analytical and simulation methods for quantifying cost risk will be discussed. In order to cover simulation methods, the general method of Monte Carlo simulation will be introduced.

**RDMT 541 Operational Technology and Innovation**

**Terms Offered:** Winter

**Prerequisite:**

This course has three components. Part one is the theory on innovation and technology ranging from the dynamics of innovation and technology S-curves, to disruptive technologies through dominate designs, and from lead users to corporate regeneration. Part two is an overview of the current state of technology in our fielded systems from fighters to satellites to communication systems. Part three is a look at the technologies developed or being developed in our laboratories, universities, and commercial firms and how these technologies may be applied in current and future defense and commercial systems. Some lectures will be held at the secret level.
Course Descriptions

RDMT 554  Management in R&D Organizations  3  Terms Offered: Summer  
**Prerequisite:**  
Technological change and innovation have impacted the socio-political economic systems in our society in a variety of ways. These changes often play a dual role - they disrupt the existing order and create new opportunities. Although most innovations and technological changes fail, companies that do not pursue innovation often fail too. Therefore, managing innovation is often considered one of the most difficult challenges a manager faces. The focus of the course is on the management of product and process innovation; both sustaining and disruptive innovations will be discussed.

RDMT 654  Seminar in Research and Development Management  4  Terms Offered: Winter  
**Prerequisite:** RDMT-541 and RDMT-554  
As the capstone course for the S&T focus sequence, this course builds on material presented in previous courses. The purpose of the course is to help students think strategically about technological innovation in an R&D environment. The text will be augmented with additional readings and case studies. Topics include entrepreneurship, managing innovation, the technology life-cycle, management of R&D personnel and projects, and integrating technology strategy with business strategy. The course will be taught in seminar fashion with substantial class discussion. This is a writing-intensive course in which assignments include case analyses and research papers.

RSCH 662  Metrics, Surveys, and Instrument Development  3  Terms Offered: Summer  
**Prerequisite:** RSCH-630  
This course provides students with the specific competencies needed to develop high quality metrics, surveys and organizational measures to support decision making. It focuses on designing, pilot testing, and interpreting measurement instruments used in management and the behavioral sciences. Topics in Psychometrics and methods for collecting descriptive and attitudinal data are drawn on to provide students with a solid base of knowledge. Applied projects are designed to stimulate procedural knowledge development. This course is very appropriate for students whose thesis research involves surveys, interviews, or other organizational measures.

RSCH 630  Research Methods  4  Terms Offered: Winter and Spring  
**Prerequisite:** STAT-525, STAT-583, or STAT-587  
Research methods is one of the foundation courses in a management-related master of science degree program. It provides an understanding of the basic methods of conducting research and concepts related to scientific inquiry. This course is designed to advance students along the research process by introducing the basic tools needed to critically analyze claims made through the written body of knowledge and determine the degree to which these claims are valid. As such, the course should help students not only in conducting research, but also in judging the validity of any claims made verbally or in writing. An important part of that process is an understanding of the statistical procedure used to analyze the data (such as linear regression, reliability of measures, correlation and causality) to support drawing conclusions about the research question. Additionally, the course will provide a foundation for students in designing and conducting their own research projects and determine how close to the truth they have come in their own efforts.

SENG 510  Introduction to Systems Engineering  4  Terms Offered: Spring  
**Prerequisite:**  
This course provides a broad introduction to a systematic approach necessary for the conceptualization, design, analysis, operation, and sustainment of complex systems within the DoD. Topics include understanding systems (to include systems thinking, systems analysis, and systems of systems concepts), the role and value of SE within DoD systems acquisition, and the exploration and application of the SE technical and management processes. This class is intended for non SE students.

SENG 520  Foundations of Systems Engineering  4  Terms Offered: Fall and Spring  
**Prerequisite:**  
This course provides a broad introduction to the systematic approach for the conceptualization, design, and analysis of complex systems within the Department of Defense. Content emphasizes modern model-based systems engineering (MBSE) methods, languages, and tools. A systems modeling tool is used throughout the course for description and engineering analysis of a Defense-related design project.

SENG 520  Systems Engineering Design  4  Terms Offered: Fall and Summer  
**Prerequisite:**  
This course provides a broad introduction to a systematic approach for the conceptualization, design, analysis, operation, and sustainment of complex systems within the Department of Defense (DoD). While this course serves as a stand-alone introduction to Systems Engineering, it also provides the foundation for further study in Systems Architecture and Engineering Software Systems.
Course Descriptions

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<td>SENG 550</td>
<td>Small UAS Concept Definition and Preliminary Design</td>
<td>4</td>
<td>Winter</td>
<td>SENG-520 or permission of instructor; ASYS-525 or EENG-510</td>
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<tr>
<td>SENG 560</td>
<td>Human Systems Integration</td>
<td>4</td>
<td>Fall and Spring</td>
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<tr>
<td>SENG 570</td>
<td>Systems Process Improvement</td>
<td>4</td>
<td>Fall and Summer</td>
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<tr>
<td>SENG 582</td>
<td>Aviation Energy Systems Engineering</td>
<td>4</td>
<td>Winter and Spring</td>
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<tr>
<td>SENG 585</td>
<td>Reliability in Systems Design</td>
<td>4</td>
<td>Winter</td>
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<tr>
<td>SENG 593</td>
<td>Agile Software Systems Engineering</td>
<td>4</td>
<td>Fall Winter and Summer</td>
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<tr>
<td>SENG 599</td>
<td>Strategic Topics in Defense Innovation</td>
<td>3</td>
<td>Fall</td>
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**SENG 550 Small UAS Concept Definition and Preliminary Design**

This is the first in a three-course specialty sequence in which systems engineering is applied in depth to an Unmanned Airborne System (UAS). In developing their own UAS, students will address early systems engineering concepts such as mission analysis, concept definition, requirements refinement, and preliminary system design. The course culminates in a preliminary design review of the selected UAS concept.

**SENG 560 Human Systems Integration**

A human-centered design approach (i.e., system includes people within an organization that apply technology to accomplish a task) is explored through readings, discussion and a project. Included are discussions of the Human Systems Integration domains (manpower, personnel, training, human factors, system safety, environmental safety, occupational health and survivability) and a method for considering these domains within the Systems Engineering Lifecycle.

**SENG 570 Systems Process Improvement**

This course introduces students to the concepts of Business Process Reengineering, Lean, Six Sigma and other related methodologies. The course will take a historical look at why organizations are structured the way they are. Students will then learn to re-conceptualize the organization in terms of systems and processes with the goal of improving the organizations effectiveness and efficiency. The students will then apply Lean and Six Sigma concepts to re-engineered business and system processes to ensure long term process improvement. Topics for this course will also include people, process, technology, and management dimensions of a Lean enterprise with particular focus on systems applications for scientists and engineers. Upon completion of the course students will be well versed in these methodologies and prepared to contribute to any continuous process improvement activity such as APSO21.

**SENG 582 Aviation Energy Systems Engineering**

This course will focus on the engineering of aviation energy systems to optimize their performance and cost. The course will provide an in-depth look at propulsion & avionics energy requirements and then examine current methods of meeting those requirements including internal combustion engines, turbine engines, auxiliary power units and batteries. A model for the conceptualization, design, analysis, operation, and sustainment of aviation energy systems will be developed, and then students will examine emerging technologies including fuel cells, hydrogen, biofuel and all-electric aircraft to determine the best technologies for systems integration when considering technical feasibility, economic feasibility and lifecycle implications.

**SENG 585 Reliability in Systems Design**

The purpose of this course is to introduce students to the probabilistic models and statistical methods used by reliability engineers. This first course gives basic definitions and terminology, investigates parametric lifetime models, non-parametric methods, coherent systems analysis. Markov analysis techniques and an introduction to repairable system analysis. Emphasis will be placed on using these mathematical tools to models RAM as a dynamic process, develop test plans, perform graphical and statistical inference, as well as model product improvement the development process.

**SENG 593 Agile Software Systems Engineering**

This course will provide a foundation for System Engineers to design and architect software intensive systems. Topics include requirements elicitation, object-oriented modeling including the use of the Unified Modeling Language (UML), design patterns, engineering reliable and reusable systems, iterative development, DoD/AF software guidance, case studies, software management best practices and software estimation. The unique challenges faced by teams when engineering large-scale software-intensive systems (i.e., systems which have a large software component) are explored. This course is an introduction to software engineering technical management for experienced engineers whose area of expertise is outside computer science. Outcomes will enable students to more effectively communicate with users and software developers and make sound management and engineering decisions.

**SENG 599 Strategic Topics in Defense Innovation**

Evolution, revolution, and innovation have defined human existence for millennia. Innovation is pervasive and resident in everything we do. Since the dawn of history, nations have engrossed themselves in developing new tools, techniques, and methodologies to protect their geographical boundaries. From the crude implements used by prehistorical people to the very modern technologies, the end game has been the same. That is, for national defense. Even in times of peace, efforts must be made to develop new machinery, equipment, processes, and devices targeted for the protection of the nation. The emergence of organized nations and structured communities facilitated even more innovative techniques of national defense. The drive to achieve new national defense tools led to better underlying science and technology, which most often end up having other beneficial societal applications that are outside the bounds of national defense. It is through the efforts of industry that those societal benefits are manifested as practical consumer products. It is important to recognize, document, and demonstrate the paths of converting defense science and technology developments into general applications through deliberate transfer actions. From the ice age to the stone age, the bronze age, the iron age, and to the modern age, innovation, rudimentary as it may be in many cases, has determined how humans move from one stage to the next. The innovation pursuits of The Wright Brothers led to the fast-tracking of aviation. This course presents a variety of topics related to how to innovate, how to use innovation, how to build innovation teams, how to lead innovation efforts, and how to teach innovation.
Course Descriptions

SENG 604 Contingency Base Energy Systems Engineering

Terms Offered Spring
Prerequisite: This course will focus on the engineering of contingency base energy systems to optimize their performance and cost. The course will provide an in-depth look at austere location energy requirements including those that result from flight operations, security, billeting and water purification. Then, students will examine current methods of meeting those requirements including diesel generators and spot generation. A model for the conceptualization, design, analysis, operation, and sustainment of contingency base energy systems will be developed, and then students will examine emerging methods to meet requirements including multiple-generator microgrids with battery storage, fuel cells and renewable energy sources to determine the best technologies for systems integration when considering technical feasibility, economic feasibility and lifecycle implications.

SENG 610 Project Management

Terms Offered Spring and Summer
Prerequisite: Provides knowledge and tools to manage projects or effectively contribute as a project member. Framed by the systems development cycle, course explains challenges specific to three major project types: systems engineering, software systems, and construction. Basic topics include project life cycle, project planning/selection, cost estimating, scheduling, and risk management. Advanced topics include critical chain analysis, adaptive project management, acquisition logistics and contracting. An optional one-hour lab may be available for software assistance.

SENG 610L Project Management Lab

Terms Offered Spring and Summer
Prerequisite: Lab associated with SENG-610

SENG 620 Quantitative Analytical Methods

Terms Offered Fall
Prerequisite: SENG-520
This course builds on the material presented in SENG 520, presenting additional depth and breadth in topics related to systems engineering. The focus of this course is on the quantitative analysis of engineering-related problems using mathematical/statistical techniques to assist with various aspects of system development, particularly those related to system dynamics, decision-making, and value assessments. Topics may include decision/analysis, utility theory, decision trees, optimization and queueing theory.

SENG 621 High-Performance Modeling & Simulation

Terms Offered Winter and Summer
Prerequisite: This is a research-focused course which will provide students with an opportunity to investigate modeling, simulation and analysis (MS&A) of space systems. Students will be exposed to MS&A methods and tools and will develop an understanding of how to assess the decision space associated with complex simulations. Systems engineering principles, including system architecture, will form the foundation for the course, especially focused on MS&A in support of early systems acquisition, mission analysis and concept evaluation. Students will build upon existing executable architectures and code.

SENG 621 High-Performance Modeling & Simulation

Terms Offered Winter and Summer
Prerequisite: This is a research-focused course which will provide students with an opportunity to investigate modeling, simulation and analysis (MS&A) of space systems. Students will be exposed to MS&A methods and tools and will develop an understanding of how to assess the decision space associated with complex simulations. Systems engineering principles, including system architecture, will form the foundation for the course, especially focused on MS&A in support of early systems acquisition, mission analysis and concept evaluation. Students will build upon existing executable architectures and code, which will enable them to get hands-on experiences and better understand the concepts discussed in the course. Finally, the unique aspect of this course is exploration of those cases where simulation time becomes overly burdensome. Students will learn how to use multiple processes and cores on the Center for Space Research and Assurance's classified cluster, and Wright-Patterson's DoD Supercomputing Resource Center's (DSRC) high performance computers.

SENG 640 Systems Architecture

Terms Offered Winter and Spring
Prerequisite: SENG 520 and SENG-593 or permission of instructor
This course provides the foundation for developing and evaluating system architectures through an intensive study of the relationships between different types of system representations and the methodologies used to obtain them. Approaches include a variety of model-based systems engineering (MBSE) techniques and heuristics to assess behavior and performance. Students will select a military concept, and iterate its design solution guided by the DoD Architecture Framework (DoDAF).

SENG 650 Small UAS Detailed Design

Terms Offered Spring
Prerequisite: SENG 550
This is the second in a three-course specialty sequence in which systems engineering is applied in depth to an Unmanned Airborne System (UAS). In this course, students will iterate and mature their preliminary system design from SENG 550 into a detailed design, with allocated functional and performance requirements. The course culminates in a critical design review of the selected UAS design, to include full traceability of established requirements.
Course Descriptions

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>Terms Offered</th>
<th>Prerequisite</th>
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<tbody>
<tr>
<td>SENG 651</td>
<td>Small UAS Test and Evaluation</td>
<td>4</td>
<td>Summer</td>
<td>SENG-650</td>
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<td><strong>Terms Offered</strong> Winter and Summer</td>
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<tr>
<td>SENG 653</td>
<td>Concept Definition and System Analysis</td>
<td>4</td>
<td>Winter</td>
<td>SENG-520 and SENG-640</td>
</tr>
<tr>
<td>SENG 660</td>
<td>Advanced Principles of Engineering Design</td>
<td>4</td>
<td>Spring</td>
<td>SENG-520 and SENG-640</td>
</tr>
<tr>
<td>SENG 670</td>
<td>Advanced Topics in DoD Engineering</td>
<td>4</td>
<td>Winter and Summer</td>
<td>SENG-520 and SENG-640</td>
</tr>
<tr>
<td>SENG 670</td>
<td>Advanced Topics in DoD Systems Engineering</td>
<td>4</td>
<td>Winter and Summer</td>
<td>SENG-520 and SENG-640</td>
</tr>
<tr>
<td>SENG 685</td>
<td>Reliability Engineering</td>
<td>4</td>
<td>Spring</td>
<td>STAT-601 and SENG-585</td>
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<tr>
<td>SENG 687</td>
<td>Advanced Topics in Reliability</td>
<td>4</td>
<td>Summer</td>
<td>SENG-685 and STAT-601 or permission of instructor</td>
</tr>
<tr>
<td>SENG 695</td>
<td>Systems Engineering Research Seminar</td>
<td>0</td>
<td>Fall Winter and Spring</td>
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</tbody>
</table>

**Prerequisite:**
- SENG-520 and SENG-640

**Terms Offered:**
- Summer

This is the third in a three-course specialty sequence in which systems engineering is applied in depth to an Unmanned Airborne System (UAS). In this course, students must implement their detailed design from SENG 650 through appropriate test planning and execution, making design modifications as necessary to meet system requirements. This course culminates in an operational flight test of the student's design.

This course provides students with theory and process to perform mission area analysis, definition of operational need, concept formulation, analysis of alternatives, program formulation, and risk management. A current DoD mission area will be chosen as the theme for the course in order to provide a relevant educational experience with defense systems. Topics for this course include the overall mission analysis and requirements development processes used to develop a weapon system and allocation of mission needs to system and subsystem functional requirements. In the latter half of the course, students transition from operational requirements to allocated functional performance requirements and synthesizing these into an affordable and operationally effective system design. The focus during this phase will be on risk identification/mitigation and cost affordability. U.S. citizens only.

This course explores various principles of system design in the context of complex and uncertain DoD programs, where traditional fixed design and valuation methods may be inadequate. The course establishes the inherent relationship between decision analysis and engineering design, which reveal shortcomings of conventional design approaches. A wide variety of topics will be covered, all relating to non-functional requirements mechanism(s) for a more effective design strategy in the real world of changing system requirements. Topics will include flexibility, modularity, and changeability.

This course advances concepts and analytical solutions beyond traditional in Systems Engineering (SE) processes presented in SENG 520, SENG 640 and SENG 593. Topics of interest will be driven by current DoD challenges and policy, as well as state-of-the-art practices in SE publications. Such topics may include: safety critical systems, air worthiness, Open Systems Architecture (OSA), System of Systems (SoS) management and analysis, the Internet-of-Things (IoT), cloud computing, mission assurance, human systems integration (HSI), or design for resilience/flexibility/ modularity.
## Course Descriptions

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<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>Terms Offered</th>
<th>Prerequisite</th>
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</thead>
<tbody>
<tr>
<td>SENG 699</td>
<td>Master's Level Special Study</td>
<td>1-12</td>
<td>All</td>
<td>Directed study at an intermediate graduate level on a special topic which is not normally covered in a regularly scheduled course or as part of thesis research. Topic, format, and course requirements are determined by the faculty member directing the study. Requires submission of Special Studies Form and syllabus to the department for registration.</td>
</tr>
<tr>
<td>SENG 740</td>
<td>Advanced Topics in Systems Architecture</td>
<td>4</td>
<td>Winter and Summer</td>
<td>This course presents advanced analysis techniques using Systems Architecture, as defined in the Department of Defense Architecture Framework (DoDAF) and prescribed by DoD policy. Various topics will be selected based upon current state-of-the-art in Systems Engineering publications with topics including System of Systems analysis, Service Orientated Architectures, Web-application design, Network-Centric Operations and executable architectures. The student will bridge military concepts of network centric warfare with engineering tools from information systems modeling, architecture, and analysis. A research paper is required which emphasizes operational capability, requirements definition and measurement, architectural design modeling and trade-space evaluation.</td>
</tr>
<tr>
<td>SENG 798</td>
<td>Master's Capstone Project</td>
<td>4</td>
<td>Winter and Summer</td>
<td>A topic is selected from a wide variety of problems of current interest to the Air Force and the Department of Defense. The Capstone Project is performed as a group or individual project under the supervision of departmental faculty. Results are provided in a formal written report. This course is similar to SENG 799, but is for non-thesis students.</td>
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<tr>
<td>SENG 799</td>
<td>Thesis Research</td>
<td>1-12</td>
<td>All</td>
<td>A topic is selected from a wide variety of problems of current interest to the Air Force and the Department of Defense. The independent study is performed as a group or individual project under the supervision of a departmental faculty. Results are reported in a written thesis and presented in a formal oral presentation.</td>
</tr>
<tr>
<td>SENG 899</td>
<td>Doctoral Level Special Study</td>
<td>1-12</td>
<td>All</td>
<td>Directed study for doctoral students on a special topic which is not normally covered in a regularly scheduled course or as part of dissertation research. Topic, format, and requirements of the course are determined by the faculty member directing the study. Requires submission of Special Studies Form and syllabus to the department for registration.</td>
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<tr>
<td>SENG 999</td>
<td>Dissertation Research</td>
<td>1-12</td>
<td>All</td>
<td>An in-depth study of a research topic selected from variety of problems of current interest to the Air Force, with the results presented in a formal dissertation written under the supervision of a departmental professor.</td>
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<tr>
<td>TENV 799</td>
<td>Thesis Completion</td>
<td>12</td>
<td>All</td>
<td>Thesis Completion course for graduating students to be taken during the last quarter of study. Registration in TENV 799 for 12 non-billable credit hours is required for all master's students whose research advisors are in the Department of Systems Engineering and Management. The grade assigned to this course is the official thesis grade.</td>
</tr>
</tbody>
</table>
Faculty List

AKERS, BENJAMIN F.
Associate Professor of Mathematics
B.S., Pennsylvania State University; M.A., Ph.D., University of Wisconsin - Madison

AHNER, DARRYL K.
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Institute of Technology

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