8-2018

Graduate School of Engineering and Management Catalog 2018-2019

Air Force Institute of Technology

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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
AFIT Leadership

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

Sivaguru S. Srinatharan, Ph.D.
Deputy Director & Vice Chancellor (Provost)

Colonel Paul Cotellesso, Ph.D.
AU DET 1 Commander/Director of Staff

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

Colonel Adam Reiman, Ph.D.
Associate Dean, Graduate School of Engineering and Management
Assistant Professor of Logistics and Supply Chain Management

Colonel Richard T. Cooney, Ph.D.
Dean of Students

Heidi R. Ries, Ph.D.
Dean for Research
Professor of Physics

Paul J. Wolf, Ph.D.
Associate Dean for Academic Affairs
Professor of Physics

Alice E. Grimes, Ph.D.
Director of Faculty Development

Graduate School of Engineering and Management

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 provide Airmen with world-class defense-focused and research-enabled advanced academic education, and career-long professional continuing education both on-command and on-demand. Through four schools and a non-resident civilian institution program, delivers: graduate education to the Medical, Line, Legal and Chaplain Corps professional continuing education to Civil Engineers, Space, Nuclear, Acquisition, and Logistics professionals cutting-edge research in many areas, including cyber, directed energy, hypersonics, stealth, navigation and space and consultation and analysis support services.

The vision of the AFIT Graduate School of Engineering and Management is to be the internationally recognized leader for defense-focused technical graduate and continuing education, research, and consultation.

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 Bane served as the Commandant and Lieutenant Edwin Aldrin, astronaut Buzz Aldrin’s father, served as the Chief of the School Section.

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. 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 880 officers and enlisted service members from the Army, Navy, Marines and Coast 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 550 officers from over 50 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 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 129 have graduated since then 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. As another first for AFIT, in 2012, Major General Todd Stewart, PhD, USAF, Retired, became the first civilian Chancellor and Director 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 (NSSI), located at Peterson AFB in Colorado Springs, CO, which 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 Airman 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.

The effects of AFIT’s educational programs pervade the Air Force and Department of Defense. Graduates are assigned to a wide range of positions in a rapidly changing technological environment. They become both practicing engineers and broadly educated leaders. No matter what degree a student earns, AFIT’s primary goal is to graduate mission-ready men and women who can positively impact the Air Force.

Looking toward its 100th year of operation, AFIT’s premier education and research are even more important and relevant today as we shape the ever changing world of aviation, space and cyberspace technology. The future promises to be even more challenging than the past, and AFIT is prepared to continue to deliver world-class defense-focused and research-enabled graduate education, professional continuing education, research and consultation in air, space, and cyberspace to sustain the technological supremacy of America’s Air, Space, and Cyber Forces.

**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 https://www.soche.org/dagsi/ 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 (http://www.SOCHEd.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
(800) 621-7440
www.hlcommission.org

In addition to its regional 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, Nuclear Engineering, Environmental Engineering and Science, Engineering Management, and Systems Engineering. Also, the Industrial Hygiene master's degree program is accredited by the Applied Science Accreditation Commission of ABET.

ABET contact information:
ABET
415 North Charles Street
Baltimore, MD 21201
Phone (410)347-7700
www.abet.org

AFIT holds general membership in the American Society for Engineering Education (ASEE).

Board of Visitors

The Air University Board of Visitors includes an Air Force Institute of Technology (AFIT) Subcommittee that is comprised of a select group of eminent educators from prominent U.S. 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 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.

Current Membership

Lt Gen (Ret) Mark D. Shackelford, Chair
Independent Consultant and President & CEO, Veritas Strategies, LLC, Trophy Club, TX
Lt Col (Ret) Dr. Stephen E. Cross
Executive VP for Research, Georgia Institute of Technology, Atlanta, GA
Lt Gen (Ret) Dr. Robert J. Elder
Research Professor and Independent Consultant, Shreveport, LA
Col (Ret) Dr. Michael L. Heil
Former President & CEO, Ohio Space Institute, Cleveland, OH
Dr. Jacqueline R. Henningsen
Retired SES & Independent Consultant, Arlington, VA
Dr. Illani Kass
Senior VP and Corporate Strategic Advisor, CACI International, Inc., Arlington, VA
Dr. Victor R. McCrary
VP for Research and Economic Development, Morgan State University, Baltimore, MD
# 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 (Ph.D.) degree. With the exception of the M.S. and Ph.D. 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.

Of the degree programs listed below, the ABET-accredited master's degree programs are identified with an asterisk.

<table>
<thead>
<tr>
<th>Program</th>
<th>Degree</th>
<th>Department</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aeronautical Engineering*</td>
<td>M.S., Ph.D.</td>
<td>Aeronautical and Astronautical Engineering</td>
</tr>
<tr>
<td>Applied Mathematics</td>
<td>M.S., Ph.D.</td>
<td>Mathematics and Statistics</td>
</tr>
<tr>
<td>Applied Physics</td>
<td>M.S., Ph.D.</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., Ph.D.</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., Ph.D.</td>
<td>Electrical and Computer Engineering</td>
</tr>
<tr>
<td>Computer Science</td>
<td>M.S., Ph.D.</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>Systems Engineering and Management</td>
</tr>
<tr>
<td>Electrical Engineering*</td>
<td>M.S., Ph.D.</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 and Supply Chain Management</td>
<td>M.S.</td>
<td>Operational Sciences</td>
</tr>
<tr>
<td>Logistics (DL)</td>
<td>M.S.</td>
<td>Operational Sciences</td>
</tr>
<tr>
<td>Materials Science</td>
<td>M.S., Ph.D.</td>
<td>Aeronautical and Astronautical Engineering; Engineering Physics</td>
</tr>
<tr>
<td>Nuclear Engineering*</td>
<td>M.S., Ph.D.</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., Ph.D.</td>
<td>Operational Sciences</td>
</tr>
<tr>
<td>Optical Science and Engineering</td>
<td>M.S., Ph.D.</td>
<td>Engineering Physics</td>
</tr>
<tr>
<td>Space Systems#</td>
<td>M.S., Ph.D.</td>
<td>Aeronautical and Astronautical Engineering</td>
</tr>
<tr>
<td>Systems Engineering*</td>
<td>M.S., Ph.D.</td>
<td>Systems Engineering and Management</td>
</tr>
</tbody>
</table>

@ 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>
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<tr>
<td>Cost Capability Analysis</td>
<td>Operational Sciences</td>
</tr>
<tr>
<td>Data Science</td>
<td>Operational Science</td>
</tr>
<tr>
<td>Human Systems</td>
<td>Systems Engineering and Management</td>
</tr>
<tr>
<td>Nuclear Weapons Effects, Policy, and Proliferation</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/en/admissions/index.cfm. Selected officers will earn the Master of Science (MS) degree in Operations Management. This is a non-thesis Masters program, taught by the Department of Operational Sciences, that begins in June each year.
2018-2019 Academic Calendar

Fall Orientation/Review Session 2018
Technical Refresher Courses Begin
Tue 4-Sep-18
Technical Refresher Course Ends
Fri 28-Sep-18

Fall Quarter 2018
Fall Quarter Classes Begin
Mon 1-Oct-18
Fall Quarter Registration Closes
Fri 5-Oct-18
Columbus Day (Holiday)
Mon 8-Oct-18
Last Day to Drop a Class Without Record
Fri 12-Oct-18
Book Lists for Next Quarter Due
Fri 26-Oct-18
Winter Quarter Registration Opens
Mon 5-Nov-18
Veterans' Day (Holiday)
Mon 12-Nov-18
Applications for Graduation w/Academic Evaluations Due
Fri 16-Nov-18
TPC Begins Accepting Completed Thesis and Dissertations
Mon 19-Nov-18
Thanksgiving Day (Holiday)
Thu 22-Nov-18
AETC Family Day - Classes IN SESSION
Fri 23-Nov-18
Last Day to Withdraw From Class
Fri 23-Nov-18
Deadline for Thesis Defense
Fri 30-Nov-18
Deadline for Submission of Final Thesis Documents
Fri 30-Nov-18
Deadline for Submission of Final Dissertation Documents
Mon 3-Dec-18
Fall Quarter Classes End
Fri 7-Dec-18
Final Examinations Begin
Mon 10-Dec-18
Final Examinations End
Thu 13-Dec-18
Final grades due NLT 1200
Mon 17-Dec-18
Fall Degree Conferral
Thu 20-Dec-18

Winter Quarter 2019
Winter Quarter Classes Begin
Wed 2-Jan-19
Winter Quarter Registration Closes
Fri 4-Jan-19
Last Day to Drop a Class Without Record
Fri 11-Jan-19
Martin Luther King Day (Holiday)
Mon 21-Jan-19
Book Lists for Next Quarter Due
Fri 25-Jan-19
Spring Quarter Registration Opens
Mon 4-Feb-19
Applications for Graduation w/Academic Evaluations Due
Fri 15-Feb-19
Presidents' Day (Holiday)
Mon 16-Feb-19
TPC Begins Accepting Completed Thesis and Dissertations
Tue 19-Feb-19
Deadline for Thesis Defense
Fri 22-Feb-19
Last Day to Withdraw From Class
Fri 22-Feb-19
Deadline for Submission of Final Thesis Documents
Fri 1-Mar-19
Deadline for Submission of Final Dissertation Documents
Mon 4-Mar-19
Winter Quarter Classes End Fri 8-Mar-19
Final Examinations Begin Mon 11-Mar-19
Final Examinations End Thu 14-Mar-19
Final grades due NLT 1200 Mon 18-Mar-19
Commencement Ceremony Thu 21-Mar-19

**Spring Quarter 2019**  
48 Days

Spring Quarter Classes Begin Mon 25-Mar-19
Spring Quarter Registration Closes Fri 29-Mar-19
Last Day to Drop a Class Without Record Fri 5-Apr-19
Book Lists for Next Quarter Due Fri 19-Apr-19
Summer Quarter Registration Opens Mon 29-Apr-19
Applications for Graduation w/Academic Evaluations Due Fri 10-May-19
TPC Begins Accepting Completed Thesis and Dissertations Mon 13-May-19
Deadline for Thesis Defense Fri 17-May-19
Last Day to Withdraw From Class Fri 17-May-19
Deadline for Submission of Final Thesis Documents Thu 23-May-19
AETC Family Day Fri 24-May-19
Memorial Day (Holiday) Mon 27-May-19
Deadline for Submission of Final Dissertation Documents Tue 28-May-19
Spring Quarter Classes End Fri 31-May-19
Final Examinations Begin Mon 3-Jun-19
Final Examinations End Thu 6-Jun-19
Final grades due NLT 1200 Mon 10-Jun-19
Spring Degree Conferral Thu 13-Jun-19
Operations Management Commencement Fri 14-Jun-19

**Summer Orientation/Review Session 2019**

Technical Refresher Course Begins Mon 20-May-19
New Student Registration for Fall Quarter Begins Mon 29-Jul-19
Technical Refresher Course Ends Fri 14-Jun-19

**Summer Quarter 2019**  
47 Days

Summer Quarter Classes Begin Mon 24-Jun-19
Summer Quarter Registration Closes Fri 28-Jun-19
Independence Day (Holiday) Thu 4-Jul-19
AETC Family Day Fri 5-Jul-19
Last Day to Drop a Class Without Record Mon 8-Jul-19
Book Lists for Next Quarter Due Fri 19-Jul-19
Fall Quarter Registration Opens Mon 29-Jul-19
Applications for Graduation w/Academic Evaluations Due Fri 9-Aug-19
TPC Begins Accepting Completed Thesis and Dissertations Mon 12-Aug-19
<table>
<thead>
<tr>
<th>Event</th>
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<tbody>
<tr>
<td>Deadline for Thesis Defense</td>
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<td>Deadline for Submission of Final Thesis Documents</td>
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<tr>
<td>Deadline for Submission of Final Dissertation Documents</td>
<td>Mon</td>
</tr>
<tr>
<td>Summer Quarter Classes End</td>
<td>Thu</td>
</tr>
<tr>
<td>AETC Family Day</td>
<td>Fri</td>
</tr>
<tr>
<td>Labor Day (Holiday)</td>
<td>Mon</td>
</tr>
<tr>
<td>Final Examinations Begin</td>
<td>Tue</td>
</tr>
<tr>
<td>Final Examinations End</td>
<td>Fri</td>
</tr>
<tr>
<td>Final grades due NLT 1200</td>
<td>Mon</td>
</tr>
<tr>
<td>Summer Degree Conferral</td>
<td>Thu</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) 255-0452
Fax: (937) 255-5989

Academic Advisor
Each student is assigned a faculty member as an academic advisor who assists the student with academic planning. While advisors are available for advice and consultation, students are responsible for understanding 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. Each student has a faculty advisor, a professor appointed by the Department Head on the basis of familiarity with Institute programs, the student's programs, and the student's individual background.

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.

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.

Audited courses can also be retaken for credit in the future.

Classification of Students
The Graduate School recognizes 12 quarter hours as a minimum course load to be considered as a full-time student. Students who hold either Research Assistantships (RA) or Teaching Assistantships (TA) are considered full-time as long as they enroll in a minimum of 9 quarter hours per term. 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.

Course Listings and Schedules
Projected course listings for an academic year are typically published on the Graduate School's website. 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
The student is 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 the department prior to the end of the first quarter of study. Both the student and the faculty advisor should 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 and the Department Head. All such
changes are incorporated into the student's education plan and placed on file in the appropriate department.

**Enrollment**

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

**Registration**

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 AFIT website at www.afit.edu.

**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 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.

**Repeated Courses**

With proper approval, a student may repeat once for credit any course for which a grade of "D," "F," or "U" 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.

**Transfer Credit**

ENOI 36-167, Transfer Credit Policy, establishes procedures for students in master's degree programs to transfer up to 12 quarter hours of graduate credit from other regionally-accredited institutions prior to matriculation at the Graduate School of Engineering and Management. For information about the possible transfer of courses taken during or after matriculation at the Graduate School, please refer to EN OI 36-104, Policy for the Removal of Academic Deficiencies for Students in Master's Degree Programs. The Graduate School does not accept transfer credit for Ph.D. programs. The faculty advisor, the head of the appropriate department, and the Academic Standards Committee must approve transfer credits. Courses will not be submitted until one quarter in residence is successfully completed. All courses transferred for credit must carry a grade of "B" 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.

**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.

**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.
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 Office or Student Services Office.

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.

Incompletes

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 "Issued to Student" 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.

Transcripts

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

<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>Good</td>
<td>3.3</td>
</tr>
<tr>
<td>B</td>
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</tr>
<tr>
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<tr>
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<tr>
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</tr>
<tr>
<td>I</td>
<td>Incomplete</td>
<td></td>
</tr>
<tr>
<td>P</td>
<td>Progress (PhD)</td>
<td></td>
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<tr>
<td>S</td>
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<tr>
<td>NG</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AU</td>
<td>Audit</td>
<td></td>
</tr>
</tbody>
</table>

Further Clarification

1. "S" grades count only toward earned hours and do not affect the grade point average (GPA). "U" grades are also to be assigned for thesis or dissertation credits during which the student's progress toward completion has been unsatisfactory.
2. The instructor or the academic advisor, in coordination with the Dean, will determine the resolution deadline.
3. Please see your instructor as soon as possible.

Grades apply only to pass/fail courses.
Academic Standards

Academic Integrity

Students are expected to adhere to the highest standards of academic integrity, in accordance with Air University Instruction 36-2309, 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 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

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.
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

### Purpose

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 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.

### 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-temp 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.

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 course work

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 Examination

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.

### 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 requirement

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*. 

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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.

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, Registration, International Military Student support and Student Operations.

Office of Admissions
Phone: (937) 255-6234 x3184 (DSN 785-6234 x3184)
or Toll Free 800-211-5097 x3184.
Fax: (937) 255-2791 (DSN 255-2791)
Email address: ENERAdmissions@afit.edu.
Web link: 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.”

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.

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.

Meet or exceed grade point average of 3.00 based on a 4.00 scale, and

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.

### Academic Eligibility Criteria – 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.

### Academic Eligibility Criteria for Certificate Programs and Non-Degree Seeking Applicants

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.

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 http://www.afit.edu/en/Admissions, look for "Online Admission Form.

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/ADMISIONS/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.

Required Documentation for Master's and Doctoral Degree Programs

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) or write to the following addresses:

Required Documentation for Certificate Programs and Non-Degree Seeking Applicants.

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

- A completed online application form.
- 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.

- 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 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.

- Admissions tests (GRE/GMAT) are not required for certificate programs and non-degree-seeking applicants.

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
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:

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.

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.

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.

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.
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).

Academic Waivers

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.

Admission Statuses

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.
Enrollment Changes After Admissions

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. 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. Here is the Internet link to the application https://www.afit.edu/Admissions/AFITApplicationProcess/. 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.
Registrar’s Office

Phone: (937) 255-6234 x3127 (DSN 785-6234 x3127)
FAX: (937) 255-2791 or (DSN FAX 785-2791)
E-mail address: registrar@afit.edu
Website: https://www.afit.edu/ENER/

Current Academic Catalog
The catalog may be viewed on line at:
https://www.afit.edu/ENER/doclib.cfm?dl=31
Click on catalog in left column.

AFIT Website
Website for AFIT, general and detailed information about the Graduate School, and its departments and programs is located at http://www.afit.edu.

Release of Student Information
AFIT may release information concerning current or former students that appears in directories and publications available to the public without the student's consent except when requested by the student to hold such information confidential.

For currently enrolled students, this information includes the student's name; major field of study; dates of attendance and full or part-time status, degrees, honors, and certificates received or anticipated. For former students, this information may include the student's name; school, major field of study; dates of attendance and full- or part-time status; honors, and certificates, or degrees earned at AFIT.

Academic credentials presented to AFIT for the purpose of establishing academic eligibility become the property of AFIT and are not subsequently released to the student or to another individual or institution.

The academic data of students subject to the Uniform Code of Military Justice may be released to officials of various government agencies for the purpose of conducting background investigations or other official purposes without the consent of the student concerned. Additionally, information may be released under the authority of the Freedom of Information Act as determined appropriate by officials interpreting FOIA policy.

The Air Force Institute of Technology (AFIT) is a component of Air University (AU). Therefore, your educational records, including personally identifiable information (PII), may be shared with AU officials who have a legitimate educational need to know. This includes, but is not limited to AU officials and/or contract personnel responsible for developing, validating, and maintaining student records, the AU Student Information System (SIS), and the AU Learning Management System (LMS).

Transcripts Release
The Registrar may release student academic information to organizations conducting studies for, or on behalf of, educational agencies or the Institute for the purpose of developing, validating, or administering predictive tests, improving instruction, and to accrediting organizations in order to carry out their accrediting functions. Such studies must be conducted in such a manner as will not permit the personal identification of students by persons other than those conducting the study, and such information must be destroyed when no longer needed for the stated purpose.
Transcript Requests

An official transcript of each student's academic record is maintained by the Registrar's Office. The permanent record is considered confidential between the student and the Institute. Transcripts are not released, except to authorized government or school representatives who need these documents for conduct of official business, without the written permission of the student. All transcripts that are issued to students will be stamped "ISSUED TO STUDENT".

There is no fee for transcript service.

Bring photo identification to the Registrar’s office or obtain a transcript request form at: https://www.afit.edu/docs/AFIT%20EN%20Transcript%20Request.pdf

If you are unable to download the PDF and wish to send a letter please make sure it contains the following information:

1. Your name, maiden name, and any other previous names (if applicable)
2. Social Security number/AFIT Student Identification number
3. Birth date
4. Dates of attendance
5. Complete address where you would like the transcript sent
6. Your current address and phone number in case we have questions
7. Your signature authorizing the release of the transcript

Send requests to: OFFICE OF THE REGISTRAR -- AFIT/ENE
BUILDING 641, 2950 HOBSON WAY
WRIGHT PATTERSON AFB OH 45433-7765
Or email to: registrar@afit.edu
Or fax to: (937) 255-2791 or (DSN 785-2791)

Student Operations

AFIT/ENE, Building 641, Room 102
2950 Hobson Way
Wright Patterson AFB OH 45433 -7765
Phone: (937) 255-6234 x4217 (DSN 785-6234 x4217)
FAX: (937) 255-2791 or DSN FAX 785-2791
E-mail address: studentservices@afit.edu
Website: https://www.afit.edu/STUDENTSERVICES/

The Student Support Division provides a wide range of services, and is the primary office of responsibility for numerous activities in the Graduate School. A sampling of their services and responsibilities are as follows:

- Student Handbook
- Newcomer orientation program
- Official student mail
- Fax service
- Access to special passes/safety forms/leave
- Loan deferments
- PhD cubicle assignments
- Training Reports and Supplemental Training Reports
- Graduation and Award Ceremonies
- Sponsorship program for incoming students
- Management of the Casual Flight
- Focal point for all early/late reporting and departure requests
INTERNATIONAL MILITARY STUDENT OFFICE

Director and International Military Student Officer (IMSO), Michael Paprocki
AFIT/ENE, Building 641, Room 102
2950 Hobson Way
Wright Patterson AFB OH 45433 -7765
Voice: (937) 255-6800 x4303 (DSN 785-6800 x4303)
Cell: (937) 977-3020
FAX: (937) 255-9981 or DSN FAX 785-9981
WhatsApp ISMO Paprocki
E-mail address: michael.paprocki@afit.edu
Website: http://www.afit.edu/imso

The International Affairs Office provides all functions related to AFIT International Programs, starting with inquiries about AFIT programs, request for evaluations for admissions, and final admissions results which the IMSO sends back to country. Coordinates all training for foreign countries through the Air Force Security Assistance Training Command (AFSAT), embassies around the world, and the Office of the Secretary of the Air Force, International Affairs (SAF/IA).

The IMSO is the sole POC for answering questions concerning International Affairs at AFIT from the Security Assistance Officer (SAO) in the foreign country embassy, AFSAT, and SAF/IA. The International Officer is responsible for the cultural, social, and academic integration of military officers and their families into the community and AFIT environment once they arrive in the US.

- Educates and supports international military officers’, Ministry of Defense personnel and their families
- Enables AFIT to accomplish US Security Assistance Objectives: teaching international recognized human rights, democracy, interrelationships of culture, ethics, economy, social diversity and free enterprise
- Maintains a critical academic International database, manages Invitational Travel Orders and is responsible for in-processing and out-processing international students
- Manage all aspects of disciplinary problems, academic issues, language concerns, medical problems, passport issues and leave requests
- Maintains academic records and training reports
- Manages a sponsor program and the Congressionally mandated Field Studies Program
| 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 ([https://www.facebook.com/AFITStudentAssociation/info](https://www.facebook.com/AFITStudentAssociation/info)) contains information on student events and a means to contact the current leadership with questions and/or ideas. |
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 Extension Services 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/](http://www.afit.edu/DL/)
- send an email to en.dl@afit.edu or
- contact the Extension Services office by phone at (937) 255-3636 x 7422 (DSN 785-3636 x7422)

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

**Certificate Programs (5)**
- Human Factors Engineering
- Supply Chain Management
- Systems Engineering
- Test and Evaluation
- Nuclear Weapons Effects, Policy, and Proliferation (NWEPP)

**Master’s Degree Programs (4)**
- Applied Systems Engineering
- Engineering Management
- Logistics
- Systems Engineering

Generally speaking, students must be unit-sponsored (i.e., unit-funded) to enroll in most AFIT DL Programs. Admission to the NWEPP program requires Engineering Physics department approval in addition to meeting the admissions criteria. See our website for more details.

**Application and Enrollment Information**
More information about these programs, including application and enrollment information, can be found at AFIT’s Extension Services website: [http://www.afit.edu/DL/](http://www.afit.edu/DL/)
Library Services

Dr. Ellis Beter, Director
AFIT/ENWL
2950 Hobson Way, Bldg. 642, Room 1400B
Wright-Patterson AFB, OH 45433-7765
Phone: (937) 255-3005 (DSN: 785-6565 ext 4216)
Fax: (937) 656-7746
Website: http://www.afit.edu/library/

Mission Statement
The primary mission of The D’Azzo Research Library is to support the educational, research and consulting programs of AFIT and AFRL.

Location
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 Networked computers. An additional five AFIT Networked and seven AFNet workstations for TDY users and new arrivals from other bases are located on the first floor, and 24 networked computers are on the second floor for student and faculty use.

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 holds a complete collection of AFIT graduate student theses and dissertations.
- A small, circulating 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.
- 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 sample of databases includes: The Aerospace Database, Compendex, EBSCO Academic Search and Business Source, IEEE Xplore, INSPEC, MathSciNet, ScienceDirect, and Science Citation Index Expanded
A complete list of databases and journals is available at the library's homepage:
www.afit.edu/library

Students, faculty and staff may use the library's interlibrary loan service to request materials that are not owned by The D'Azzo Research Library. Registration for an interlibrary loan account, (using ILLiad), 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'Azzo 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

Director, Financial Management, Ms. Amber L. Richey
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@afit.edu

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 an approved SF 182. 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. DL students only: Submit either an approved SF 182 OR an e-mail from your supervisor stating that the course work will not be done during duty hours.

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
carol.autry@afit.edu or Bursar@afit.edu

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

Refund Policy
Tuition refunds can only be given if the payment was made via credit card on the Pay.Gov web site. Invoices are not sent until after the drop period has passed. For refund purposes, the effective date of cancellation is the date the student submits the completed drop form to the Registrar's Office, not the last day the student attends class.

In special circumstances, AFIT will consider an extended period for refund of tuition when withdrawal is certified by the individuals unit to be in the best interest of the Air Force to fulfill mission essential activities (such as deployments). In this case, the student's supervisor should contact the AFIT Bursar's Office with specific details.

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%

Tuition refunds for Distance Learning Students will otherwise be limited according to the following schedule:

- Prior to the Monday beginning the fourth week of classes 100%
- After Monday, beginning the fourth week of classes 70%
- After the Monday of the fifth week of classes 0%

Research Assistantships (RA)
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 Maggie.Varga@soche.org

Tuition Assistance
AFIT will no longer accept Tuition Assistance.

VA Education Benefits
Students can use their VA Education Benefits. Contact the Admission’s office for more details.
**Computer Support**

**Director, Communications and Information, Sarah Mashburn, Maj, USAF**

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](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](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 enable 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.

**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.

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).
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.

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

Professor

Richard G. Cobb structural dynamics and control
Donald L. Kunz dynamics and control
Bradley S. Liebst dynamics and control
Anthony Palazotto (Distinguished Professor) structural mechanics
Marc D. Polanka heat transfer and propulsion
Mark F. Reeder fluid dynamics
Marina B. Ruggles-Wrenn structures and materials
William E. Wiesel astrodynamics

Associate Professor

Robert B. Greendyke fluid dynamics, physical chemistry, air weapons
James L. Rutledge fluid mechanics and heat transfer

Assistant Professor

Bradley J. Ayres dynamics and control
Robert A. Bettinger dynamics and control
Darrell S. Crowe computational fluid dynamics, air weapons and propulsion
Jacob A. Freeman computational fluid dynamics, aerodynamics, uncertainty quantification
Carl R. Hartsfield propulsion and air weapons
Joshua A. Hess orbital mechanics, spacecraft attitude determination, optimization
Kirk W. Johnson orbital mechanics and astrodynamics
Jeffrey Komives computational fluid dynamics and hypersonics
Andrew J. Lingenfelter aircraft survivability and weapons testing
Levi M. Thomas laser measurement and combustion
Michael M. Walker aerodynamics and active flow control

Professor Emeritus

Milton E. Franke aerodynamics, propulsion, and weapons
Peter J. Torvik dynamics
**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.

**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.

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.

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.

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.

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.

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<tr>
<th>Instructional Method</th>
<th>Thesis</th>
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<tr>
<td>Min Hours</td>
<td>1</td>
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<tr>
<td>Max Hours</td>
<td>12</td>
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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.

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<tr>
<th>Instructional Method</th>
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<td>Min Hours</td>
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<td>Terms Offered</td>
<td>All</td>
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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.

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 pro-temp 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

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 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.
Mathematics
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.

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

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

School and Program Admissions 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/

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.

Mathematics
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 Sequence
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
The thesis is an independent investigation of a problem of current Air Force interest, conducted and documented by the student, with supervision of the faculty. This independent study may be done under the direction of either the Department of Aeronautics and Astronautics (for structural materials) or the Department of Engineering Physics (for non-structural materials) and can be carried out either at AFIT or at a directorate of the Air Force Research Laboratory. Theses by GMS students can be theoretical, experimental, or numerical. Topics will be proposed by Air Force research and development organizations, particularly the Materials and Manufacturing Directorate of the Air Force Research Laboratory. Flexibility in the program is maintained in order to take full advantage of the varied backgrounds and abilities of individual students.

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

Materials Science (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 Admissions 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.
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

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

Mathematics
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.

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.

Specialty Sequence
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.

Space Systems (Ph.D.)*

Program Description
Students are admitted to a study leading toward the PhD degree in Space Systems. A pro-temp 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
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)

Interim Department Head: Kenneth M. Hopkinson, PhD
2950 Hobson Way, Building 640, Room 315
Wright-Patterson AFB, OH 45433-7765
Phone: (937) 255-2024 (DSN 785-2024)
Fax: (937) 656-7061 (DSN 986-7061)
E-mail address: eng@afit.edu
Website: http://www.afit.edu/en/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)

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

Peter J. Collins Low observables, electromagnetic materials design and remote sensing, electromagnetic theory, computational electromagnetics, signature metrology

Michael J. Havrilla Electromagnetism, guided waves, material characterization, low observables

Kenneth M. Hopkinson Wired/wireless networking, fault tolerant and reliable distributed systems, information security, net-centric warfare, use of networks to enhance critical infrastructures, cognitive radios, space applications, remote sensing

Gary B. Lamont Artificial intelligence, computer science, computer engineering, digital control systems, parallel and distributed computation, software engineering, network security, UAVs, evolutionary computing

Richard K. Martin Signal processing, through-wall imaging, geolocation and navigation, electronic warfare, laser radar target recognition

Robert F. Mills Electronic warfare, cyber operations, computer/network/embedded systems security

Barry E. Mullins Cyber-physical systems security, cyber operations, critical infrastructure protection, computer/network/embedded systems security, wired/wireless networking, reverse code engineering

Meir N. Pachter Integrated and network navigation systems, inertial navigation, guidance, vision-based navigation, optimal control

Gilbert L. Peterson Uncertainty in artificial intelligence, robotics, machine learning, data mining

John F. Raquet Global positioning system (GPS), non-GPS navigation, vision-aided navigation, sensor integration

Michael A. Temple Radio frequency signal exploitation, communication systems, navigation systems, radar systems, cyberspace

Associate Professor

Brett J. Borghetti Machine learning, deep learning, human subject research, seismic research, hyperspectral imagery analysis, artificial intelligence, opponent modeling, agents, multi-agent systems, mechanism design

Stephen C. Cain Digital systems, image processing, optics

Douglas D. Hodson Software engineering, modeling and simulation

Julie A. Jackson Radar signal processing, electromagnetics, automatic target recognition, multi-static radar, novel image formation techniques, sensor fusion
Andrew J. Terzuoli  Electromagnetics, low observables, antennas remote sensing, object recognition, model-based vision, computer methods

Assistant Professor

David J. Becker  Electro-optics, image processing, space object detection
Joan A. Betances  Software defined radios, cognitive radios, communication systems, wireless networks, mobile ad hoc networks, signal processing
Aaron J. Canciani  Magnetic anomaly navigation, non-GPS navigation, sensor integration
Daniel J. Casey  Software defined networks, network security, cyber operations, reverse engineering, navigation warfare
Hengky Chandrabalim  Optofluidics, photoacoustics, biophotonics, optomechanics, symbiotically enhancing phononic, magnonic and photonic devices, mutually assisting micro- and nano-systems, fabrications of integrated novel micro- and nano-systems
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
Scott R. Graham  Cyber-physical systems security, automotive and avionics cyber vulnerabilities, data bus architectures, critical infrastructure protection
Sanjeev Gunawardena  Satellite navigation and timing systems, navigation warfare, positioning navigation and timing (PNT) receiver design, satnav signal monitoring, digital signal processing, digital systems design, RF systems design, embedded systems design, reconfigurable computing, software defined radio, high performance computing
Tod V. Laurvick  NEMS, Microelectronic thin films/surface effects, microelectronic integration, additive manufacturing
Robert C. Leishman  vision-based non-GPS navigation, autonomous aerial vehicles, autonomy, sensor fusion
James R. Lievsay  Radar signal processing, passive radar, space-time adaptive processing, signal/target detection and estimation
Laurence D. Merkle  Algorithms, computability and complexity, computational science and engineering, cybersecurity education, evolutionary computation, games in computing education, optimization, quantum computing, space situational awareness
Scott L. Nykl  Computer graphics, computational geometry, GPGPU, Parallel/concurrent systems, UAVs, networking, computer vision, augmented reality, sensor fusion, software engineering, virtual worlds
Scott J. Pierce  Non-GPS navigation, image processing, target tracking
Mark G. Reith  Cyber education techniques, multi-domain command and control, cyber mission mapping, defensive cyber operations, enterprise mission assurance, integrated cyber defense systems, insider threats, software engineering, software security, trust management
Clark N. Taylor  estimation theory, vision-aided navigation, geo-registration/localization, unmanned aerial vehicles, distributed data fusion

Professor Emeritus

Frank M. Brown  discrete mathematics, operations research
Nathaniel J. Davis IV  computer networks, computer security, computer architecture, parallel computing
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, pattern recognition

Associate Professor Emeritus

Thomas C. Hartrum  computer database systems, software engineering
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 Admissions 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.

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)

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 Admissions 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.
- CSCE 999 - Dissertation Research
- EENG 999 - Dissertation Research
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 Admissions 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.

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.

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 Admissions 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 (M.S.)

Program Description
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 Admissions 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.

Degree Requirements
Core Courses
24 hours
- CSCE 525 Introduction to Information Warfare
- CSCE 526 Secure Software Design and Development
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 Admissions Requirements

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.

Degree Requirements

36 hours

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 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 Admissions 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 Admissions 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
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, Ph.D.
2950 Hobson Way, Building 640, Room 219
Wright-Patterson AFB, OH 45433-7765
Phone: (937) 255-3636 x46
Fax: (937) 656-6000 (DSN 986-6000)
E-mail address: enp@afit.edu
Website: http://www.afit.edu/en/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 in-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, 470, and 194. 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.

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
- Combating Weapons of Mass Destruction (currently unavailable)
- Materials Science
- Nuclear Engineering
- Optical Science and Engineering

**Doctor of Philosophy**

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

**Certificate Programs**

- Combating Weapons of Mass Destruction (currently unavailable)
- Nuclear Weapons Effects, Policy, and Proliferation (DL)

**Faculty**

**Professor**

- **Larry W. Burggraf** computational and materials chemistry, optical/nuclear spectroscopy, exotic particles
- **Nancy C. Giles** experimental solid state physics, photoluminescence, absorption, Raman, and magnetic resonance (EPR) spectroscopy
- **Michael A. Marciniak** optical/infrared signatures, electro-optics
- **Glen P. Perram** laser physics, chemical kinetics, molecular spectroscopy
- **James C. Petrosky** nuclear engineering, radiation effects on materials
- **Heidi R. Ries** nonlinear optical materials, electron paramagnetic resonance imaging spectroscopy, laser processing of materials, Dean for Research
- **David E. Weeks** computational chemical physics
- **Paul J. Wolf** atomic, molecular and optical physics, Associate Dean of Academic Affairs
Associate Professor

Steven T. Fiorino research faculty, atmospheric physics, microwave remote sensing
Kevin C. Gross molecular spectroscopy, remote sensing; Dir CTISR
John W. McClory nuclear engineering, radiation effects on electronics, radiation-induced defects
Ronald F. Tuttle measurement and signature intelligence

Assistant Professor

Abigail A. Bickley research faculty; nuclear chemistry, nuclear engineering, nuclear forensics
James E. Bevins optimization, neutron spectroscopy, nuclear effects, post-detonation forensics, radiation detector development, and nuclear policy
Santasri Bose-Pillai research faculty; laser beam propagation and imaging through atmosphere, partially coherent sources, laser communications
Kenneth W. Burgi Fourier Optics, statistical optics
Samuel D. Butler optical physics
Michael J. Caylor research faculty; space systems
Justin A. Clinton nuclear engineering. NWEPP course instruction
Michael L. Dexter nuclear weapons effects
Daniel J. Emmons plasma physics, space physics
Manuel R. Ferdinandus optics, fast-pulse lasers, nonlinear optics
Anthony Franz lasers, optics
Michael R. Hawks research faculty; optics, remote sensing
Nicholas C. Herr laser/material interactions; materials
Edward L. Hobbs radiation transport
Michael R. Hogsed engineering physics, radiation effects on devices
Robert D. Loper quantum scattering, computational physics
Jesse J. Lutz research faculty; quantum chemistry, quantum physics, modeling solid state defects
Jack E. McCrae research faculty; directed energy weapons systems
Omar A. Nava atmospheric science
Christopher A. Rice research faculty; image processing, laser development, remote sensing, rare-gas laser
Michael B. Shattan nuclear engineering
Bryan J. Steward research faculty; optical engineering, optical characterization, remote sensing
Robert. C. Tournay atmospheric science, land surface interaction, ML/AI forecasting applications
H. Rose Tseng atmospheric science

Professor Emeritus

William F. Bailey plasma physics, space physics
Robert L. Hengehold experimental solid state physics
Kirk A. Mathews computational nuclear engineering

Adjunct Faculty

Kevin S. Bartlett atmospheric science
John R. Bruzzese lasers, photonics
Xiaofeng Frank Duan computational chemistry and materials science
Michael T. Eismann hyperspectral imaging
F. Kenneth Hopkins directed energy, photonic devices
Gary S. Kedziora computational chemistry and materials science
Tony D. Kelly nuclear engineering
C. David Lewis II computational physics
Douglas R. Lewis biodefense, weapons of mass destruction
Joseph Meola hyperspectral imaging
Buckley E. O’Day nuclear engineering, radiation health physics
Gregory A. Pitz diode pumped alkali laser, hollow core gas-filled fiber lasers, laser spectroscopy
Mark Spencer adaptive optics, directed energy

Applied Physics (M.S.)

Program Description
The Applied Physics program provides each student with a broad, graduate-level foundation in applied physics with a focus on one of three educational tracks: engineering physics, atmospheric and space sciences, or space physics. Core courses address the foundational aspects of physics (mechanics, quantum mechanics, statistical physics and electrodynamics), 8 credit hours in this area are required. Both analytic and discrete mathematics are important. There is a 4-credit hour requirement in this area. Curriculum content in the applications area requires 12 credit hours, designed to achieve an educational breadth (example: directed energy, solid state physics, and plasma physics). The research experience is the capstone of graduate education. All students are required to complete and defend a thesis (12 credit hours).

Laboratory techniques and computational methods are emphasized in all three tracks, providing a balanced exposure to experimental and theoretical practices. A graduate lab course is required.

Depending on the track, the program length is six or seven quarters. The first two quarters of the program stress foundational physics and mathematics. During the remaining four 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, in the case of an Air Force officer, the requirements associated with the officer’s Air Force education code.

Concentration in the two tracks is as follows:

- **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 and ionosphere and the 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.

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 AFIT to these tasks.
• 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, 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 Admissions 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.

**MATHEMATICS REQUIRED:** Ordinary Differential Equations

**TEST REQUIRED:** GRE - 153V/148Q

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

**USAF EDUCATION CODES:**
4KDY, Engineering Physics; 8FDD, Ionospheric Environment (21 mo); 8FDY, Solar and Space Sciences (21 month); 8HCG, Lasers, Atomic and Molecular Physics; 8HCX, Atomic and Molecular Physics, Other; 8HCY, Atomic and Molecular Physics; 8HEY, Electromagnetism; 8HFG, Physics, Semiconductor Devices; 8HFX, 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 Op- tics; 8MH, Infrared Phenomena; 8MJ, Lasers; 8MHY, Optics; 8HNH, Incompressible Fluid Dynamics; 8HNJ, Plasma Physics; 8HNY, Physics of Fluids; 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.
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 Admissions 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; 8HNY, Physics of Fluids (Plasmas); 8HOY, Solid State Physics; 8HFG, Physics, Semiconductor Devices; 8HMA, Physics, Atmosphere and Space Optics; 8HMH, Physics, Infrared, Incompressible Fluid Dynamics; 8HNI, 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.

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.

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, re- search proposals, and conference presentations. Be able to contribute and communicate their results and understanding in these same forums.

School and Program Admissions Criteria

**DEGREE REQUIRED:** BS 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.

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

AFIT Nuclear Engineering Student Outcomes
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
• 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 Admissions 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).

Nuclear Engineering (Ph.D.)

Program Description

The Ph.D. 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, counterproliferation, 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 Admissions 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 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.

Nuclear Weapons Effects, Policy, and Proliferation Certificate (DL)

Program Description

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.

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.

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)

Admissions

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.

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. This independent study may be done under the direction of either the Department of Engineering Physics or appropriate Department of Electrical and Computer Engineering faculty. 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.
- 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 Admissions 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).
Optical Science and Engineering (Ph.D.)

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 Admissions 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.

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 Dept 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


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 his or her 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.

**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.

**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.

**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 Admissions 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: 4FY, Materials Science and Engineering, General; 4KCB, Mechanical Properties of Materials; 4FY, Electronic and Optical Materials; 4GCK, Nuclear Chemical Engineering; 4FCY Ceramic Engineering. Current sponsors of Air Force military education quotas are 4FY - AFRL/RXPS (WPAFB and Robins AFB), 4KCB - AFRL/RXLMN (WPAFB), 4NCY - AFRL/RXLMMP (WPAFB), 4FY - 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: http://www.afit.edu/en/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.

Faculty

Professor

Matthew C. Fickus  applied harmonic analysis, frame theory, compressed sensing
Alan V. Lair  partial differential equations, functional analysis
Mark E. Oxley  partial differential equations, wavelets, information fusion
Edward D. White, III  biostatistics, design of experiments, regression
Aihua W. Wood  partial differential equations, electromagnetics, rarefied gas dynamics

Associate Professor

Benjamin F. Akers  nonlinear waves, numerical analysis, fluid mechanics
William P. Baker  asymptotic and perturbation methods, wave propagation
Dursun A. Bulutoglu  design of experiments, combinatorial optimization
Christine M. Schubert Kabban  biostatistics, classification methods, information fusion

Assistant Professor

Andrew M. Armstrong  statistical machine learning, big data, wavelet analysis
Travis J. Bemrose  applied harmonic analysis, frame theory
Eric L. Brooks  statistical machine learning, big data
Andrew J. Geyer  design of experiments, combinatorial optimization
Jeremy D. Jordan  operations research, analytics, network optimization
Dana F. Morrill  numerical analysis, fluid mechanics
Beau A. Nunnally  biostatistics, classification systems
Richard P. Uber  partial differential equations, electromagnetics

Research Assistant Professor

Amy L. Magnus  computational intelligence, biometrics, information fusion, constraint programming

Professor Emeritus

Dennis W. Quinn  partial differential equations
Daniel E. Reynolds  environmental statistics
Programs

Master of Science

- Applied Mathematics (M.S.)

Doctor of Philosophy

- Applied Mathematics (Ph.D.)

Applied Mathematics (M.S.)

Program Description

The aim of this Master’s degree program is to provide a balanced foundational education in mathematical and statistical analysis, an understanding of appropriate applications of the theory, and some depth in an area of specialization. The program, which requires a thesis, usually takes 18 months to complete and is designed for students who have completed an undergraduate major in mathematics or statistics. However, students from other disciplines who have a strong record in mathematics will usually find their preparation to be adequate. For those with weaker mathematics backgrounds, completing the program will normally take longer than 18 months.

The core courses common to all Applied Mathematics master of science degree options are STAT 601 (Theory of Probability), STAT 602 (Mathematical Statistics), MATH 601 (Complex Analysis), and either MATH 600 (Mathematical Analysis) or MATH 602 (Modern Applied Mathematics I). The student will specialize in analysis, statistics, or numerical analysis by taking three courses within the specialty area.

The department believes that the applied nature of the program is enhanced by interaction with at least one other department in the Graduate School of Engineering and Management. Therefore, an out-of-department sequence (minimum of eight hours) taken from another department is required, and serves to help the future applied mathematician gain an appreciation for communicating with other scientists and engineers. In addition, the thesis project is invariably linked to an Air Force or Defense Department organization, further enhancing the student’s appreciation for and experience in working with the non-mathematician.

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.

Program Outcomes (POs)

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

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.

Degree Requirements
Core Courses
16 hours

Out-of-Department sequence
8 hours

Specialization
12 hours

Thesis
12 hours

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 Admissions 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
Completion of at least 36 hours of coursework beyond the Master’s degree to include:

Specialization
24 hours

Out-of-Department Requirements
8 hours

Dissertation Research
48 hours

Admission to candidacy
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: Dr. Joseph J. Pignatiello
2950 Hobson Way, Building 641, Room 201
Wright Patterson AFB, OH 45433-7765
Phone: (937) 255-3636, Extension 3136
Fax: (937) 656-4943 (DSN 986-4943)
E-mail address: ens@afit.edu
Website: www.afit.edu/ENS/

The Department of Operational Sciences offers world class graduate programs in operations research and logistics. 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 http://www.afit.edu/en/COA/index.cfm.

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.

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

- Combat Modeling Laboratory http://www.afit.edu/en/ens/combatmodelinglab.cfm
- Future Operations Investigation Laboratory http://www.afit.edu/en/ens/futureoperations.cfm
- Sensor Fusion Laboratory http://www.afit.edu/en/ens/sensorfusionlab.cfm
Programs

Master of Science

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

Doctor of Philosophy

- Logistics
- Operations Research

Graduate Certificate

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

Faculty

Professor

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, measure of effectiveness and assessment, behavioral modeling including social networks, modeling fourth generation operations, counter insurgency and irregular warfare, applied mathematical programming and optimization, project and program management, modeling and analysis, space applications, campaign modeling, technology selection and management, scheduling, network models, advanced manufacturing methods, multi-criteria decision making, and decision analysis

Raymond R. Hill, Jr. - 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 with particular interests in the area of agent-based modeling and the validation of such models

Alan W. Johnson – space logistics, strategic mobility, discrete-event simulation, logistics management, reliability and maintainability, and discrete optimization and heuristics

Joseph J. Pignatiello - statistical process monitoring, change-point models, design and analysis of experiments, reliability, statistical data analysis, robust design, and six sigma methods

Jeffery D. Weir - decision analysis, applied statistics, deterministic optimization

Associate Professors

Darryl K. Ahner - dynamic programming applications, queueing applications, mathematical control theory and model predictive control of complex systems, missile defense, combat modeling algorithm development, models for supply chain management
Benjamin T. Hazen - empirical research in the areas of closed-loop supply chains, reverse logistics, remanufacturing, sustainability, innovation, and the supply chain management/information systems interface

Seong-Jong Joo - sourcing, transportation, performance measurement and benchmarking, inventory management

Brian J. Lunday - theoretical research interests include math programming, game theoretic models, algorithmic design for global optimization; application research interests include network design, network interdiction, network restoration, facility location, resource allocation/assignment

John O. Miller - computer simulation, ranking and selection, agent based modeling, combat modeling, network centric warfare, high performance computing, applied statistics, and nonparametric statistics

Assistant Professors

Jason R. Anderson - transportation, logistics management, inventory, sourcing, operations management, simulation

Timothy W. Breitbach - supply chain finance, logistics, inventory and petroleum management, qualitative and quantitative supply chain analysis

Lance E. Champagne - agent-based simulation, combat simulation, emergent system behavior

Bruce A. Cox - linear and convex optimization, robust optimization, optimal control

Christopher M. Smith - decision analysis, risk analysis, data mining, network analysis, social media analysis

Daniel W. Steeneck - inventory management, remanufacturing, scheduling, service parts management, supply chain analytics, retail operations

Thomas P. Talafuse - reliability, reliability growth, optimization, stochastic processes, design of experiments, applied statistics, risk analysis

Heidi M. Tucholski - decision analysis, incentive theory, statistical data analysis, game theory, behavioral and experimental economics

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 Program 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.

School and Program Admissions 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 Logistics
- 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

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 Program 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.

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.

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.

**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

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 Program 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 Admissions 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 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.

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 Program 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 refered 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/](http://www.afit.edu/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/](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/](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.
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 Program 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 Admissions 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.

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
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 Program 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 Admissions 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 Program
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.

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
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 Admissions 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
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 Program 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.

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.

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 Program 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.

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
Systems and Engineering Management (ENV)

Department Head: Michael R. Grimaila, PhD, CISM, CISSP
2950 Hobson Way, Building 640, Room 101
Wright-Patterson AFB, OH 45433-7765
Phone: (937) 255-2998 (DSN 785-2998)
Fax: (937) 656-4699 (DSN 986-4699)
E-mail address: env@afit.edu
Website: http://www.afit.edu/en/env/

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
- Human Systems 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

Doctoral Programs
- Systems Engineering with several available specializations
- Specializations in autonomous systems, environmental systems, information/cyber systems, industrial hygiene, infrastructure systems, quantum information, space systems, and unmanned aerial systems
Certificates

- Systems Engineering Certificate
- Human Systems Certificate

Faculty

Professor

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

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

Associate Professor

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, DoD acquisition research, modeling & simulation

Michael E. Miller human systems integration (HSI), human factors, human machine interface design, lighting and display design

Alfred E. Thal, Jr. facility/infrastructure management, engineering management, project management, risk management, economic analysis, innovation, sustainability

Assistant Professor

Amy M. Cox systems engineering, user innovation, design, flexibility, system architecture, flight test

Scott T. Drylie cost analysis, cost growth, economic analysis, acquisition reform, profit analysis, incentives

John J. Elshaw 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, cognition and emotions, motivation (self-regulation, intrinsic versus extrinsic control), human performance, learning curve analysis, organizational trust, performance, commitment project management

Robert M. Eninger exposure assessment, aerosol science, environmental risk analysis, toxicology, ionizing radiation

Robert D. Fass cost analysis, risk analysis, decision analysis and optimization, leadership, organizational performance, research methods, government acquisition system, strategic alliances, project management

Thomas C. Ford systems architecture, interoperability, resiliency, model-based systems engineering, systems modeling and simulation, space systems, systems integration

Jason K. Freels 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, structures and materials, survival/reliability analysis, systems engineering

Christopher A. Gay project management

Andrew J. Hoisington infrastructure asset management, environmental engineering, built environment, indoor air quality, microbiome of built environment, microbiome influencing human performance

Clay M. Koschnick economic analysis, dynamic programming, econometrics, decision analysis, systems engineering

Brent T. Langhals data management and analysis, data analytics, human computer interaction, systems engineering, resource management, knowledge management,

David S. Long systems architecture, complex systems, systems of systems, human systems integration, project management, organizational development
Eric G. Mbonimpa sustainability and life, environmental sustainability, life cycle assessment, surface water quality modeling, disinfection of water using solar radiation, water quality and treatment
Jonathan D. Ritschel cost analysis, economic institutional analysis, acquisition reform, public choice
Steven Schultd civil engineering, project management, construction management, optimal resource utilization, multi-objective optimization, genetic algorithms, risk management, installation resiliency, sustainability
Jeremy M. Slagley industrial hygiene, environmental management, waste to energy
John E. Stubbs environmental engineering and science, water treatment and remediation
Torrey J. Wagner systems engineering, renewable energy systems, electro-optics, agile software development

Adjunct Faculty
Juan Leon infectious disease, epidemiology, outbreak response
David R. Mattie inhalation toxicology, toxicokinetics
Joseph Pellettiere biomechanics, crash dynamics and passenger safety
Leeann Racz environmental engineering, environmental microbiology, environmental health and science
Christina F. Rusnock human factors, human performance modeling, simulation of cognitive workload, project management
Terry A. Wilson systems engineering, data analytics, information and knowledge management

Professor Emeritus
Charles A. Bleckmann environmental remediation, environmental microbiology
Anthony P. D’Angelo logistics management, federal financial management
Mark N. Goltz environmental engineering, environmental modeling, environmental technology transfer, fate and transport of contaminants
Jan P. Muczyk leadership, business strategy, implementation, streamlining bureaucracy
Freda F. Stohrer communications
David K. Vaughan scientific and technical communication, Air Force history

Applied Systems Engineering (M.E.)

Program Description
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/.

Admission Criteria
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 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

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TEST REQUIRED: GRE - 153V/148Q.
P RP Q 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/

Program Educational Objectives
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

Student Outcomes
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

Degree Requirements
The ASE program requires a minimum of 48 credit hours covering the following program elements: core courses, mathematics, a Specialization, an applied Analytical Toolset requirement, and a Capstone Project. The program elements are discussed below.

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
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.

**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

**Cost Analysis (M.S.)**

**Program Description**
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

Program Outcomes (POs)

- 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 Admissions 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.

Degree Requirements

Cost Specialty Core
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
12 hours
- STAT 525 - Applied Statistics for Managers I
- STAT 535 - Applied Statistics for Managers II

Other
8 Credits
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.
Admission Standards

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 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.
Environmental Engineering and Science and Industrial Hygiene Thrust Area*

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.

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.

Admission Standards and Procedures

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

Admission Standards and Procedures
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 ≥ 153 (500 if taken prior to August 2012); Quantitative ≥ 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.

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
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 an 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.

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 2 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 (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

Student Outcomes (SOs)
The Systems Engineering program provides a substantial technical foundation in systems 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/](http://www.afit.edu/ADMISSIONS/).

**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 Requirements**

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
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 (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 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/.

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

Aeronautical Engineering

AERO 500 - Introduction to Aeronautical Engineering
Introduction to fluid mechanics, airfoil and wing aerodynamics, steady and accelerated aircraft performance, and stability and control. Not open to graduates of an Aeronautical Engineering program.
Credit Hours 4
Terms Offered Summer

AERO 517 - 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.
Credit Hours 4
Prerequisites AERO 534 or Permission of Instructor
Corequisite AERO 517L
Terms Offered Spring

AERO 517L - Fluid Measurement Lab
Lab associated with AERO-517
Credit Hours 0
Corequisite AERO 517
Terms Offered Spring

AERO 534 - Incompressible Aerodynamics
Introduction to the fundamental 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.
Credit Hours 4
Terms Offered Fall

AERO 537 - Advanced Aerodynamics
Using potential flow theory and linearized potential flow theory to quantify ground effect and trends in subsonic, transonic, and supersonic flows. Using the method of characteristics for the design of supersonic nozzles and to assess flow in a shock tube. Taylor-Maccoll solution for supersonic flow past a cone. Additional topics include Crocco’s theorem, aspects of compressible boundary layers, and discussion of aerodynamic heating.
Credit Hours 4
Terms Offered Winter

AERO 543 - 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.
Credit Hours 4
Corequisite AERO-543L
Terms Offered Spring
AERO 543L - Advanced Computational Modeling for Aerodynamics Lab
Lab associated with AERO-543
Credit Hours 0
Corequisite AERO-543
Terms Offered Spring

AERO 551 - 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.
Credit Hours 4
Prerequisites Undergraduate CS/programming, undergraduate linear algebra & differential equations
Terms Offered Fall

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.
Credit Hours 4
Prerequisites core Aeronautical Engineering
Terms Offered Summer

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.
Credit Hours 4
Prerequisites AERO 534 or equivalent (MECH 515 recommended)
Terms Offered Winter

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.
Credit Hours 4
Prerequisites MECH 529 or equivalent, AERO 610
Terms Offered Summer

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, low density aerodynamics, high temperature aerodynamics,
gas-surface interactions, SCRAMJET propulsion and re-entry trajectories are also discussed.
Credit Hours 4
Prerequisites AERO 534 or equivalent
Terms Offered Winter
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.
Credit Hours 4
Prerequisites AERO 634
Terms Offered Summer

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.
Credit Hours 4
Prerequisites AERO 534 or equivalent
Terms Offered Fall

AERO 640 - Hypersonic Computational Fluid Dynamics
The use of commercial and government ITAR software for the simulation of hypersonic flows. Topics covered include mesh generation, simulation of chemically reacting and thermally nonequilibrium flowfields that occur at hypersonic velocities, and post-processing flow visualization and data reduction techniques. In addition, high performance computing and parallel programming will be studied.
Required: U.S. Citizenship
Credit Hours 3
Prerequisites AERO-622
Corequisite AERO-640L
Terms Offered Spring

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.
Credit Hours 4
Prerequisites AERO-551 and AERO-534 or permission of instructor
Terms Offered Winter

AERO 699 - Master's Level Special Study
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.
Credit Hours 1 - 12
Prerequisites Permission of Instructor
Terms Offered All
AERO 729 - Theory of Gases for Aerodynamics and Propulsion
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.
Credit Hours 4
Prerequisites undergraduate thermodynamics
Terms Offered Spring

AERO 740 - Nonequilibrium Hypersonic Flows
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.
Credit Hours 4
Prerequisites AERO-729 and AERO-622
Terms Offered Fall

AERO 753 - Advanced Computational Fluid Dynamics
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 viscous solution schemes in FORTRAN.
Credit Hours 4
Prerequisites AERO 652 or Permission of Instructor
Terms Offered Spring

AERO 799 - Thesis Research
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.
Credit Hours 1 - 12
Terms Offered All

AERO 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.
Credit Hours 1 – 12
Prerequisites Permission of Instructor
Terms Offered All

AERO 999 - Dissertation Research
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.
Credit Hours 1 - 12
Terms Offered All
Astronautical Engineering

ASYS 525 - Linear Systems Analysis
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.
Credit Hours 4
Terms Offered Fall

ASYS 530 - Introduction to Space Programs and Operations
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.
Credit Hours 3
Prerequisites Permission of Instructor
Terms Offered This is a single 3-credit course divided over three quarters (must enroll in all three quarters)

ASYS 531 - Space Mission Analysis and System Design
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.
Required: U.S. Citizenship
Credit Hours 4
Corequisites ASYS 531L
Terms Offered Winter

ASYS 531L - Space Mission Analysis and System Design Lab
Lab associated with ASYS-531.
Credit Hours 0
Corequisites ASYS 531
Terms Offered Winter

ASYS 535 - Military Space Systems and Applications
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.)
Notes U.S. Citizenship Required and Top Secret Clearance with eligibility for SCI access required
Credit Hours 3
Prerequisites Permission of Instructor
Terms Offered This is a single 3-credit course divided over three quarters (must enroll in all three quarters)

ASYS 545 - Linear Systems Analysis for Control
This course covers the fundamentals of Linear System Analysis which is used as a basis for Control Theory Design. Topics include transfer function development, response analysis and controllability & observability concepts. The interrelation between conventional and modern control approaches is emphasized. Control specific topics include classical feedback systems analysis, root locus, Bode and Nyquist analysis, state-space feedback systems analysis.
Credit Hours 4
Prerequisites Permission of Instructor
Terms Offered Winter
ASYS 563 – Terminal Effects and Delivery of Conventional Weapons
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. The following terminal effects topics are studied in some detail: chemical explosives and blast waves, guns and projectiles, fragmentation warheads, projectile impact, target hardness, armor penetration, and shaped charge weapons.
Required: U.S. Citizenship and Secret Clearance
Credit Hours 4
Prerequisites: AERO 534, Permission of Instructor

ASYS 565 - Control and State Space Concepts
This course covers topics in conventional and modern control theory. The interrelation between conventional and modern approaches is emphasized. Topics include; feedback systems analysis, root locus, Bode and Nyquist analysis, state space feedback systems analysis, and control system compensation design.
Credit Hours 4
Prerequisites ASYS 525 or equivalent
Terms Offered Winter

ASYS 590 – Aircraft Survivability
This course provides the student with an understanding of the essential elements in the study of survivability and system safety engineering of aerospace vehicles. Presented are technologies for increasing survivability and methodologies for assessing the probability of survival in hostile (non-nuclear) environments. Air defense threat technology, identification of mission threat characteristics and threat operations are presented. Primary areas of study include identification, assessment and reduction of susceptibility and vulnerability and survivability enhancement of aerospace vehicles.
Required: U.S. Citizenship and Secret Clearance
Credit Hours 4
Prerequisites: undergraduate degree in engineering or science

ASYS 625 - Non-Linear Systems Analysis and Control
This course serves as 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.
Credit Hours 4
Prerequisites ASYS-525 and ASYS-565 or equivalent
Terms Offered Summer

ASYS 630 - Analysis and Design for Weapons Delivery
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.
Notes U.S. Citizenship Required
Credit Hours 4
Terms Offered Fall

ASYS 631 - Spacecraft Systems Engineering
This course provides a detailed introduction to the design of complex space systems. The key elements and subsystems of several important classes of space systems are presented. The systematic approach necessary to effectively design space systems is illustrated through case studies. Individual or group design projects are conducted and presented.
Credit Hours 4
Prerequisites MECH 532 or Permission of Instructor
Terms Offered Spring
ASYS 632 - Satellite Design & Test
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, build, test, and qualify space systems is illustrated through hands-on labs using satellite hardware and space testing facilities. Individual or group projects are conducted and presented.

**Required:** U.S. Citizenship

**Credit Hours** 4

**Prerequisites** ASYS 631 or Permission of Instructor

**Corequisite** ASYS 632L

**Terms Offered** Summer

ASYS 632L - Satellite Design & Test Lab
Lab associated with ASYS-632.

**Credit Hours** 0

**Corequisite** ASYS 632

**Terms Offered** Summer

ASYS 635 - Conventional Explosives & Effects
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.

**Required:** U.S. Citizenship and Secret Clearance

**Credit Hours** 4

**Terms Offered** Winter

ASYS 640 - Aircraft Combat Survivability
Introduction into aircraft combat survivability engineering and effects of conventional weapons on aircraft systems. Probability theory, radar fundamentals, infrared fundamentals, counter-measures, weapons effects.

**Required:** U.S. Citizenship and Secret Clearance

**Credit Hours** 4

**Terms Offered** Spring

ASYS 650 - Advanced Explosives and Warhead Design
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.

**Credit Hours** 4

**Prerequisites** ASYS 635

**Terms Offered** Fall

ASYS 699 - Master's Level Special Study
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.

**Credit Hours** 1-12

**Prerequisites** Permission of Instructor

**Terms Offered** All

ASYS 765 - Robust Control
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.
Credit Hours: 4  
Prerequisites: ASYS 565  
Terms Offered: Spring

**ASYS 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.

Credit Hours: 1-12  
Prerequisites: Permission of Instructor  
Terms Offered: All

**Biology**

**BIOL 597 - Biological Weapons Effects and Technology**

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.

Notes: US Citizenship Required  
Credit Hours: 4  
Terms Offered: All

**Chemistry**

**CHEM 560 - Chemistry for Engineers**

The course presents a quantitative treatment of selected topics from physical chemistry that are important to environmental and nuclear engineering. Topics presented will include thermodynamics principles, chemical equilibrium, kinetic theory of gases, liquids and solutions, acids and bases, electrochemistry, kinetics, chemical bonding, etc. Emphasis is on fundamental physical chemistry that plays an important role in engineering processes.

Credit Hours: 4  
Terms Offered: Winter

**CHEM 597 - Chemical Weapons: Materials, Effects, and Technology**

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.

Notes: US Citizenship Required  
Credit Hours: 4  
Terms Offered: Fall

**CHEM 675 - Upper Atmospheric Chemistry**

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.

Credit Hours: 4  
Prerequisites: PHYS 519  
Terms Offered: Spring
CHEM 680 - Atmospheric Chemistry
This course is a study of atmospheric physics and atmospheric chemistry to understand natural atmospheric processes and the effects of human activities on the atmosphere. The course begins with a study of physical and chemical processes in the atmosphere, focusing largely on atmospheric water, carbon, and nitrogen in the oxidizing environment. The origin and nature of chemistry of atmospheric pollutions is framed for particulate pollutants, gaseous inorganic pollutants, and organic pollutants. The chemistry of these materials in the atmosphere is given emphasis. A particularly important focus is the photochemical induced radical, ion, and excited state chemistry of pollutants. Models of anthropomorphic changes in the atmosphere are considered. A quantiative, problem-solving approach is used throughout the course. This course will be useful to individuals involved in compliance issues associated with the Environmental Protection Agency (EPA) Clean Air Act, with atmospheric environmental assessment, and in the interpretation of environmental data obtained from air sampling (environmental engineers and managers involved with Resource Conservation and Recover Act [RCRA] and Comprehensive Environ-mental Response, Compensation, and Liability Act [CERLA] sites).
Credit Hours 4
Terms Offered As needed

CHEM 681 - Nuclear Chemical Engineering
Chemical engineering aspects of the military nuclear fuel cycles are studied to characterize weapon sources. Top-ics include an overview of the nuclear fuel cycle, including uranium mining and milling; solvent extraction for fuel reprocessing; and U-235 enrichment. Chemical and physical properties of plutonium and the actinides are applied to understand sources of plutonium and the properties of irradiated fuel. A detailed treatment of stable isotope separation is included with particular emphasis on uranium enrichment techniques, tritium production, and their use in nuclear weapons.
Note: SECRET (RESTRICTED DATA) clearance required
Credit Hours 4
Terms Offered Winter

CHEM 699 - Master’s Level Special Study
Course content determined by faculty member based on student need.
Credit Hours 1-12
Terms offered: All

CHEM 720 - Kinetics of Fast Reactions
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.
Credit Hours 4
Terms Offered Spring

CHEM 750 - Computational Chemistry and Materials Science
This computational laboratory will build on topics covered in MATL 662 through a series of four to five computa-tional projects. Each project will explore a specific technique used in computational chemistry and materials scien-ce through the use of the computational facilities at the Major Shared Resource Center (MSRC).
Credit Hours 4
Prerequisite/Corequisites CHEM 662, CSCE656
Terms offered As needed

CHEM 780 - Radiation Chemistry
Advanced treatment of chemistry produced by ionizing radiation. Important radiation interactions and reaction mechanisms involved in irradiation of gas and condensed phases will be reviewed. The nature, properties and reaction of intermediate species, including solvated electron and important radicals, will be studied.
Credit Hours 4
Prerequisites/Corequisites CHEM 560, PHYS 665 or permission of the instructor.
Terms offered As needed
CHEM 825 - Chemical Physics
An advanced study in the area of chemical physics. Topics covered include the approximate solutions of the time dependent Schroedinger equation for reacting systems and for systems interacting with an electromagnetic field. The foundations of infrared and ultraviolet spectroscopy, angular momentum considerations, symmetry studies, and electronic states are included.
Credit Hours: 4
Prerequisite/Corequisites: CHEM 720 or permission of instructor
Terms Offered: As needed

CHEM 840 - Advanced Chemical Kinetics
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.
Credit Hours: 4
Prerequisites: CHEM 720 or CHEM 825 or Permission of Instructor
Terms Offered: Spring

CHEM 850 - Molecular Orbital Theory
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.
Credit Hours: 4
Prerequisites: PHYS 655
Terms Offered: As needed

Communication
COMM 680 - Technical Reports and Thesis
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 one 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.
Credit Hours: 3
Terms Offered: Summer

Cost
COST 510 - Principles of Cost Estimating
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.
Credit Hours: 3
Terms Offered: Fall

COST 520 - Advanced Concepts in Cost Estimating
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.
Credit Hours: 3
Prerequisites COST 510
Terms Offered Winter

COST 610 - Project Risk Analysis
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.
Credit Hours 3
Prerequisites STAT 525
Terms Offered Spring

COST 630 - Defense Cost Economics
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.
Credit Hours 3
Terms Offered Winter

COST 668 - Cost Analysis Colloquium
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.
Credit Hours 0
Terms Offered All

COST 674 - Seminar in Cost Analysis
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.
Credit Hours 4
Prerequisites COST 510
Terms Offered All

COST 699 - Master's Level Special Study
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.
Credit Hours 1-12
Terms Offered Winter

COST 799 - Thesis Research
This independent study provides the student the opportunity to conduct and report independent research on a topic of interest to the Air Force cost estimating community. The student develops a research proposal in conjunction with a qualified faculty advisor. Based upon the objectives identified in the proposal, the student conducts research and presents the results of the research as a Master's thesis prior to graduation. The purpose of the thesis is to allow the student to develop research and
communications knowledge and skills that can be applied to future problems during each student's career. The thesis also allows the student to integrate and apply many of the qualitative and quantitative theories and techniques that have been learned throughout the program. Many theses are developed to help solve various real-world cost analysis problems encountered by the Air Force cost estimating community. Recommendations from these theses are often implemented as problem solutions. Each student must present the results of the research in an open forum. Ordinarily this study extends over three quarters and no credit is given until the last quarter.

**Credit Hours** 1-12

**Terms Offered** All

## Computer Science/Computer Engineering

### CSCE 486 - Fundamentals of Data Structures and Program Design
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.

**Credit Hours** 4

**Corequisite** CSCE 486L

**Terms Offered** Summer

### CSCE 486L - Fundamentals of Data Structures and Program Design Lab
Lab associated with CSCE-486.

**Credit Hours** 0

**Corequisite** CSCE 486

**Terms Offered** Summer

### CSCE 489 - Operating Systems
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.

**Credit Hours** 4

**Terms Offered** Summer

### CSCE 492 - Computer Systems Architecture
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.

**Credit Hours** 4

**Prerequisites** None

**Terms Offered** Summer

### CSCE 523 - Artificial Intelligence
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).

Credit Hours 4
Prerequisites CSCE 531 and CSCE 586
Terms Offered Winter

CSCE 525 - Introduction to Cyber Warfare and Security
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.

Credit Hours 4
Terms Offered Fall and Summer

CSCE 526 - Secure Software Design and Development
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.

Credit Hours 4
Terms Offered Fall

CSCE 527 - Cyber Forensics
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.

Credit Hours 4
Terms Offered Summer

CSCE 528 - Cyber Defense and Exploitation I
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.

Credit Hours 4
Corequisite CSCE 528L
Terms Offered Winter

CSCE 528L - Cyber Defense and Exploitation I Lab
Lab associated with CSCE-528.

Credit Hours 0
Corequisite CSCE 528
Terms Offered Winter

CSCE 531 - Discrete Mathematics
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.

**Credit Hours** 4  
**Terms Offered** Fall

**CSCE 532 - Automata and Formal Language Theory**  
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.

**Credit Hours** 4  
**Prerequisites** CSCE 531  
**Terms Offered** Winter

**CSCE 544 - Data Security**  
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.

**Credit Hours** 4  
**Terms Offered** Spring

**CSCE 554 - Fundamental of Performance Analysis and Experimental Design**  
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: queueing theory and random-variate generation are covered.

**Credit Hours** 4  
**Prerequisites** STAT 583 or STAT 586  
**Terms Offered** Summer

**CSCE 560 - Introduction to Computer Networking**  
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.

**Credit Hours** 4  
**Terms Offered** Fall

**CSCE 586 - Design and Analysis of Algorithms**  
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.

**Credit Hours** 4  
**Terms Offered** Fall
CSCE 587 - Microprocessor Design and Synthesis
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.
Credit Hours 4
Prerequisites CSCE 492 or Permission of Instructor
Terms Offered Spring

CSCE 593 - Introduction to Software Engineering
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.
Credit Hours 4
Corequisite CSCE 593L
Terms Offered Fall

CSCE 593L - Introduction to Software Engineering Lab
Lab associated with CSCE-593.
Credit Hours 0
Corequisite CSCE 593
Terms Offered Fall

CSCE 623 - Statistical Machine Learning
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.
Credit Hours 4
Prerequisites CSCE 523
Terms Offered Spring

CSCE 625 - Formal Analysis of Security Systems
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.
Credit Hours 4
Terms Offered As Needed

CSCE 629 - Cyber Attack
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.
Credit Hours 4  
Prerequisites CSCE 560 or Permission of Instructor  
Corequisite CSCE 629L  
Terms Offered Winter

CSCE 629L - Cyber Attack Lab  
Lab associated with CSCE-629.  
Credit Hours 0  
Corequisite CSCE 629  
Terms Offered Winter

CSCE 631 - Machines, Languages, and Logic  
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 Godel 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.  
Credit Hours 4  
Prerequisites CSCE 531, CSCE 532, and CSCE 586  
Terms Offered Winter

CSCE 654 - Computer Communication Networks  
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.  
Credit Hours 4  
Prerequisites CSCE 560 and STAT 583, STAT 586 or STAT 601  
Terms Offered Spring

CSCE 656 - Parallel and Distributed Processing Algorithms  
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 sorting, searching, vector/matrix operations, graph algorithms, simulation, differential equations, logic programming and knowledge-based systems. A variety of programming assignments on parallel and distributed computers are required using a selected concurrent language.  
Credit Hours 4  
Prerequisites CSCE 586  
Terms Offered Spring

CSCE 660 - Mobile, Wireless, and SCADA Device Security  
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.  
Credit Hours 4  
Prerequisites CSCE 528 or Permission of Instructor  
Corequisite CSCE 660L  
Terms Offered Spring
CSCE 660L - Mobile, Wireless, and SCADA Device Security Lab
Lab associated with CSCE-660.
Credit Hours 0
Corequisite CSCE 660
Terms Offered Spring

CSCE 684 - Information Visualization
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.
Credit Hours 4
Terms Offered Spring

CSCE 686 - Advanced Algorithm Design
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.
Credit Hours 4
Prerequisites CSCE 586
Terms Offered Spring

CSCE 687 - Advanced Microprocessor Design Laboratory
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.
Credit Hours 4
Corequisite CSCE 687L
Terms Offered Summer

CSCE 687L - Advanced Microprocessor Design Lab
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.
Credit Hours 0
Corequisite CSCE 687
Terms Offered Summer

CSCE 689 - Distributed Software Systems
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.
Credit Hours 4
Terms Offered Winter
CSCE 692 - Design Principles of Computer Architecture  
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.  
Credit Hours 4  
Terms Offered Winter

CSCE 693 - Software Evolution  
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 commercial 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.  
Credit Hours 4  
Prerequisites CSCE 593  
Terms Offered Winter

CSCE 698 - Research Seminar  
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.  
Credit Hours 0  
Terms Offered Winter and Spring

CSCE 699 - Master's Level Special Study  
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.  
Credit Hours 1-12  
Terms Offered All

CSCE 723 - Advanced Topics in Artificial Intelligence  
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.  
Credit Hours 4  
Prerequisites CSCE 623  
Terms Offered Summer

CSCE 725 - Reverse Engineering  
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.  
Credit Hours 4  
Corequisite CSCE 725L  
Terms Offered Spring
CSCE 725L - Reverse Engineering Lab  
Lab associated with CSCE-725.  
Credit Hours 0  
Corequisite CSCE 725  
Terms Offered Spring

CSCE 754 - Advanced Topics in Computer Networks  
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.  
Credit Hours 4  
Prerequisites CSCE 560  
Terms Offered Spring

CSCE 790 - Advanced Parallel and Distributed Computation  
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.  
Credit Hours 4  
Prerequisites CSCE 656  
Terms Offered As Needed

CSCE 793 - Advanced Topics in Software Engineering  
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.  
Credit Hours 4  
Prerequisites CSCE 693  
Terms Offered Spring

CSCE 799 - Thesis Research  
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.  
Credit Hours 1-12  
Terms Offered All

CSCE 823 - Advanced Topics in Statistical Machine Learning  
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.

**Credit Hours** 4  
**Prerequisites** CSCE 623  
**Terms Offered** Summer

**CSCE 886 - Evolutionary Algorithms**
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.

**Credit Hours** 4  
**Prerequisites** CSCE 686  
**Terms Offered** Summer

**CSCE 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.

**Credit Hours** 1-12  
**Terms Offered** All

**CSCE 999 - Dissertation Research**
This course supports doctoral research under the direction of a faculty research advisor from the Department of Electrical and
Computer Engineering.

**Credit Hours** 1-12  
**Terms Offered** All

**Combating Weapons of Mass Destruction**

**CWMD 596 - Physiologic Effects of CBRN**
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.

**Credit Hours** 4  
**Terms Offered** Fall

**CWMD 699 - Master's Level Special Study**
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.

**Credit Hours** 1-12  
**Terms Offered** All
CWMD 791 - Combating Weapons of Mass Destruction
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.

Notes  US Citizenship Required

Credit Hours 4

Prerequisites Permission of instructor

Terms Offered Winter

CWMD 799 - Thesis Research
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 re-search are required.

Credit Hours 1-12

Terms Offered All

Economics

ECON 520 - Managerial Economics
ECON 520 familiarizes students with selected concepts of managerial economics, enhancing their ability to analyze situations with microeconomic tools, generate and evaluate alternatives, analyze and solve complex problems, and make good economic decisions. The course incorporates critical thinking skills, creative problem solving techniques, and microeconomic theory allowing students to internalize fundamental economic principles and concepts and then apply them to real-world problems. The course considers the nature of economic incentives facing consumers, workers, and businesses. Topics include demand, supply, individual behavior theory, the time value of money, personal finance, production processes and costs, problem solving, decision making, organization of firms and industry, game theory, and international applications. Also, the role and impact of government is addressed from a microeconomic perspective. Where possible, classroom discussions and assignments include examples tailored to the Department of Defense (DoD).

Credit Hours 3

Terms Offered Fall

ECON 580 - Fundamental Methods of Mathematical Economics
This course focuses on mathematical methods. Applications of mathematical techniques to selected topics including: theories of choice, theories of the firm, consumer behavior, general equilibrium, optimization, constrained optimization, distribution, growth and stability.

Credit Hours 4

Terms Offered Spring

Electrical Engineering

EENG 510 - Linear Systems
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.

Credit Hours 4

Terms Offered Fall
EENG 527 - Introduction to Fourier Optics
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.
Credit Hours: 4
Prerequisites: Permission of Instructor
Terms Offered: Fall

EENG 530 - Fundamentals of Radio Frequency (RF) Analysis
This course will provide students with an understanding of modulated analog 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 systems transfer function. Students will develop a fundamental knowledge of common real-world analog signals, Software Defined Radio (SDR) architectures, as well as basic signal analysis of digitally sampled analog amplitude and angle modulated signals in Matlab.
Credit Hours: 4
Terms Offered: Fall

EENG 533 - Navigation Using the Global Positioning System
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.
Credit Hours: 4
Terms Offered: Winter

EENG 534 - Fundamentals of Aerospace Instruments and Navigation System
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.
Credit Hours: 4
Corequisite: EENG 562
Terms Offered: Winter

EENG 535 - Radar Systems Analysis
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.
Credit Hours: 4
Prerequisites: EENG 530 or EENG 580
Terms Offered: Fall
EENG 550 - Introduction to Autonomy
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.
Credit Hours: 2
Terms Offered: Fall

EENG 562 - Feedback Systems
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.
Credit Hours: 4
Prerequisites: EENG 510
Terms Offered: Fall

EENG 571 - Satellite Communications
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.
Credit Hours: 4
Terms Offered: Winter

EENG 576 - Microwave Circuits
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.
Credit Hours: 4
Terms Offered: Fall

EENG 580 - Introduction to Signal Processing
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.
Credit Hours: 4
Terms Offered: Fall

EENG 596 - Integrated Circuit Technology
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.
Credit Hours: 4
Terms Offered: Fall
EENG 599 - Master's Level Special Study
Directed study at a 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.
Credit Hours 1-12
Terms Offered All

EENG 622 - Advanced Electromagnetics I
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.
Credit Hours 4
Corequisite MATH 504
Terms Offered Fall

EENG 624 - Electromagnetic Characterization of Materials
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.
Credit Hours 4
Prerequisites EENG 622
Corequisite EENG 624L
Terms Offered Winter

EENG 624L - Elettromagnetic Characterization of Materials Lab
Lab associated with EENG-624.
Credit Hours 0
Prerequisites EENG 622
Corequisite EENG 624
Terms Offered Winter

EENG 625 - Antennas
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.
Credit Hours 4
Prerequisites EENG 622
Terms Offered Winter

EENG 627 - RCS Analysis, Measurement, and Reduction
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.
Notes Enrollment limited to US citizens only
Credit Hours 4
Prerequisites EENG 626 and EENG 630
Corequisite EENG 627L
Terms Offered Summer
EENG 627L - RCS Analysis, Measurement, and Reduction Lab
Lab associated with EENG-627
Notes US Citizenship Required
Credit Hours 0
Corequisite EENG 627
Terms Offered Summer

EENG 628 - Advanced Electromagnetic Waves
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.
Credit Hours 4
Prerequisites EENG 622
Terms Offered Winter

EENG 629 - Electronic Warfare I
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.
Credit Hours 4
Prerequisites EENG 535
Terms Offered Spring

EENG 630 - Applications of Electromagnetic Theory
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.
Credit Hours 4
Prerequisites EENG 622
Terms Offered Winter

EENG 631 - Advanced Antennas
Transform methods for analyzing antennas are explored. Broadband and frequency independent antennas are discussed, such as biconical, bow-tie, traveling wave, spiral, log-periodic, etc. In addition to frequency domain analysis, time domain techniques are explored including solving Maxwell's Equations in the differential time domain form.
Credit Hours 4
Prerequisites EENG 625
Terms Offered Winter

EENG 633 - Global Navigation Satellite System Receiver Design
This course covers analog and digital signal processing of Global Navigation Satellite System (GNSS) receivers including GPS. Laboratory projects involve incremental development of a sample-level baseband GNSS signal simulator and processor. Labs culminate in a GNSS software receiver that processes live sky sampled data files to produce pseudo-range and accumulated Doppler range measurements. Topics include: GNSS signal structures, link budget, RF front-end architectures, correlation processing, signal acquisition and tracking techniques (FLL, PLL, DLL), C/N0 and other special baseband functions, bit and
frame synchronization, navigation message decoding, channel control state machine design and range measurement computation. Also covers advanced topics such as interference/multipath mitigation techniques and signal quality monitoring.

Credit Hours 4
Prerequisites EENG 533
Terms Offered Spring

EENG 634 - Computational Methods in Electromagnetics
This course develops the numerical techniques commonly used to solve electromagnetic radiation and scattering problems. Focusing on the two major branches of the "First Principle Methods" (Integral and Differential Equation), the primary subjects are the method of moments, finite element and finite difference time domain formulations. The strengths and limitations of each method as applied to practical problems are discussed. Students learn the application and implementations of the methods through computer projects. While this course stands on its own, it is designed to be a companion course to EENG 630 Applications of Electromagnetic Theory together providing the student a firm grasp of all the major modeling and simulation tools used for electromagnetic analysis and design.

Credit Hours 4
Prerequisites EENG 622
Terms Offered Spring

EENG 635 - Inertial Navigation Subsystems
The Inertial Navigation System (INS) concept is defined and analyzed in the context of space stabilized, local level and strapdown configurations. Perturbation techniques are applied in the derivation of unified INS error models. The earth's gravitational field model is developed. Advantages and disadvantages of various configurations are presented within the context of the INS error dynamics. Methods of systems alignments are examined. System response to inertial instrument errors and initial misalignments are studied in frequency and time domains. System analysis tools, such as MATLAB, are used.

Credit Hours 4
Prerequisites EENG 534
Terms Offered Winter

EENG 636 - Micro-Electro-Mechanical Systems (MEMS)
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.

Credit Hours 4
Corequisite EENG 636L
Terms Offered Winter

EENG 636L - Micro-Electro-Mechanical Systems (MEMS) Lab
Lab associated with EENG-636.

Notes The fabrication designs will be ready for testing in the follow-on course for this class, EENG 777, Advanced Micro Electro Mechanical Systems (MEMS)

Credit Hours 0
Corequisite EENG 636
Terms Offered Winter

EENG 644 - Alternative Navigation Methods
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.
Credit Hours 4
Terms Offered Winter

EENG 653 - Introduction to VLSI Design
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.
Notes US Citizenship Required
Credit Hours 4
Corequisite EENG 653L
Terms Offered Fall

EENG 653L - Introduction to VLSI Design Lab
Lab associated with EENG-653.
Notes US Citizenship Required
Credit Hours 0
Corequisite EENG 653
Terms Offered Fall

EENG 658 - Light Detection and Ranging Systems
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.
Credit Hours 4
Prerequisites EENG 580 and STAT 586
Terms Offered Winter and Spring

EENG 663 - Signal Detection and Estimation
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 maximum posteriori estimators, and Cramer-Rao lower bound. The detection theory includes Bayesian, minimax, and Neyman-Pearson detection; multiple hypotheses; composite detection; and receiver operating characteristics.
Credit Hours 4
Prerequisites EENG 665
Terms Offered Winter and Spring

EENG 665 - Random Signal and Systems Analysis
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.
Credit Hours 4
Prerequisites STAT 586 or STAT 601
Terms Offered Winter

EENG 668 - Advanced Radar System Analysis
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.

**Credit Hours** 4  
**Prerequisites** EENG 535 and STAT-586  
**Terms Offered** Spring

**EENG 669 - Digital Communications I**
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.

**Credit Hours** 4  
**Prerequisites** EENG 530 and STAT 586  
**Terms Offered** Winter

**EENG 670 - Digital Communications II**
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.

**Credit Hours** 4  
**Prerequisites** EENG 665 and EENG 669  
**Terms Offered** Spring

**EENG 672 - Statistical Optics**
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.

**Credit Hours** 4  
**Prerequisites** EENG 527 or OENG 644  
**Terms Offered** Winter

**EENG 673 - Spread Spectrum Communications**
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.

**Credit Hours** 4  
**Prerequisites** EENG 670  
**Terms Offered** Summer

**EENG 675 - Semiconductor Devices**
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.

**Credit Hours** 4  
**Prerequisites** PHYS 570  
**Terms Offered** Winter

### EENG 676 - Microwave Electronic Devices

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 TWTs and magnetrons.

**Credit Hours** 4  
**Prerequisites** EENG 576 and EENG 675  
**Terms Offered** Spring

### EENG 677 - Optical Communication Systems

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.

**Credit Hours** 4  
**Prerequisites** EENG-530 and EENG-665  
**Terms Offered** As Needed

### EENG 680 - Multidimensional Signal and Image Processing

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.

**Credit Hours** 4  
**Prerequisites** EENG 580 and MATH 521  
**Terms Offered** Spring

### EENG 695 - VLSI System Design

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.

**Notes** US Citizenship Required  
**Credit Hours** 4  
**Prerequisites** EENG-653 and CSCE-492  
**Corequisite** EENG-695L  
**Terms Offered** Winter

### EENG 695L - VLSI System Design Lab

Lab associated with EENG-695.

**Notes** US Citizenship Required  
**Credit Hours** 0  
**Corequisites** EENG 695  
**Terms Offered** Winter
EENG 699 - Master's Level Special Study
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.
Credit Hours 1-12
Terms Offered All

EENG 700 - Seminar in Remote Sensing and Communications Systems
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.
Credit Hours 1
Terms Offered All

EENG 714 - Advanced Topics in Radar Applications
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.
Credit Hours 4
Prerequisites EENG 535 and EENG 668
Terms Offered Summer

EENG 717 - Advanced Topics in Microelectronic Devices
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.
Credit Hours 4
Prerequisites EENG 675
Corequisite EENG 717L
Terms Offered Summer

EENG 717L - Advanced Topics in Microelectronic Devices Lab
Lab associated with EENG-717.
Credit Hours 0
Prerequisites EENG 675
Corequisite EENG 717
Terms Offered Summer

EENG 734 - Multi-Target Tracking
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
Lab associated with EENG-734.
Credit Hours 0
Prerequisites EENG 765
Corequisite EENG 734
Terms Offered As Needed

EENG 735 - Inertial Navigation System Analysis and Integration
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.
Credit Hours 4
Prerequisites EENG 635 and either EENG 712 or EENG 765
Terms Offered Spring

EENG 765 - Stochastic Estimation and Control I
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.
Credit Hours 4
Prerequisites EENG 510, STAT 586 and STAT 601
Terms Offered Winter

EENG 766 - Stochastic Estimation and Control II
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.
Credit Hours 4
Prerequisites EENG 765
Terms Offered Spring

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.
Credit Hours 4
Prerequisites EENG 636
Corequisite EENG 777L
Terms Offered Summer
EENG 777L - Advanced Micro Electro Mechanical Systems (MEMS) Lab
Lab associated with EENG-777.
Credit Hours 0
Prerequisites EENG 636
Corequisite EENG 777
Terms Offered Summer

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, nano-magnetics, 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.
Credit Hours 4
Terms Offered Summer

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.
Credit Hours 4
Prerequisites EENG 663 and EENG 658
Terms Offered Spring

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.
Notes US Citizenship Required
Credit Hours 4
Prerequisites EENG 695
Corequisite EENG 795L
Terms Offered Spring

EENG 795L - Advanced Topics in VLSI Systems Lab
Lab associated with EENG-795.
Notes US Citizenship Required
Credit Hours 0
Prerequisites EENG 695
Corequisite EENG 795
Terms Offered Spring

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.

**Credit Hours** 1-12  
**Terms Offered** All

### 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.

**Credit Hours** 1-12  
**Terms Offered** All

### 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.

**Credit Hours** 1-12  
**Terms Offered** All

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**Engineering Management**

### EMGT 500 - Engineering Management Research Colloquium

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 students the opportunity to informally present their research to student peers and faculty.

**Credit Hours** 0  
**Terms Offered** All

### EMGT 501 - Engineering Management Curriculum and Research Options

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.

**Credit Hours** 0  
**Terms Offered** Fall

### EMGT 502 - Engineering Management Research Perspectives

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.

**Credit Hours** 0  
**Terms Offered** Winter

### EMGT 503 - Critical Review of Research Literature

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.

**Credit Hours** 0

**Terms Offered** Spring and Summer

**EMGT 504 - Engineering Management Thesis Research Review**

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.

**Credit Hours** 0

**Terms Offered** Summer

**EMGT 505 - Engineering Management Thesis Research Review**

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.

**Credit Hours** 0

**Terms Offered** Fall

**EMGT 550 - Engineering Economic Decision Analysis**

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.

**Credit Hours** 3

**Terms Offered** Summer

**EMGT 560A - Future DoD Energy Systems Engineering**

This course focuses 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 that includes ground vehicles, air vehicles, space vehicles and their associated weapons and sensors. 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 feasibility, economic feasibility and operational impact. New energy sources, efficiency, conservation and resilience will be discussed.

**Credit Hours** 4

**Terms Offered** Fall and Spring

**EMGT 621 - Asset Management I**

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.

**Credit Hours** 3

**Terms Offered** Winter
EMGT 622 - Asset Management II
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.
Credit Hours 3
Prerequisites STAT 535 and OPER 501
Terms Offered Spring

EMGT 631 - Construction Management I
This course will focus on advanced concepts in project estimating. The primary objective of the course is to create understanding of a proper estimate and the business decisions that are a major contribution during its creation, including (but not limited to) the impacts of the economic market, workforce, cost of business, and productivity factors. The course highlights the direct correlations with the schedule, as well as the contract and specifications. Topics to be covered include: labor and equipment calculations, the use of price databases, direct and indirect cost, bid preparation and computer applications, case study analysis, and critical thinking/solution planning.
Credit Hours 3
Terms Offered Winter

EMGT 632 - Construction Management II
This course will focus on advanced concepts in planning and scheduling. The primary objective of the course is to create understanding of proper project planning as well as the potential impacts and corresponding implications of changes to that plan throughout its execution. This course also highlights the direct linkage to the estimate as well as the contracts and law course. Topics to be covered include: work breakdown structures, calculating activity durations, precedence diagrams and network modeling, productivity and decision impact analysis, procurement, critical path, forecasting, earned value, time in contract provisions, case study analysis, and critical thinking/solution planning.
Credit Hours 3
Prerequisites EMGT 631
Terms Offered Spring

EMGT 641 - Construction Contracts and Law
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.
Credit Hours 3
Terms Offered Fall

EMGT 642 - Systems Dynamic Analysis
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 mindset 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.
Credit Hours 4
Corequisite EMGT 642L
Terms Offered As Needed

EMGT 642L - System Dynamics Analysis Lab
Lab associated with EENG-642
Credit Hours 0
Corequisite EMGT 642
Terms Offered As Needed
EMGT 643 - Introduction to Geographic Information Systems: A Computing Perspective
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.
Credit Hours 4
Corequisite EMGT 643L
Terms Offered As Needed

EMGT 643L - Geographic Information Systems and Science Lab
Lab associated with EMGT-643.
Credit Hours 0
Corequisite EMGT 643
Terms Offered As Needed

EMGT 680 - Advanced Project Management with Risk Analysis
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.
Credit Hours 4
Prerequisites SENG 610
Terms Offered Winter

EMGT 699 - Master's Level Special Study
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.
Credit Hours 1 - 12
Terms Offered All

EMGT 723 - Advanced Topics in Infrastructure Asset Management
This course is an advanced course covering contemporary topics in infrastructure asset management. Topics will include the role of engineers in the management of federal facilities and infrastructure systems, the state of the art in predicting infrastructure decay, critical infrastructure protection, infrastructure as socio-technical systems, resiliency in infrastructure, and other topics of relevance in the infrastructure asset management domain.
Credit Hours 3
Prerequisites EMGT 621 and EMGT 622
Terms Offered Winter

EMGT 733 - Advanced Topics in Construction Management
This is the capstone course for the construction management specialty track. Working in small groups, students will devise and execute a construction management research project. Students will apply the principles and techniques learned in EMGT 631, 632, and 641 while performing appropriate quantitative and qualitative analysis to address a real-world construction management problem.
Credit Hours 3
Prerequisites EMGT 631, EMGT 632, EMGT 641, and SENG 610
Terms Offered Summer

EMGT 799 - Thesis Research
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.
Credit Hours 1 - 12
Terms Offered All

Environmental

ENVR 501 - GES/GIH Seminar
This course presents the principles of organizing and conducting research and will assist students in completing their thesis prospectus. There is a significant focus on literature review. Other specific topics: ethics/plagiarism, thesis checklist process, and PA approval process. Students from the class matriculating one year earlier will present and discuss their research. Faculty and guests may also provide lectures detailing current research topics.
Credit Hours 0
Terms Offered Fall

ENVR 502 - GES/GIH Seminar
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.
Credit Hours 0
Terms Offered Winter

ENVR 503 - GES/GIH Seminar
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.
Credit Hours 0
Terms Offered Spring

ENVR 504 - GES/GIH Seminar
This course includes discussion on applicable business, managerial, and leadership skills relevant to graduating students. Discussions will include techniques, skills, and tools necessary for managers/leaders. Guest speakers will provide their personal leadership philosophies and views on mentorship, especially when faced with diverse, multidisciplinary teams. Faculty and guests may also provide lectures detailing current research topics.
Credit Hours 0
Terms Offered Summer

ENVR 505 - GES/GIH Seminar
This course provides students an opportunity to informally present their thesis research before their student 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.
Credit Hours 0
Terms Offered Fall
ENVR 511 - Environmental Management and Policy
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.
Credit Hours 3
Terms Offered Winter

ENVR 532 - Air Resources Management
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.
Credit Hours 3
Terms Offered Fall

ENVR 534 - Ecology, Limnology, and Natural Resources
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.
Credit Hours 3
Terms Offered Summer

ENVR 535 - Solid and Hazardous Waste Management
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.
Credit Hours 3
Terms Offered Summer

ENVR 536 - Ecology and Natural Resource Management
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.
Credit Hours 3
Prerequisites ENVR 511
Terms Offered Summer

ENVR 540 – ESOH Management
This course provides an overview of environment, safety, and occupational health management with specific applications in total exposure health, review of construction plans, occupational health surveillance strategies, risk management of contaminants, and incident investigations. It is offered in-resident at and in conjunction with the US Air Force School of Aerospace Medicine’s (USAFSAM) Bioenvironmental Engineering Officer Advanced Course (BOA).
Credit Hours 3
Terms Offered Summer (out of cycle, with the USAFSAM offering)

ENVR 541 - Industrial Hygiene Applications I
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).

**Credit Hours** 3
**Terms Offered** Fall

**ENVR 543 - Industrial Hygiene Applications II**
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.

**Credit Hours** 4
**Prerequisites** ENVR 541
**Corequisite** ENVR 543L
**Terms Offered** Winter

**ENVR 543L - Industrial Hygiene Applications II Lab**
Lab associated with ENVR-543.

**Credit Hours** 0
**Corequisite** ENVR 543
**Terms Offered** Winter

**ENVR 546 - Applied Science Studies**
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.

**Credit Hours** 4
**Terms Offered** Winter

**ENVR 547 - Non-Ionizing and Ionizing Radiation**
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.

**Credit Hours** 3
**Prerequisites** None
**Terms Offered** Spring

**ENVR 548 - Industrial Hygiene Application III**
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.

**Credit Hours** 4
**Prerequisites** ENVR 543
**Corequisite** ENVR 548L
**Terms Offered** Summer
ENVR 548L - Industrial Hygiene Applications III Lab
Lab associated with ENVR 548
Credit Hours 0
Corequisite ENVR 548
Terms Offered Summer

ENVR 550 - Environmental Systems Engineering
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.
Credit Hours 4
Terms Offered Summer

ENVR 556 - Sustainable Life Cycle Design
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 sustainability 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.
Credit Hours 3
Terms Offered Winter

ENVR 575 - Applied Environmental Health
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.
Credit Hours 3
Terms Offered Winter

ENVR 615 - Industrial Hygiene Site Surveys
This course provides exposure to various industrial workplaces in the local area, in order to better understand the industrial hygiene "anticipate, recognize, evaluate, control" (AREC) paradigm. Students will go on several field trips and will write trip reports to summarize their occupational, environmental, safety, and management observations.
Credit Hours 1
Prerequisites ENVR 541 or permission of instructor
Terms Offered Winter

ENVR 616 - Advanced Industrial Hygiene
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.
ENVR 622 - Ecosystem Dynamics
This course looks at the integration of individual organisms and non-organic materials into ecological systems. The flow, cycling, and storage of materials and energy are studied as it relates to the maintenance of ecological balance. Nutrient cycling and nutrient limitation are emphasized as a control mechanism. The modeling of these systems in homeostasis as well as prediction of cascading disruption upon environmental insult is explored at length. Also included are alternative modeling approaches to ecological population dynamics as related to various conservation management strategies. The use of tools of system dynamics modeling is employed throughout.

Credit Hours 2
Prerequisites ENVR 548 or Permission of Instructor
Terms Offered Fall

ENVR 624 - Water Chemistry for Environmental Engineers
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.

Credit Hours 3
Prerequisites ENVR 642
Terms Offered Summer

ENVR 625 - Environmental Microbiology
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.

Credit Hours 4
Prerequisites ENVR 550
Terms Offered Spring

ENVR 628 - Physiology of NBC Weapons Effects
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.

Credit Hours 3
Prerequisites ENVR 528
Terms Offered Summer

ENVR 640 - Groundwater Hydrology and Contaminant Transport
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.
ENVR 643 - Environmental Transport Processes
Starting with the law of conservation of mass, this course introduces students to the processes that govern the fate and transport of containments 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 containment 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.
Credit Hours 3
Prerequisites ENVR 550
Terms Offered Spring

ENVR 645 - Water and Wastewater Treatment Design
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.
Credit Hours 4
Prerequisites ENVR 550
Terms Offered Winter

ENVR 646 - Water Treatment in Rural and Austere Conditions
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.
Credit Hours 3
Prerequisites ENVR 645
Terms Offered Fall

ENVR 648 – Physical and Biological Aspects of Aerosols
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.
Credit Hours 3
Prerequisites ENVR 541 or Permission of Instructor
Terms Offered Spring

ENVR 651 - Environmental Risk Analysis
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.
Credit Hours 3
Corequisite STAT 525 and ENVR 550
Terms Offered Fall

ENVR 661 - Environmental Sampling and Analysis
ENVR 661LThis 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.

Credit Hours 4
Prerequisites STAT 525
Corequisite ENVR-661L
Terms Offered Spring

ENVR 661L - Environmental Sampling and Analysis Lab
Lab associate with ENVR-661
Credit Hours 0
Corequisite ENVR 661
Terms Offered Spring

ENVR 699 - Master's Level Special Study
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.
Credit Hours 1 - 12
Terms Offered All

ENVR 772 - Remediation Design and Management
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.
Credit Hours 3
Prerequisites ENVR 640, ENVR 624 and ENVR 625
Terms Offered Fall

ENVR 799 - Thesis Research
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.
Credit Hours 1 - 12
Terms Offered All

ENVR 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.
Credit Hours 1-12
Terms Offered All

Environmental Science

EVSC 560-Environmental Monitoring
This laboratory/lecture course is an integrated approach to sampling and analyses of pollutants or target molecules in various environmental media. The student will have a hands-on laboratory experience to illustrate statistical sampling, sampling methods, instrumental chemistry analysis, and data handling. Students will study and apply selected principles and techniques of environmental monitoring, including learning to develop sampling and analysis plans, implement sampling and analysis plans, and report results of a monitoring study.
Credit Hours 4
Prerequisites/Corequisites  STAT 526 or permission of instructor  
Terms offered  as needed  

**EVSC 650-Environmental Measurement Techniques**  
This course treats the proper application of the various chemical, physical, and thermophysical analytical methods that are used to characterize environmental samples. Techniques include emission spectroscopy, atomic absorption spectroscopy, x-ray fluorescence analysis, neutron activation analysis, gamma-ray spectroscopy, wet analytical chemistry, gas chromatography, mass spectrometry, scanning electron microscopy, transmission electron microscopy, and x-ray diffractometry. Hands-on experience will be obtained in the associated library.  
Credit Hours  4  
Prerequisites/Corequisites  EVSC 560 or permission of instructor  
Terms offered  As needed  

**EVSC 666-Remote Sensing of the Environment**  
This course considers techniques for remote sensing of atmospheric and water pollution, which uses nearly the entire electromagnetic spectrum. For example, airborne and satellite visible and infrared measurements are used to map oil spills and monitor chemical effluents from facilities. Radiation source characterization and transport of that radiation through free space, along with principles of optical detection, are considered. Remote laser techniques for monitoring gaseous pollutants, including infrared absorption, laser back-scatter (lidar), laser-induced fluorescence, and Raman back-scatter, are also treated.  
Credit Hours  4  
Prerequisites/Corequisites  None  
Terms offered  As needed  

**Human Factors**  

**HFEN 560 - Introduction to Human Factors**  
This course examines the study and application of humans and the system interface, including the knowledge of human cognitive/social/physical behavior, capabilities, and limitations. Topics include anthropometrics, sensation-perception, decision-making, mental workload, situational awareness, display/control design, warnings/alerts, human error and accident investigation. Numerous case studies are used to highlight course topics.  
Credit Hours  4  
Terms Offered  Winter  

**HFEN 610 - Human Performance Measurement**  
Theories, concepts, and methods for measuring and evaluating human performance will be discussed with an emphasis on facilitating the design of systems having enhanced human performance and satisfaction. The student will gain practice in measuring human performance and applying the results to suggest and validate system design improvements. Influence of fatigue, environmental/task stressors, and social/team factors will be discussed.  
Credit Hours  4  
Terms Offered  As Needed  

**HFEN 620 - Human Systems Modeling**  
This course introduces students to using discrete event simulation to model complex human-machine systems. Through this course students will gain an appreciation of defining systems, processes, and workflows using task network analysis. This course is intended to provide students with the requisite knowledge to construct and validate discrete event simulations as well as use simulation outputs to interpret system behavior and evaluate potential solutions with respect to impacts on system performance, human performance, and operator workload.  
Credit Hours  4  
Prerequisites  STAT 583 05 STAT 587  
Terms Offered  Spring
HFEN 660 - Human Factors Engineering
This course examines the application of human factors engineering to the system interface, including the knowledge of human cognitive/social/physical behavior, capabilities, and limitations. Topics include anthropometrics, sensation-perception, decision-making situational awareness, display/control design, warnings/alerts, automation, human error, and accident investigation. Students are expected to apply this knowledge through design projects. Additionally, each student will analyze state of the art research within a selected topic area of interest in this field.
Credit Hours 4
Terms Offered Winter

HFEN 663 - Human-Computer Interaction
This course covers the principles of human-computer interaction in the design and evaluation of useful, usable interfaces as well as the social consequences of technological innovations. Topics include the joint performance of tasks by humans and machines, the structure of communication between human and machines (including machine response to changes in user state), algorithms and programming of the interface itself, engineering concerns that arise in the design and construction of interfaces, the process of specification, design, and implementation of interfaces, and design trade-offs.
Credit Hours 4
Prerequisites HFEN 560
Terms Offered Spring

HFEN 665 – Human Agent Interaction
This course explores operator interaction in human-machine teams to understand significant design trade-offs during the design of the Human Agent (H-A) Interface. Topics to be covered include: Task Allocation, Trust, Interaction Styles, Implicit/Explicit Communication, Relevant Human Biases, Automation Classification/Taxonomies and influences of automation limitations. Interface design decisions and trade-offs will be explored through readings from the course text and select academic articles, as well as analysis and development of design options.
Prerequisites: HFEN 560, HFEN 663
Terms Offered: Summer

HFEN 670 - Human Interaction Technologies
Robust human-system interaction requires information flow between the system and human brain. This course will introduce technologies available to mediate this flow of information, discussing the important characteristics and considerations for input and output technologies. Emphasis will be provided on visual information processing and visual display design. Human auditory processing and various input device technologies will also discussed.
Credit Hours 4
Terms Offered Spring

HFEN 699 - Master's Level Special Study
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.
Credit Hours 1-12
Terms Offered All

HFEN 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.
Credit Hours 1-12
Terms Offered ALL
Information Management

**IMGT 561 - Applications of Database Management Systems**
With emphasis on data in information systems, and with the increasing complexity of data management, this course explores the applications of computer database systems to support organizational and administrative functions. More specifically, the course covers both a user's and designer's perspective the concept of database management systems (DBMSs); DBMS security, integrity, recovery, and concurrency considerations; DBMS data models (the relations will be emphasized, but the hierarchical, network, and object-oriented models will also be covered), data manipulation, and database design. Additional emphasis is placed on emerging technologies, including, but not limited to data warehousing, data marts, and data mining. Principles studied, will be reinforced in the laboratory. Students will use a relational DBMS to build a management-oriented application, further, students will be introduced to a variety of database and database related programs when opportunities arise. The four credit hours for this course consist of three lecture hours and two hours in the laboratory.

- **Credit Hours**: 4
- **Corequisite**: IMGT 561L
- **Terms Offered**: Spring

**IMGT 561L - Applications of Database Management Systems Lab**
Lab associated with IMGT-561

- **Credit Hours**: 0
- **Corequisite**: IMGT 561
- **Terms Offered**: Spring

**IMGT 657 - Data Communications for Managers**
Introduces concepts of data communication systems, balancing technical and managerial issues, to prepare managers to participate in decisions regarding data communication applications. Topics addressed include industry standards, hardware and software requirements for controlling the flow of data, transmission media, security, and trends in the telecommunications industry.

- **Credit Hours**: 4
- **Terms Offered**: Summer

**IMGT 662 - Database Security**
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.

- **Credit Hours**: 3
- **Corequisite**: IMGT 662L
- **Terms Offered**: Spring

**IMGT 662L - Database Security Lab**
Lab associated with IMGT-662.

- **Credit Hours**: 1
- **Corequisite**: IMGT 662
- **Terms Offered**: Spring

**IMGT 669 - Business Process Improvement**
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.
Credit Hours 3
Terms Offered Fall

IMGT 680 - Advanced Topics in Data Management and Analysis
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.
Credit Hours 4
Terms Offered Summer

IMGT 684 - Strategic Information Management
This course explores the strategic use of organizational information. This 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.
Credit Hours 3
Terms Offered Winter and Summer

IMGT 687 - Cyber Systems Security
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.
Credit Hours 4
Terms Offered Spring

Logistics Management

LOGM 520 - Managerial Economics
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.
Credit Hours 4
Terms Offered Winter

LOGM 525 - Statistics for Mobility Managers
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.
Notes This course is open only to students in the Ft. Dix Air Mobility program.
Credit Hours 4
Terms Offered Summer-Ft. Dix Only

LOGM 542 - Management of Logistics Organizations
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.
Credit Hours 4
Terms Offered Winter

LOGM 545 - Introduction to Management and Organizations
Notes 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.
Credit Hours 3
Terms Offered Winter and Spring

LOGM 565 - Strategic Sourcing
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.
Credit Hours 3
Terms Offered Winter and Spring

LOGM 567 - Lean Operations Management
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 leaness 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.
Credit Hours 4
Terms Offered As Needed

LOGM 568 - Introduction to Supply Chain Management
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.
Credit Hours 3
Terms Offered Winter, Spring and Summer

LOGM 569 - Maintenance and Production Management
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.
Credit Hours 3
Terms Offered Fall
LOGM 570 - Principles of Inventory Management
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.
Credit Hours 4
Terms Offered Spring

LOGM 590 - Computer Simulation for Managers
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.
Credit Hours 4
Prerequisites MATH 291, STAT 525, STAT 535
Corequisite LOGM 590L
Terms Offered Spring

LOGM 590L - Computer Simulation for Managers Lab
Lab associated with LOGM 590
Credit Hours 0
Corequisite LOGM 590
Terms Offered Spring

LOGM 601 - Principles and Methods of Research
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.
Credit Hours 4
Terms Offered Fall and Spring

LOGM 617 - Transportation Systems and Strategic Mobility
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.
Credit Hours 3
Terms Offered Fall, Winter, and Summer

LOGM 619 - Transportation Policy and Strategic Mobility
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.
Credit Hours 3
Terms Offered Fall and Spring

LOGM 620 - Activity Based Costing/Management
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.

Credit Hours 4
Terms Offered Summer

LOGM 621 - Air Transportation Management
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.

Credit Hours 3
Prerequisites LOGM 617
Terms Offered Winter

LOGM 626 - Supply Chain Management Capstone
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.

Credit Hours 3
Terms Offered Spring and Summer

LOGM 627 - Supply Chain Management
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.

Credit Hours 4
Terms Offered Fall, Winter and Spring

LOGM 630 - Forecasting Management
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.

Credit Hours 3
Prerequisites STAT 525 and STAT 535
Terms Offered Fall

LOGM 631 - Scheduling: Theory and Application
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.

Credit Hours 3
Prerequisites MATH 291, STAT 525, and STAT 535
Terms Offered Summer

LOGM 634 - Reliability, Maintainability, and Supportability
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.
Credit Hours 3
Prerequisites Any STAT 500 level or higher
Terms Offered Fall and Winter

LOGM 636 - Service Operations Management
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.
Credit Hours 3
Prerequisites LOGM 568
Terms Offered Winter

LOGM 644 - Current Topics in Logistics
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.
Credit Hours 3
Prerequisites None
Terms Offered Summer

LOGM 650 - Seminar in Space Logistics
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.
Credit Hours 3
Terms Offered Summer

LOGM 651 - Seminar in Petroleum Management
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.
Credit Hours 3
Terms Offered Summer
LOGM 660 - Strategy for Logistics
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.
Credit Hours 3
Terms Offered Fall

LOGM 668 - Special Topics in Nuclear Deterrence
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 “health” of the nuclear stockpile?
Credit Hours 4
Terms Offered Summer

LOGM 675 - Logistics Management Colloquium
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.
Credit Hours 0
Terms Offered All

LOGM 699 - Master's Level Special Studies
Special topics of study for masters students in Logistics and Supply Chain Management under the direction of a member of the Logistics faculty.
Credit Hours 1-12
Terms Offered All

LOGM 701 - Advanced Research Methods
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.
Credit Hours 3
Prerequisites Permission of Instructor
Terms Offered Winter

LOGM 768 - Advanced Topics in Logistics
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.
Credit Hours 3
Prerequisites LOGM 627
Terms Offered Fall

LOGM 770 - Advanced Inventory Theory
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.
Credit Hours 3
Prerequisites LOGM 570
Terms Offered Fall
LOGM 791 - Research Project for Mobility Managers
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.
Credit Hours 1-7
Terms Offered All

LOGM 799 - Thesis Research
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.
Credit Hours 1-12
Terms Offered All

LOGM 899 - Doctoral Level Special Study
Special topics of study for doctoral students in Logistics under the direction of a member of the Logistics faculty.
Credit Hours 1-12
Terms Offered All

LOGM 999 - Dissertation Research
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.
Credit Hours 1-12
Terms Offered All

Mathematics

MATH 291 - Calculus for Engineering Managers
Preparatory course in which the student reviews and studies mathematical prerequisites required for the core courses in graduate mathematics programs. This course establishes competence with standard material in differential and integral calculus, including multivariable calculus.
Credit Hours 4
Terms Offered Fall and Summer-Ft Dix only

MATH 302 - Elementary Differential Equations
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.
Credit Hours 4
Prerequisites Calculus
Terms Offered Summer

MATH 504 - Differential Equations of Mathematical Physics
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
Credit Hours 4
Terms Offered Fall

MATH 509 - Mathematical Methods in the Physical Sciences
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.
Credit Hours 4
Terms Offered Winter and Spring

MATH 511 - Methods of Applied Mathematics I
Credit Hours 4
Terms Offered Fall, Winter and Summer

MATH 513 - Methods of Applied Mathematics II
Credit Hours 4
Prerequisites MATH 511
Terms Offered Fall, Winter and Summer

MATH 521 - Applied Linear Algebra
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.
Credit Hours 4
Terms Offered Winter

MATH 523 - Numerical Analysis and Linear Algebra
This course presents the basic concepts necessary for the qualitative and quantitative analysis of mathematical systems. The goal is to understand the underlying mathematical concepts as well as be able to explain the numerical issues when faced with a computational technique. Topics include vector spaces, systems of linear equations, norms, eigenvalues, and numerical iterative methods.
Credit Hours 4
Terms Offered Fall

MATH 600 - Mathematical Analysis
This course provides the transition from elementary calculus to advanced courses (6XX, 7XX, 8XX) which require mathematical analysis with rigor. Topics include basic notions of set theory, point set topology, limits and continuity, derivatives, functions of bounded variation, Riemann-Stieltjes Integration, uniform convergence of sequences and series of functions and their consequences and Lebesgue measure and integration theory.
Credit Hours 4  
Terms Offered Fall and Spring

MATH 601 - Complex Analysis
Introduction to the theory of complex variables, analytic functions, elementary functions and their geometry, integrals, power series, residues and poles, conformal mapping, applications.
Credit Hours 4  
Prerequisites MATH 600 or MATH 602  
Terms Offered Summer

MATH 602 - Modern Applied Mathematics I
Introduction to the foundations and applications of modern applied mathematics for students of applied science. Topics include distribution theory and Green's functions applied to one-dimensional boundary value problems, classical and weak solutions, alternative theorems, functions and transformations, Banach and Hilbert spaces, linear functionals, basic properties of linear and metric spaces including topology, continuity, differentiability, convergence of sequences and series of functions.
Credit Hours 4  
Terms Offered Fall

MATH 604 - Modern Applied Mathematics II
This is a course in applied functional analysis. Topics include linear operator theory and applications to (approximate) solutions of boundary value problems of applied science, closed operators, the inverse operator, adjoint and compact operators, spectrum, contraction mappings, Fredholm integral equations.
Credit Hours 4  
Prerequisites MATH 602  
Terms Offered Winter

MATH 605 - Nonlinear Differential Equations
Topics include linear systems with an introduction to phase space analysis, existence theory, stability of linear and almost linear systems. Lyapunov's second method, applications to nonlinear problems and optimal control theory, bifurcation theory and chaos.
Credit Hours 4  
Prerequisites MATH 600 or MATH 602  
Terms Offered Spring

MATH 607 - Calculus of Variations
Topics include a study of functionals, fixed and variable end point problems, canonical forms of the Euler equations and related topics, sufficient conditions for a weak extremum, fields, sufficient conditions for a strong extremum, variational problems involving multiple integrals, direct variational methods and applications.
Credit Hours 4  
Prerequisites MATH 600 or MATH 602  
Terms Offered Winter

MATH 611 - Introduction to Partial Differential Equations
Introduction to the fundamental concepts of partial differential equations and applications emphasizing the use of these basic concepts. Topics considered include classification, reduction to canonical form, existence of solutions, variational principles, methods of obtaining solutions of the basic types of equations using analytical methods. Some numerical methods are presented.
Credit Hours 4  
Prerequisites MATH 600 or MATH 602  
Terms Offered Winter

MATH 621 - Linear Algebra
Basic algebraic properties of vector spaces and matrices, including dimension and bases, linear transformations, determinants, similarity and congruence, solutions of linear systems of
equations, generalized inverses, singular value decompositions, Jordan normal form, norms and inner products.

Credit Hours: 4
Prerequisites: MATH 521 or MATH 523
Terms Offered: Fall and Spring

MATH 631 - Algebraic Structures
An introduction to the algebra of semigroups, monoids, groups, rings, integral domains, fields and categories. Emphasis is placed on gaining a fundamental understanding of these basic algebraic structures so that the successful student will be able to apply the material in familiar and unfamiliar settings.

Credit Hours: 4
Terms Offered: Winter of even-numbered years

MATH 633 - Graph Theory
An introduction to the theory and application of graphs. Topics include introductory concepts and definitions, digraphs, connected and disconnected graphs, graph traversals, connection problems, trees, planar and nonplanar graphs, Eulerian and Hamiltonian graphs, coloring problems, graph isomorphisms, multigraphs.

Credit Hours: 4
Terms Offered: Spring

MATH 672 - Numerical Linear Algebra

Credit Hours: 4
Prerequisites: Calculus, linear algebra, and working knowledge of a scientific programming language
Terms Offered: Winter

MATH 674 - Introduction to Numerical Analysis
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.

Credit Hours: 4
Prerequisites: Calculus, linear algebra, and working knowledge of a scientific programming language
Terms Offered: Spring

MATH 676 - Numerical Analysis for Partial Differential Equations

Credit Hours: 4
Prerequisites: Multivariable calculus, ordinary differential equations, linear algebra, and working knowledge of a scientific programming language
Terms Offered: Fall

MATH 699 - Master's Level Special Studies
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.

Credit Hours: 1-12
Terms Offered: As needed
MATH 705 - Linear Functional Analysis
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.
Credit Hours 4
Prerequisites MATH 600 and either MATH 621 or MATH 672
Terms Offered Spring

MATH 799 - Thesis Research
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 department 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.
Credit Hours 1-12
Terms Offered All

MATH 831 - Mathematical Optimization and Control
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.
Credit Hours 4
Prerequisites MATH 705
Terms Offered Fall

MATH 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.
Credit Hours 1-12
Terms Offered As needed

MATH 999 - Dissertation Research
Dissertation research conducted in mathematical analysis, 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.
Credit Hours 1-12
Prerequisites Approval of Research Advisor
Terms Offered All

Materials

MATL 525 - Thermodynamics and Kinetics of Materials
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.
Credit Hours 4
Prerequisites undergraduate Materials Science course
Terms Offered Spring
MATL 545 - Mechanical Properties of Materials
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.
Credit Hours 4
Prerequisites: Permission of Instructor
Terms Offered Fall

MATL 560 - Electronic, Magnetic and Optical Properties of Materials
Introduction to the theory and engineering applications, magnetic, and optical materials. Atomic bonding, crystal structure, crystal defects, lattice properties, diffusion, 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.
Credit Hours 4
Prerequisites undergraduate Materials Science course
Terms Offered Fall

MATL 598 - Materials and Processes Seminar
Current technologies, applications, and research issues in the materials and processes are presented by experts from the Air Force, Industries and other universities.
Credit Hours 1
Prerequisites/Corequisites Undergraduate materials science course
Terms offered As needed

MATL 620 - Chemistry of Materials
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.
Credit Hours 4
Prerequisites: CHEM 590
Terms Offered Fall and Winter

MATL 662 - Electronic Properties of Molecules and Solids
This course is an introduction to the electronic behavior of molecules and solid state materials with an emphasis on the symmetrization, postulate, tight binding methods, band theory, Hartree Fock-self consistent field methods, con-figuration interaction methods, and density functional theory.
Credit Hours 4
Prerequisites/Corequisites MATL 620, PHYS 655
Terms offered As needed

MATL 672 - Optical Properties of Materials
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.
Credit Hours 4
Prerequisites PHYS 670
Terms Offered Summer
MATL 680 - Materials Characterization
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.

Credit Hours 4
Prerequisites undergraduate Materials Science course
Terms Offered Winter

MATL 685 - Materials Selection and Processing
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.

Credit Hours 4
Prerequisites undergraduate Materials Science course
Terms Offered Spring

MATL 699 - Master's Level Special Study
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.

Credit Hours 1-12
Terms Offered All

MATL 701 - Research and Apprenticeship
Students will work on special problems related to an individual professor’s or laboratory scientist’s material research program. These special problems will range from pedagogical problems intended to bring the student up to the state of knowledge to problems which represent immediate goals of a research program. The programs may be computational, experimental or theoretical and will vary depending upon the needs of the student and the individual research interests of the professor or laboratory scientist.

Credit Hours 4
Corequisites Permission of instructor
Terms offered Summer

MATL 799 - Thesis Research
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.

Credit Hours 1-12
Terms Offered All

MATL 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.

Credit Hours 1-12
Terms Offered All
Mechanics

**MECH 500 - Fundamentals of Solid Mechanics**
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-section is analyzed by applying St. Venant's Semi-Inverse Principle.

**Credit Hours** 4
**Prerequisites** undergraduate Strength of Materials
**Terms Offered** Fall

**MECH 505 - Introduction to Aircraft Structural Analysis and Mechanics**
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.

**Credit Hours** 4
**Terms Offered** Spring and Summer

**MECH 515 - Theory of Vibrations**

**Credit Hours** 4
**Prerequisites** MECH 521 or equivalent, undergraduate dynamics and ODEs, or Permission of Instructor
**Terms Offered** Summer

**MECH 521 - Intermediate Dynamics**
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.

**Credit Hours** 4
**Prerequisites** undergraduate Dynamics
**Terms Offered** Fall

**MECH 529 - Dynamics and Control of Flight Vehicles**

**Credit Hours** 4
**Prerequisites** MECH 521 or equivalent, or Permission of Instructor
**Terms Offered** Winter

**MECH 532 - Introductory Space Flight Dynamics**
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.

**Credit Hours** 4
**Prerequisites** undergraduate dynamics or Permission of Instructor
**Terms Offered** Fall and Winter
MECH 541 - Mechanics of Composite Materials
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.

Credit Hours 4
Prerequisites MECH 500
Terms Offered Winter

MECH 542 - Introduction to Finite Element Analysis and Computer-Aided Design

Credit Hours 4
Prerequisites ASYS-525, MECH-500 or MECH-545
Corequisite MECH-542L
Terms Offered Winter

MECH 542L - Introduction to Finite Element Analysis and Computer-Aided Design Lab
Lab associated with MECH-542.

Credit Hours 0
Corequisite MECH 542
Terms Offered Winter

MECH 545 - Aerospace Structural Analysis
External loads on the aircraft, forces and load factors on space structures, spanwise airload 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.

Credit Hours 4
Prerequisites undergraduate Strength of Materials
Terms Offered Summer

MECH 600 - Elasticity

Credit Hours 4
Prerequisites MECH 500 or Permission of Instructor
Terms Offered Winter

MECH 601 - Introduction to Time-Dependent Material Behavior
The course provides a fundamental background in inelastic solid 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.

Credit Hours 4
Prerequisites MECH 500
Terms Offered Summer
MECH 605 - Fracture Mechanics
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.

Credit Hours 4
Prerequisites MECH 500 or MECH 545 or Permission of Instructor
Terms Offered Spring

MECH 620 - Systems Optimization
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.

Credit Hours 4
Prerequisites MATLAB programming
Terms Offered Winter

MECH 622 - Functional Optimization and Optimal Control
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; "bang-bang" control, dynamic programming, terminal controllers, and regulators, perturbation techniques and singular solutions.

Credit Hours 4
Prerequisites ASYS 565 or equivalent
Terms Offered Winter and Spring

MECH 628 - Aircraft Control
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.

Credit Hours 4
Prerequisites MECH-529 and ASYS-565
Terms Offered Spring

MECH 629 - Aircraft Handling Qualities and Performance
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.

Credit Hours 4
Prerequisites MECH 529
Terms Offered Summer

MECH 632 - Intermediate Space Flight Dynamics
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.

Credit Hours 4
Prerequisites MECH 521 and MECH 532
Terms Offered Spring
MECH 637 - Astrodyanmic Re-Entry
Introduction to astrodyanmic re-entry with an examination of planetary atmospheres, aerodynamic forces, and endo-atmospheric re-entry trajectories. Preliminary topics will include the concept, theory, and performance of exo-atmospheric spaceflight and the associated equations of flight over a spherical planet. Next, the basic equations for planar entry trajectories will be developed, with subsequent analysis of first-order planetary entry solutions, Loh’s Second-Order theory, Yaroshvskii’s theory, and Chapman’s theory. Additional topics will include entry corridors, the unified theory of re-entry, and orbit contraction due to atmospheric drag.

Credit Hours 4
Prerequisites MECH 521
Terms Offered Fall
Corequisite MECH 532 or Permission of Instructor

MECH 642 - Finite Element Methods for Structural Analysis I
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.

Credit Hours 4
Prerequisites MECH 542 or Permission of Instructor
Terms Offered Spring

MECH 644 - Finite Element Methods for Structural Analysis II
Advanced topics in finite element techniques. Formulation and solution of the system equations. Application to free forced response, stability, and nonlinear analysis.

Credit Hours 4
Prerequisites MECH 642
Terms Offered As needed

MECH 646 – Structural Optimization

Credit Hours 4
Prerequisites MECH 500

MECH 662 - Introduction to Aeroelasticity

Credit Hours 4
Prerequisites AERO 534 and MECH 515 or equivalent
Terms Offered As needed

MECH 699 - Master's Level Special Study
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.

Credit Hours 1-12
Prerequisites Permission of Instructor
Terms Offered All

MECH 712 - Nonlinear Oscillations
MECH 719 - Vibration Damping and Control
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.

Credit Hours 4
Prerequisites MECH 720 or Permission of Instructor
Terms Offered Spring

MECH 719L - Vibration Damping and Control Lab
Lab associated with MECH-719
Credit Hours 0
Corequisite MECH 719
Terms Offered Fall

MECH 720 - Analytical Mechanics
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.

Credit Hours 4
Prerequisites MECH 521
Terms Offered Fall

MECH 731 - Modern Methods of Orbit Determination
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.

Credit Hours 4
Prerequisites MECH 532
Terms Offered Summer

MECH 732 - Advanced Astrodynamics
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.

Credit Hours 4
Prerequisites MECH 521
Terms Offered Winter

MECH 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.

Credit Hours 1 – 12
Prerequisites Permission of Research Advisor
Terms Offered All
Mechanical Engineering

MENG 501 - Aerospace Propulsion
This course provides the student with an understanding of the essential elements of airbreathing and non-air-breathing propulsion systems. Covered are basic principles of thermodynamics and fluid dynamics applied to the analysis of on-design and off-design performance of turbojet systems (turbojet, turbofan, turboprop), to performance parameters of ramjet and scramjet engines and to fundamentals of chemical and non-chemical rocket propulsion. Performance trade-offs are reviewed relative to military applications.

Credit Hours 4  
Prerequisites undergraduate thermodynamics  
Terms Offered Fall

MENG 530 - Chemical Rocket Propulsion
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.

Credit Hours 4  
Prerequisites undergraduate thermodynamics  
Terms Offered Winter

MENG 531 - Space Propulsion and Power Systems
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 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.

Credit Hours 4  
Prerequisites undergraduate thermodynamics  
Terms Offered Summer

MENG 571 - Fundamentals of Heat Transfer
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.

Credit Hours 4  
Terms Offered Winter

MENG 585 - Air Breathing Engine Design
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.

Credit Hours 4  
Prerequisites MENG-501 or Permission of Instructor  
Terms Offered Summer

MENG 633 - Fundamentals of Combustion
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.

**Credit Hours** 4  
**Prerequisites** undergraduate thermodynamics and chemistry  
**Terms Offered** Fall

### MENG 673 - Radiation Heat Transfer
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.

**Credit Hours** 4  
**Prerequisites** MENG 571 or equivalent  
**Terms Offered** Winter

### MENG 674 - Convection Heat Transfer
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.

**Credit Hours** 4  
**Prerequisites** AERO 634 or equivalent  
**Terms Offered** Spring

### MENG 699 - Master's Level Special Study
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.

**Credit Hours** 1-12  
**Prerequisites** Permission of Instructor  
**Terms Offered** All

### MENG 732 - Advanced Turbomachinery
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.

**Credit Hours** 4  
**Prerequisites** MENG 501  
**Terms Offered** Spring

### MENG 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.

**Credit Hours** 1-12  
**Prerequisites** Permission of Research Advisor  
**Terms Offered** All

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**Atmospheric Science/Meteorology**

### METG 610 - Radiative Transfer
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 612 - Cloud Physics
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.
Credit Hours 4
Terms Offered Spring

METG 620 - Advanced Atmospheric Dynamics
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.
Credit Hours 4
Prerequisites Permission of Instructor
Terms Offered Winter

METG 634 - General Circulation and Tropical Meteorology
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.
Credit Hours 4
Terms Offered Winter

METG 640 - Applied Climatology
This course introduces the student to the field and application of climatology and it's 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.
Credit Hours 4
Prerequisites METG 634
Terms Offered Summer

METG 642 - Radar Meteorology
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.
Credit Hours 4
Prerequisites METG 612
Terms Offered Summer

METG 644 - Satellite Meteorology
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.
Credit Hours 4
Terms Offered Spring
METG 650 - Numerical Weather Prediction (NWP) for Scientists and Engineers
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.
Credit Hours 4
Prerequisites METG 620
Terms Offered Spring

METG 655 - Fine Scale, Specialized and Probabilistic NWP
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.
Credit Hours 4
Prerequisites METG 650
Terms Offered Summer

METG 660 - Operational Assessments in Atmospheric Science Laboratory
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.
Credit Hours 4
Prerequisites METG 612, METG 644 and METG 650
Terms Offered Winter

METG 799 - Thesis Research
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.
Credit Hours 1-12
Terms Offered All

Nuclear Engineering

NENG 500 - Nuclear Weapons Strategy and Policy
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.
Notes US Citizenship Required
Credit Hours 4
Terms Offered Fall, Winter and Spring

NENG 585 - Introduction to Modern Fortran with Applications in Computational Nuclear Engineering
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.

Notes US Citizenship Required
Credit Hours 4
Terms Offered Fall

NENG 591 - Nuclear Weapons and Proliferation
This course examines the elements and technology involved in building a nuclear weapons capability, including producing or obtaining nuclear fuel; assembling a weapon; fuzing 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.

Notes US Citizenship Required
Credit Hours 4
Terms Offered Fall, Winter and Summer

NENG 596 - Nuclear Weapons Effects
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.

Notes US Citizenship Required
Credit Hours 4
Terms Offered Fall, Spring and Summer

NENG 601 - Research Apprenticeship
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.

Notes US Citizenship Required
Credit Hours 4
Terms Offered Winter

NENG 605 - Physics of Nuclear Explosives
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.

Notes US Citizenship Required. SECRET Clearance Required.
Credit Hours 4
Prerequisites NENG 651
Terms Offered Winter

NENG 612 - Nuclear Engineering Laboratory
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 spectrometry, coincidence methods, activation with fast and thermal neutrons, X-ray fluorescence. Special techniques include Mossbauer spectrometry 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 620 - Nuclear Reactor Theory and Engineering
This course presents nuclear reactor theory, building upon the coverage of nuclear physics (reactions, radiations, fission, etc.) from NENG 651 and the coverage of neutron diffusion, prompt fast criticality and prompt kinetics from NENG 605. Delayed and thermal neutrons are incorporated into the treatment of criticality and kinetics. Reactor dynamics are examined, including aspects of reactor core and system design, which provide reactivity feedback for reactor control. Nuclear reactor engineering topics include thermal management, energy conversion, radiation shielding, and mechanical and structural aspects of reactor and system design. This course provides a broadened exposure to applications of nuclear science, and provides the necessary foundation for the study of space nuclear power and of the nuclear fuel cycle.

Credit Hours 4  
Prerequisites NENG 651 and MATH 508  
Corequisite NENG 605  
Terms Offered Winter

NENG 625 - Electromagnetic Pulse Effects
Source, propagation, and interaction of the nuclear weapon generated electromagnetic pulse. Source generation is developed for high altitude burst, surface burst and system generated situations. Propagation of the radiated signal is developed from classical electromagnetism (solution of Maxwell's equations) for free space and extended to the atmosphere. EMP interaction is examined using antenna theory. Energy coupling from the wave is developed. Methods of shielding are considered.

Notes US Citizenship Required  
Credit Hours 4  
Prerequisites PHYS 531 and NENG 605  
Terms Offered Summer

NENG 630 - Radiation Health Physics
This course in radiation health physics provides the foundation for understanding the biological effects of ionizing radiation and protecting individuals and population groups. The content depends in part on the students’ backgrounds and curricular goals. Topics may include physical measurements and properties of different types of radiation and radioactive materials; quantitative relationships between radiation exposure and biological damage; movement of radioactivity through the environment; and the design of radiologically safe equipment, processes, and environments with the intent on assessing the radiological impact on humans. In some offerings of the course, the effects of non-ionizing radiation may be included. This course will be useful to bioenvironmental engineers, environmental managers, radiation safety officers, nuclear research officers, or medical personnel who will have responsibility for managing radiation safety programs and managing environmental activities of military installations that have nuclear sources (hospital, PMEL, or nuclear weapons) or who must interact in their environmental management jobs with the Department of Energy.

Notes US Citizenship Required  
Credit Hours 4  
Prerequisites NENG 650 and NENG 651  
Terms Offered Spring
NENG 631 - Prompt Effects of Nuclear Weapons
Topics include source, transmission and mechanisms of interaction of x-ray, blast, thermal, neutron and prompt gamma radiation. X-ray interactions include shock generation and propagation. The conservation equations of fluid dynamics are used to describe shocks. These same equations are applied to blasts in air and underwater shock. Shock “jump conditions” and scaling laws are derived and applied. Thermal transmission is examined. The heat transfer equation is used to study thermal interaction. Build up factors and fits of transport calculations are employed to study neutron and gamma transmission. Various neutron and gamma interaction phenomena are studied. In the case of each effect, systems response is examined, hardening techniques are surveyed, and design trade-offs are discussed. Some secret (RD) material is discussed.

Notes US Citizenship Required. SECRET (RESTRICTED DATA) Clearance Required.
Credit Hours 4
Prerequisites NENG 605
Terms Offered Spring

NENG 635 - Residual Effects of Nuclear Weapons
Environmental radioactivity from natural, nuclear industry and weapon fallout is treated. The emphasis is on weapon fallout, both local and global. Methods of fallout modeling are included for both ground dose and airborne crew dose. Health physics fundamentals including mechanisms of biological response calculation of dose, body burdens and maximum permissible concentrations are also included. Seismic detection of nuclear explosions and worldwide detection systems are examined.

Notes US Citizenship Required
Credit Hours 4
Prerequisites NENG 605
Terms Offered Spring and Summer

NENG 650 - Nuclear Instrumentation
Radiation detectors and detection systems; characteristics, applications, and principles of operation of gas-filled detectors, scintillation detectors, semiconductor detectors; applications and principles of electronic components such as single and multi-channel analyzers, pulse amplifiers, discriminators, scalers, etc.

Notes US Citizenship Required
Credit Hours 4
Prerequisites NENG 651
Corequisite NENG 650L
Terms Offered Winter

NENG 650L - Nuclear Instrumentation Lab
Lab associated with NENG-650.

Notes US Citizenship Required
Credit Hours 0
Corequisite NENG 650
Terms Offered Winter

NENG 651 - Nuclear Physics
A basic graduate level treatment of nuclear physics with emphasis on interaction of radiation with matter, nuclear reactions and radioactive decay processes. Essential ideas of nuclear structure, stability of nuclei and quantum characterization of nuclear energy levels are covered. A practical understanding and interpretation of nuclear data tabulations to serve the needs of the nuclear engineer are stressed.

Notes US Citizenship Required
Credit Hours 4
Terms Offered Fall and Summer

NENG 660 - Radiation Effects on Electronics
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
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 681 - The Nuclear Fuel Cycles
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
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
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
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.
**Prerequisites** MATH 504 and NENG 605  
**Terms Offered** Spring

**NENG 720 - Nuclear Reactor Systems**  
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.  
**Notes** US Citizenship Required  
**Credit Hours** 4  
**Prerequisites** NENG 631 and NENG 635  
**Terms Offered** Winter

**NENG 721 - Space Nuclear Power Systems**  
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.  
**Notes** US Citizenship Required  
**Credit Hours** 4  
**Prerequisites** NENG 631  
**Terms Offered** Winter

**NENG 725 - Monte Carlo Methods of Radiation Transport**  
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.  
**Notes** US Citizenship Required  
**Credit Hours** 4  
**Prerequisites** NENG 705  
**Terms Offered** Spring and Summer

**NENG 751 - Nuclear Physics II**  
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.  
**Credit Hours** 4  
**Prerequisites** NENG 651  
**Terms Offered** Spring

**NENG 785 - Topics in Computational Nuclear Engineering**  
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.  
**Notes** US Citizenship Required  
**Credit Hours** 4  
**Prerequisites** MATH 674 or NENG 685  
**Terms Offered** Fall
NENG 790 - Nuclear Systems Design
Students are assigned to groups for the purpose of conducting a design study on an open-ended problem. Students must mathematically model the problem and propose solutions. Solutions are evaluated against established objectives and realistic constraints such as cost, reliability, survivability, safety, human factors, ethics, and social impact. The best solution is then optimized. Recent class problems have included future terrestrial and space-based Air Force systems.
Credit Hours 4
Prerequisites/Corequisites NENG 631
Terms offered As needed

NENG 791 - Non-Proliferation of Nuclear Weapons and Technologies
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.
Notes US Citizenship Required
Credit Hours 4
Prerequisites NENG 635
Terms Offered Winter

NENG 799 - Thesis Research
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.
Notes US Citizenship Required
Credit Hours 1-12
Terms Offered All

NENG 816 - Advanced Topics in Neutral Particle Transport
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.
Notes US Citizenship Required
Credit Hours 4
Prerequisites NENG 705
Terms Offered Winter

NENG 830 - Advanced Nuclear Weapons Effects
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.
Notes US Citizenship Required
Credit Hours 4
Prerequisites NENG 631 and NENG 635
Terms Offered Summer

NENG 880- Advanced Nuclear Forensics
This advanced PhD topics course covers nuclear technologies used in pre- and post-detonation forensics. The course is designed to provide students with an opportunity to explore the most recent experimental and computational methods in the field and apply them to real problems related to modern national security. A wide range of topics are explored. Some travel to interact with experts in the field and observe data collection is required.
NOTE: Clearance Required
Credit Hours 4
Prerequisites NENG605 NENG631 NENG635 CHEM681 NENG650
Terms offered Spring

NENG 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.
Notes US Citizenship Required
Credit Hours 1-12
Terms Offered All

NENG 999 - Dissertation Research
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.
Notes US Citizenship required
Credit Hours 1-12
Terms Offered All

Optical Engineering

OENG 520-Lasers for Engineers
A basic course in lasers for the non-specialist. The course covers systems engineering, the laser weapon, basic physics of a laser system, solid state, chemical, free electron, semiconductor lasers, laser beam propagation and control, laser lethality and laser weapon design.
Credit Hours 4
Terms offered Limited; as approved by Dept Head

OENG 530 - Fundamentals of Remote Sensing Data Exploitations & Sensor Technology
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.
Notes US Citizenship required
Credit Hours 4
Terms Offered All

OENG 531-Wide Area Overhead Electro-Optical Surveillance
The principles developed in OENG 530 will be applied to explore the current technology for collecting, processing, and exploiting satellite-based infrared sensor data for missile warning, missile defense, support for military operations, technical intelligence, and environmental monitoring.
Credit Hours 3
Prerequisites/Corequisites OENG 530
Terms offered Limited

OENG 533-Spectral Imagery Systems and Data Exploitation
Presents commercial and DOD/IC multi-/hyper-spectral sensors, including data collection issues and GEOINT applications. Examines information that can be extracted from multi-/hyper-spectral data sets collected by GEOINT sensors. Introduces concepts of signature exploitation for materials identification and pattern recognition. Techniques covered include background suppression, principle components, anomaly detection, and signature-based detection.
OENG 616 - Electro-Optical Systems Laboratory
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.

Credit Hours 3
Prerequisite/Corequisites OENG 530
Terms offered Limited; as approved by Dept Head

OENG 616L - Electro-Optical Systems Lab
Lab associated with OENG-616.

Credit Hours 0
Corequisite OENG 616
Terms Offered Summer

OENG 620 - Laser Engineering
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.

Credit Hours 4
Prerequisites PHYS 640 and PHYS 556 or PHYS 655
Terms Offered Spring

OENG 644 - Linear Systems and Fourier Optics
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.

Credit Hours 4
Prerequisites PHYS 640
Terms Offered Winter and Spring

OENG 645 - Wave Optics I
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.

Credit Hours 4
Prerequisites EENG 672 and either OENG 644 or EENG 527
Terms Offered Spring

OENG 647 - Hyperspectral Remote Sensing
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.

Credit Hours 4
Prerequisites PHYS 640 and OENG 650
Terms Offered Summer
OENG 650 - Optical Radiometry and Detection
Develops the solid state and semiconductor technology necessary for an understanding of optical detection. Specific application will be made to photomissive, photoconductive 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.
Credit Hours 4
Prerequisites PHYS 640
Terms Offered Winter

OENG 651 - Optical Diagnostics
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.
Credit Hours 4
Prerequisites OENG 620 and PHYS 542
Corequisite OENG 651L
Terms Offered Summer

OENG 651L - Optical Diagnostics Lab
Lab associated with OENG-651.
Credit Hours 0
Corequisite OENG 651
Terms Offered Summer

OENG 660 - Introduction to Non-Linear Optical Devices
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.
Credit Hours 4
Prerequisites PHYS 640
Terms Offered Winter and Spring

OENG 681 - Digital Image Processing
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.
Credit Hours 4
Prerequisites PHYS 640
Terms Offered Spring

OENG 699 - Master's Level Special Study
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.
Credit Hours 1-12
Terms Offered All

OENG 720 - Laser Devices and Applications
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.

**Credit Hours**

4

**Prerequisites**

OENG 620

**Terms Offered**

Winter

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**OENG 740 - Optical System Design**

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.

**Credit Hours**

4

**Prerequisites**

PHYS 640

**Terms Offered**

As Needed

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**OENG 775 - Introduction to Photonic Devices**

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, bitable optical devices, and self-electro-optic-effect devices.

**Credit Hours**

4

**Terms Offered**

Winter

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**OENG 780 - Infrared Technology**

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.

**Credit Hours**

4

**Prerequisites**

OENG 650

**Terms Offered**

Spring

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**OENG 799 - Thesis Research**

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.

**Credit Hours**

1-12

**Terms Offered**

All

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**OENG 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.

**Credit Hours**

1-12

**Terms Offered**

All

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**OENG 999 - Dissertation Research**

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.

**Credit Hours** 1-12
**Terms Offered** All

### Operations Research

**OPER 498 - Research Methods**
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.

**Credit Hours** 1
**Terms Offered** Spring

**OPER 500 - Operational Sciences Seminar**
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.

**Credit Hours** 0
**Terms Offered** All

**OPER 505 - Business Analytics**
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 queuing theory.

**Credit Hours** 4
**Corequisite** OPER 505L
**Terms Offered** Fall

**OPER 505L - Business Analytics Lab**
Lab associated with OPER-505.

**Credit Hours** 0
**Terms Offered** Fall

**OPER 510 - Introduction to Mathematical Programming**
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.

**Credit Hours** 4
**Prerequisites** MATH 523 or Approval of Instructor
**Terms Offered** Fall

**OPER 540 - Stochastic Modeling & Analysis I**
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.

**Credit Hours** 4
**Prerequisites** STAT 583, STAT 587 or Approval of Instructor
**Terms Offered** Winter
OPER 542 - Decision Analysis using Value Focused Thinking
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 with decision trees and 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.
Credit Hours 4
Prerequisites STAT 583, STAT 587 or Approval of Instructor
Terms Offered Winter

OPER 544 - Operational Decision Support Systems
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.
Credit Hours 2
Prerequisites OPER542, OPER 561, and OPER 610 or Approval of Instructor
Corequisite OPER 544L
Terms Offered Summer

OPER 544L - Operational Decision Support Systems Lab
This course is a 1 credit lab taught in conjunction with OPER 544 lecture
Credit Hours 1
Prerequisites OPER542, OPER 561, and OPER 610 or Approval of Instructor
Corequisite OPER 544
Terms Offered Summer

OPER 561 - Discrete-Event Simulation
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.
Credit Hours 4
Prerequisites STAT 583 and STAT 587 or Approval of Instructor
Terms Offered Spring

OPER 595 - Issues in Defense Analysis
This course discusses the role of analysis in defense decisions and examines the historical contributions and limitations of analysis in the decision-making process. Specific topics include the origins of defense analysis, measures of merit, modeling, analytical pitfalls, contemporary topics, and issues of bias, advocacy, and ethics in defense analysis.
Credit Hours 3
Terms Offered As Needed

OPER 601 - Operations Research Seminar
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.
Credit Hours 0
Terms Offered All
OPER 610 - Linear Programming
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.
Credit Hours 3
Prerequisites OPER 510 and MATH 523 or Approval of Instructor
Terms Offered Winter

OPER 612 - Nonlinear Programming
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.
Credit Hours 3
Prerequisites OPER 610 or Approval of Instructor
Terms Offered Fall

OPER 613 - Integer Programming
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.
Credit Hours 3
Prerequisites OPER 510 or Approval of Instructor
Terms Offered Summer

OPER 614 - Dynamic Programming
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.
Credit Hours 3
Prerequisites OPER 510 and OPER 504 or OPER 540, or Approval of Instructor
Terms Offered Fall

OPER 615 - Large Scale Systems Optimization
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.
Credit Hours 3
Prerequisites OPER 610 or Approval of Instructor
Terms Offered Fall

OPER 616 - Graph Theory
An introduction to the theory and application of graphs. Topics include introductory concepts and definitions, digraphs, connected and disconnected graphs, graph traversals, connection problems, trees, planar and non-planar graphs, Eulerian and Hamiltonian graphs, coloring problems, graph isomorphisms, and multigraphs. Applications of graph theory to problems in network flows and in combinatorial optimization are described.
Credit Hours 4
Prerequisites MATH 523 or Approval of Instructor
Terms Offered Spring (Cross-listed with MATH 633)

**OPER 617 - Networks**
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.

Credit Hours 3
Prerequisites OPER 510 or Approval of Instructor
Terms Offered Spring

**OPER 621 - Multicriteria Optimization**
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.

Credit Hours 3
Prerequisites OPER 505, OPER 510 or Approval of Instructor
Terms Offered Winter

**OPER 623 - Heuristic Search Methods**
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.

Credit Hours 3
Prerequisites OPER 505, OPER 510 or Approval of Instructor
Terms Offered Winter

**OPER 626 - Scheduling Theory**
The course covers the theory and solution methods for scheduling several tasks over time. Topics include terminology, measures of performance, single machine sequencing, flowshop scheduling, the job shop problem and priority dispatching. Side constraints within scheduling, such as precedence, release dates, and due dates are addressed.

Credit Hours 3
Prerequisites OPER 510 or Approval of Instructor
Terms Offered Spring

**OPER 638 - Assessing Operational Cost and Risk**
This course develops the theory of operational cost analysis, the evaluation of operational risk, and game theory. The effects of time on economic and monetary evaluation are studied, and risk and its impact on decision making is investigated. Specific topics covered include cost estimation, economic evaluation, risk assessment, value and utility functions, and multiattribute utility theory. A systems analysis perspective is used in the presentation of course material.

Credit Hours 3
Prerequisites OPER 510, OPER 540, OPER 542, and STAT 587 or Approval of Instructor
Terms Offered Fall

**OPER 641 - Stochastic Modeling and Analysis II**
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.

Credit Hours 3
Prerequisites OPER 540 or Approval of Instructor
Terms Offered Spring
OPER 642 - Decision Analysis under Uncertainty and Risk
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.
Credit Hours 3
Prerequisites OPER 542
Terms Offered Spring

OPER 645 - Risk Modeling and Analysis
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.
Credit Hours 4
Prerequisites OPER 540 or Approval of Instructor
Terms Offered Summer

OPER 647 - Queuing System Analysis
This course begins with an overview of stochastic modeling and transforms methods. These techniques are then employed in equilibrium analysis of simple Markov and imbedded 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.
Credit Hours 3
Prerequisites OPER 540 or Approval of Instructor
Terms Offered Fall

OPER 660 - Statistical Aspects of Simulation: Input Analysis
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 input modeling. Topics include random number generation, random variate modeling and generation, the structure of simulation programs, and model validation.
Credit Hours 3
Prerequisites OPER 561 or Approval of Instructor
Terms Offered Summer

OPER 661 - Statistical Aspects of Simulation: Output Analysis
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.
Credit Hours 3
Prerequisites OPER-561 or Approval of Instructor
Terms Offered Summer

OPER 671 - Combat Modeling I
The purpose of this course is to present high resolution combat modeling. High resolution combat modeling provides detailed interactions of individual combatants or weapons systems. Topics include: simulating the battlefield environment, target search, acquisition and selection processes, single round accuracy and lethality models, and multiple round assessment models. Models currently used for DoD analysis are used for class projects and examined in the context of support to major analytical simulation studies.
Credit Hours 3
Prerequisites OPER 561 or Approval of Instructor
Terms Offered Summer
OPER 672 - Combat Modeling II
The purpose of this course is to present modeling of large scale air/ground combat operations using aggregated force on force combat models. Topics include: aggregation and disaggregation, types of models used for large scale operations, firepower index and Lanchester equation approaches to attrition modeling, movement, rate of advance, air allocation, logistics, and C3I models. Models currently in use for DoD analysis are used as examples throughout the course.
Credit Hours 3
Prerequisites OPER 671 or Approval of Instructor
Terms Offered Winter

OPER 674 - Joint Mobility Modeling
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 in the air mobility problem and its relation to land and sea mobility. Both strategic and theater mobility are explored.
Credit Hours 3
Terms Offered Winter

OPER 676 - Information Operations Research
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.
Notes U.S. Military Only; U.S. Citizenship Required
Credit Hours 3
Terms Offered Summer

OPER 679 - Empirical Modeling
Analysis of experimental and observational data from engineering systems. Focus on empirical model building using observation data for characterization, estimation, inference and prediction.
Credit Hours 3
Prerequisites STAT 583, STAT 587, or Approval of Instructor
Terms Offered Fall

OPER 681 - Statistical Process Control
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.
Credit Hours 3
Prerequisites STAT 583, STAT 587 or Approval of Instructor
Terms Offered Fall

OPER 683 - Response Surface Methodology
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.
Credit Hours 3
Prerequisites OPER 679 or STAT 696 and OPER 688 or Approval of Instructor
Terms Offered Fall

OPER 684 - Quantitative Forecasting Techniques
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.

**Credit Hours** 3  
**Prerequisites** STAT 583, STAT 587 or Approval of Instructor  
**Terms Offered** Winter

**OPER 685 - Applied Multivariate Analysis I**  
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, discriminate analysis, and neural networks. Emphasis will be on practical application to data sets using computerized statistical packages.

**Credit Hours** 3  
**Prerequisites** STAT 583, STAT 587 or Approval of Instructor  
**Terms Offered** Fall and Spring

**OPER 688 - Operational Experimentation**  
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.

**Credit Hours** 3  
**Prerequisites** OPER-679, STAT-696 or Approval of Instructor  
**Terms Offered** Summer

**OPER 689 - Advanced Statistical Methods for Test**  
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.

**Credit Hours** 3  
**Prerequisites** OPER 679 and OPER 688  
**Terms Offered** Winter

**OPER 699 - Master's Level Special Study**  
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.

**Credit Hours** 1-12  
**Prerequisites** Approval of Instructor  
**Terms Offered** All

**OPER 710 - Advanced Linear Programming and Extensions**  
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.

**Credit Hours** 3  
**Prerequisites** OPER 610  
**Terms Offered** Summer

**OPER 712 - Advanced Math Programming**  
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
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.
Credit Hours 3
Prerequisites OPER 612
Terms Offered Fall and Spring

OPER 741 - Advanced Stochastic Modeling
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.
Credit Hours 3
Prerequisites OPER 641 or Approval of Instructor
Terms Offered Fall

OPER 743 - Decision Analysis Practice
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
Credit Hours 3
Prerequisites At least two of the following courses: OPER 542, OPER 621, OPER 642, OPER 645 or Approval of Instructor
Terms Offered Fall and Winter

OPER 746 - Advanced Topics in Reliability
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.
Credit Hours 3
Prerequisites OPER 540
Terms Offered Fall and Winter

OPER 785 - Applied Multivariate Analysis II: Pattern Recognition
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.
Credit Hours 3
Prerequisites OPER 685 or Approval of Instructor
Terms Offered Winter

OPER 786 - Multivariate Analysis III: Advanced Topics
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.
Credit Hours 3
Prerequisites OPER 785 or Approval of Instructor
Terms Offered Spring
OPER 791 - Research Project for Operational Sciences
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.
Credit Hours: 1-7
Terms Offered: All

OPER 799 - Thesis Research
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.
Credit Hours: 1-12
Terms Offered: All

OPER 899 - Doctoral Level Special Study
Special topics of study for doctoral students under the direction of a member of the Department of Operational Sciences faculty.
Credit Hours: 1-12
Prerequisites: Approval of Instructor
Terms Offered: All

OPER 999 - Dissertation Research
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.
Credit Hours: 1-12
Terms Offered: All

Organizational Science

ORSC 542 - Management and Behavior in Organizations
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.
Credit Hours: 4
Terms Offered: Fall and Winter

ORSC 638 - Seminar in Contemporary Leadership Theory and Application
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.
Credit Hours: 4
Prerequisites: ORSC 542
Terms Offered: As Needed
ORSC 647 - Organizational Policy and Strategic Management

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.

Credit Hours 4
Prerequisites ORSC 542 or Permission of Instructor
Terms Offered As Needed

Research

PENP 798 - IDE Research Project

Project completion course. Credit given for completion of research project.
Credit Hours 9
Terms Offered All

PENS 791 - Research Project Completion

Project completion course. Credit given for completion of research project.
Credit Hours 1-7
Terms Offered All

PENV 798 - Group Design Project Completion

Project completion course. Credit given for completion of research project.
Credit Hours 1-9
Terms Offered All

Physics

PHYS 519 - The Space Environment

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.
Credit Hours 4
Terms Offered Fall and Summer

PHYS 521 - Space Surveillance

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.
Credit Hours 4
Terms Offered Fall and Winter
PHYS 531 - Electromagnetism
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.
Credit Hours 4
Terms Offered Summer

PHYS 542 - Optics Laboratory Course
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, spectrometry, coherence, and detectors.
Credit Hours 2
Prerequisites PHYS 640
Corequisite PHYS 542L
Terms Offered Spring

PHYS 542L - Lab for Optics Laboratory Course
Lab associated with PHYS-542.
Credit Hours 0
Corequisite PHYS 542
Terms Offered Spring

PHYS 556 - Introduction to Quantum Physics
Basic mathematical and conceptual principles of quantum physics. Includes black body radiation, photoelectric effect, Rutherford scattering, Bohr theory of the atom, wave-particle duality, Schrödinger wave equation and applications, one electron atom, atomic spectra, X-rays, periodic table, statistical physics, and statistical distribution functions.
Credit Hours 4
Terms Offered Summer

PHYS 570 - Physics of Solid State Devices
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.
Credit Hours 4
Prerequisites PHYS 556 or Permission of instructor
Terms Offered Fall

PHYS 598 - Engineering Physics Seminar
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&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&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.
Credit Hours 1
Terms Offered Spring

PHYS 600 - Dynamics
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.
Credit Hours 4
Terms Offered Spring
PHYS 601 - Electrodynamics I
A course in classical electromagnetic radiation. Treats wave propagation in space and in material media, reflection and refraction, and radiating systems.
Credit Hours 4
Terms Offered Fall

PHYS 620 - Directed Energy Effects
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.
Credit Hours 4
Terms Offered Fall and Summer

PHYS 624 - High Power Microwave Systems
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.
Credit Hours 4
Prerequisites PHYS 531 or PHYS 601
Terms Offered As needed

PHYS 635 - Thermal Physics
Treats statistical mechanics and thermodynamics. Topics include statistical methods; statistical thermodynamics with applications; ensemble theory; and Maxwell-Boltzmann, Fermi-Dirac, and Bose-Einstein statistics with applications.
Credit Hours 4
Prerequisites PHYS 556 or PHYS 655
Terms Offered Winter

PHYS 640 - Optics
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.
Credit Hours 4
Terms Offered Fall

PHYS 650 - Kinetic Theory of Plasmas
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 Bebye shielding, plasma waves, magnetic confinement, and Ionospheric physics.
Credit Hours 4
Prerequisites PHYS 531 or PHYS 601
Terms Offered Fall

PHYS 655 - Quantum Mechanics I
An introduction to the Schrodinger 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.
PHYS 661 - Atomic and Molecular Spectroscopy
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.
Credit Hours 4
Prerequisites PHYS 655
Terms Offered Fall

PHYS 670 - Introduction to Solid State Physics
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.
Credit Hours 4
Prerequisites PHYS 635 and PHYS 655
Terms Offered Spring

PHYS 671 - Selected Topics in Solid State Physics
This course embodies the study of various phenomena in solids. Topics will be selected from semiconductors and semiconductor devices, optical and surface phenomena, transport properties, and superconductivity.
Credit Hours 4
Prerequisites/ Corequisites PHYS 670
Terms offered: As needed

PHYS 686 - Computational Methods for Atmospheric and Space Sciences
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 ODE's, finite difference discretization of PDE's and data assimilation.
Credit Hours 4
Terms Offered Fall

PHYS 699 - Master's Level Special Study
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.
Credit Hours 1-12
Terms Offered All

PHYS 730 - Electrodynamics II
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.
Credit Hours 4
Prerequisites PHYS 601
Terms Offered Fall

PHYS 735 - Statistical Physics
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.
Credit Hours 4
Prerequisites PHYS 635
Terms Offered Winter

PHYS 740 - Optics II
This course is designed to give a more rigorous mathematical treatment of optics principles. The properties of light propagation through practical optical components and systems, as well as free space, are described both in terms of geometric optics and physical optics languages. In particular, wave front aberrations and their implications on image quality and focal intensity are discussed in depth. Topics covered include matrix method in geometric optics and Gaussian beam optics, Jones matrix treatment of polarization, optics of the solids (crystal optics), coherence theory, and diffraction theory of aberration.
Credit Hours 4
Prerequisites PHYS 601 and PHYS 640
Terms Offered Winter

PHYS 751-Plasma Dynamics
Expands the development of plasma physics beyond the basic phenomena discussed in PHYS 650 to include derivations of the Vlasov, Boltzmann, and Fokker-Planck equations. These equations are applied to plasma problems that illustrate the fluid equations and wave phenomena. Plasma oscillations, dispersion relations, Landau damping, and velocity space instabilities will be included in a study of plasma confinement and gas discharges.
Credit Hours 4
Prerequisites/Corequisites PHYS 650
Terms offered As needed

PHYS 755 - Quantum Mechanics II
Intermediate quantum mechanics: develops the formal mathematical basis and postulates of quantum mechanics. Examines topics in measurement theory, two level systems, scattering, spin and quantum dynamics. Applications in atomic and nuclear physics are developed.
Credit Hours 4
Prerequisites PHYS 655
Terms Offered Fall

PHYS 756 - Quantum Mechanics III
Advanced quantum mechanics: examines topics of in-variance and symmetries, systems of identical particles, time independent and dependent perturbation theory, and relativistic quantum theory of the Klein-Gordon and Dirac equations. Application topics in lasers, solid state and plasma physics are developed.
Credit Hours 4
Prerequisites PHYS 755
Terms Offered As needed

PHYS 770 - Solid State Physics I
First course in a sequence of courses covering topics in solid state physics at an advanced level. Topics include free electron theory, crystal structure, x-ray diffraction, reciprocal lattice, electron dynamics, energy band calculations, transport theory, Fermi surfaces, band structure of metals, electronic scattering and cohesive energy.
Credit Hours 4
Prerequisites PHYS 670 and PHYS 755
Terms Offered As needed

PHYS 771 - Solid State Physics II
Second course in a sequence of courses covering solid state physics at an advanced level. Topics include lattice dynamics, phonons, anharmonic effects, dielectric properties, semiconductor properties, defects, magnetism, and superconductivity.
Credit Hours 4
Prerequisites PHYS 770
Terms Offered As needed
PHYS 772 - Solid State Physics III (Advanced Topics in SSP)
An in-depth study of advanced topics in solid state physics. Special emphasis will be given to the topics covering the optical properties and optical processes in semiconductors, dealing with the interactions among photons, electrons, holes, and impurities in semiconductor crystals. Topics include energy states, radiative and non-radiative transitions, emissions, and absorptions in semiconductors, processes and p-n junctions, and photovoltaic effects on semiconductors.
Credit Hours 4
Prerequisites PHYS 771
Terms Offered As needed

PHYS 775 - Ionospheric Physics and Chemistry
Formation and chemical properties of the ionosphere. Topics include ionization mechanisms, conductivity, energy loss mechanisms, electromagnetic wave propagation.
Credit Hours 4
Prerequisites CHEM 675, PHYS 635 and PHYS 650
Terms Offered Summer

PHYS 776 - Structure and Dynamics of the Magnetosphere
Physics of solar wind, formation of the magnetosphere, and properties of magnetosphere. Topics include solar wind flow, solar wind-earth magnetic field interaction, magnetosphere plasma-wave interactions, Van Allen belts, auroral phenomena.
Credit Hours 4
Prerequisites PHYS 650
Terms Offered Summer

PHYS 777 - The Solar Atmosphere
This course deals with the source of the Earth’s space weather, the sun. In particular, the student will study the outer solar regions, including the “quiet” photosphere, the chromosphere, the corona, and solar wind. The course heavily emphasizes both descriptions of instrumentation and data used to observe solar conditions and the “active” sun, which perturbs the Earth’s environment, and it is intended to provide the space environment student with a quantitative description of solar events that impact the forecaster’s mission. Class discussion will focus on sunspot activity, flares, prominence, coronal mass ejections, coronal holes, and other pertinent observables that indicate active conditions on the sun’s surface.
Credit Hours 4
Prerequisites PHYS 635 and PHYS 650
Terms Offered Spring

PHYS 780 - Group Theory and Quantum Mechanics
Treats abstract theory of groups and the theory of group representations in sufficient detail to aid in understanding current theories of the structure of atoms, molecules and solids.
Credit Hours 4
Prerequisites PHYS 755
Terms Offered As needed

PHYS 781 - Laser Spectroscopy
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.
Credit Hours 4
Prerequisites PHYS 661 and OENG 620
Terms Offered Summer
PHYS 782-Selected Topics In Nonlinear Optics
An advanced course in nonlinear optics designed to provide the student with the fundamental principles underlying nonlinear optical phenomena. Topical coverage includes the discussion of nonlinear interaction of light with matter in terms of nonlinear susceptibility. A semi classical theory of nonlinear susceptibility is also included. These topics are followed by a discussion of applications in selected subject areas in nonlinear optics and/or laser spectroscopy, such as frequency conversion, phase conjugation, stimulated Raman and Brillouin scattering, and coherent anti-Stokes Raman spectroscopy.
Credit Hours 4
Prerequisites/Corequisites OENG 660, OENG 620, PHYS 755
Terms offered As needed

PHYS 790-Engineering Physics Design
Treats the principles involved in the design of systems in the areas of optics, solid state physics, plasma physics and others. The student will participate in an engineering design study in one of these areas. Classified papers may be included.
Credit Hours 4
Prerequisites/Corequisites Permission of instructor
Terms offered As needed

PHYS 791 - Operational Assessments in Atmospheric and Space Sciences
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.
Credit Hours 4
Prerequisites PHYS 775
Terms Offered Winter

PHYS 792 - Space Weather Laboratory
This laboratory course utilizes instrumentation and models to observe and characterize the environment from the earth to the sun in order to study current operational aspects of USAF space weather forecasting and observing. The student is introduced to space weather computer codes used to provide operational 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. Additionally, students will be exposed to experiments that illustrate how space weather impacts daily operations. Finally, students will attempt to solve a current or future DoD operational environment-related problem through a class design study.
Credit Hours 2
Prerequisites PHYS 775, PHYS 776, PHYS 777
Corequisite PHYS 792L
Terms Offered Winter

PHYS 792L - Space Weather Laboratory
This laboratory course utilizes instrumentation and models to observe and characterize the environment from the earth to the sun in order to study current operational aspects of USAF space weather forecasting and observing. The student is introduced to space weather computer codes used to provide operational 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. Additionally, students will be exposed to experiments that illustrate how space weather impacts daily operations. Finally, students will attempt to solve a current or future DoD operational environment-related problem through a class design study.
Credit Hours 2
Prerequisites PHYS 775, PHYS 776, PHYS 777
Corequisite PHYS 792
Terms Offered Winter
PHYS 798 - Departmental Seminar
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&D community within the Air Force.
Credit Hours 1
Terms Offered All

PHYS 799 - Thesis Research
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 re-search are required.
Credit Hours 1-12
Terms Offered All

PHYS 840 - Advanced Topics in Optics
Selections from a host of advanced topics such as the use of variational principles in geometrical optics, Fresnel-Kirchoff scalar diffraction theory, coherence, holography, imaging theory, interaction of light with materials and waves, dielectric waveguides and optical fibers.
Credit Hours 4
Prerequisites/Corequisites PHYS 740, OENG 644, OENG 620
Terms Offered As needed

PHYS 845 - Quantum Optics
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.
Credit Hours 4
Prerequisites PHYS 730 and PHYS 755
Terms Offered As needed

PHYS 880 - Positron Physics and Chemistry
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.
Credit Hours 4
Prerequisites CHEM 780, CHEM 850 or PHYS 755 or Permission of Instructor
Terms Offered As Needed

PHYS 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.
Credit Hours 1-12
Terms Offered All

PHYS 999 - Dissertation Research
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.

Credit Hours 1-12
Terms Offered All

Quantitative Management

QMGT 680 - Project Risk Analysis
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.
Credit Hours 4
Prerequisites Any 500 level STAT course
Terms Offered As Needed

Research Management

RDMT 541 - Operational Technology and Innovation
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 successful manager must understand the dynamics of how technologies are changing, who might be involved in potentially complementary (yet often competitive) work, and how to achieve and maintain a technological advantage. The focus of the course is on the management of innovation; both sustaining and disruptive innovations will be discussed.
Credit Hours 3
Terms Offered As Needed

RDMT 554 - Management in R&D Organizations
The purpose of the course is to help students think strategically about technological innovation in an R&D (or S&T) 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.
Credit Hours 3
Prerequisites RDMT 541
Terms Offered As Needed

RDMT 654 - Seminar in Research and Development Management
As the capstone course for the S&T focus sequence, this course builds on material presented in previous courses and is designed to introduce students to the effective functioning and management of organizations in the public sector. The course will focus on key management issues in public sector organizations and how to more effectively function in leadership roles in those organizations. In doing so, it attempts to examine how the behaviors of individuals, groups, and organizations influence the operation of government agencies and nonprofit organizations. 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.
Credit Hours 4
Prerequisites RDMT 541 and RDMT 554
Terms Offered As Needed

RSCH 630 - Research Methods
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 the 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.

**Credit Hours** 4  
**Prerequisites** STAT 525, STAT 583 or STAT 587  
**Terms Offered** Winter and Spring

**RSCCH 662 - Metrics, Surveys, and Instrument Development**  
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.

**Credit Hours** 3  
**Prerequisites** RSCCH 630  
**Terms Offered** As Needed

**SENG 520 - Foundations of Systems Engineering**  
SENG 520 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.

**Credit Hours** 4  
**Terms Offered** Fall and Spring

**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.

**Credit Hours** 4  
**Prerequisites** SENG 520 and ASYS 525 or EENG 510  
**Terms Offered** Winter

**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.

**Credit Hours** 4  
**Terms Offered** Fall and Spring

**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 AFSO21.

Credit Hours 4
Terms Offered Fall and Summer

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.

Credit Hours 4
Terms Offered Fall

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.

Credit Hours 4
Terms Offered Fall, Winter and Summer

SENG 610 - Project Management
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. A one hour lab illustrates course principles using Microsoft Project software.

Credit Hours 4
Corequisite SENG 610L
Terms Offered Spring and Summer

SENG 610L - Project Management Lab
Lab associated with SENG-610.
Credit Hours 0
Corequisite SENG 610
Terms Offered Spring and Summer

SENG 620 - Quantitative Analytical Methods
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.

Credit Hours 4
Prerequisites SENG 520
Terms Offered Fall
SENG 640 - System Architecture
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).

Credit Hours 4
Prerequisites SENG 520 and SENG 593 or Permission of Instructor
Terms Offered Winter and Spring

SENG 650 - Small UAS Detailed Design
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.

Credit Hours 4
Prerequisites SENG 550
Terms Offered Spring

SENG 651 - Small UAS Test and Evaluation
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.

Credit Hours 4
Prerequisites SENG 650
Terms Offered Summer

SENG 660 – Advanced Principles of Engineering Design
This course explores various principles of systems 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.

Credit Hours 4
Prerequisites SENG 520, SENG 640
Terms Offered Summer

SENG 670 – Advanced Topics in DoD Systems Engineering
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.

Credit Hours 4
Prerequisites SENG 520
Terms Offered Spring

SENG 685 - Reliability Engineering
This course is a continuation of SENG 585. This course introduces the students to some advanced reliability modeling and statistical analysis techniques. The student will be introduced to a variety of statistical inference procedures. Topics include sequential procedures, Bayesian procedures, and parameter estimation with covariates. Some of the specialized reliability models introduced in SENG 585 will be examined in more detail. In particular, competing risks, accelerated life, and proportional hazard
models will be discussed. The final third of the course will focus on strategies currently being used to optimize the design of systems using the most cost effective combination of design parameters under uncertainty. Electrical circuits, mechanical structures, and manufacturing processes will be used as examples.

Credit Hours 4
Prerequisites STAT 601 and SENG 585
Terms Offered Spring

SENG 687 - Advanced Topics in Reliability
The objective of this course is to introduce students to advanced topics in systems design in the areas of reliability, maintainability, and availability applied to system design. Comparison of current Eastern/Western approaches to design is focus of course. Emphasis is on the application of design of experiments to improve quality of complex systems.

Credit Hours 4
Prerequisites SENG 685, STAT 601 or Permission of Instructor
Terms Offered Summer

SENG 695 - Systems Engineering Research Seminar
This seminar will guide students in selecting a research topic and a thesis advisor as part of the resident Graduate Systems Engineering (GSE) program. Students will be presented the principles of organizing and conducting research and will be introduced to the fundamentals of literature reviews, a variety of research methods and thesis construction. Thesis development and time lines will also be discussed.

Credit Hours 0
Terms Offered Fall, Winter and Spring

SENG 699 - Master's Level Special Study
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.

Credit Hours 1 - 12
Terms Offered All

SENG 740 - Advanced Topics in System Architecture
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.

Credit Hours 4
Prerequisites SENG 640
Terms Offered Winter and Summer

SENG 798 - Master's Capstone Project
A topic is selected from a wide variety of problems of current interest to the Air Force and/or 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.

Notes Distance Learning.
Credit Hours 4
Terms Offered Winter and Summer

SENG 799 - Thesis Research
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.

**Credit Hours** 1 - 12

**Terms Offered** All

**SENG 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.

**Credit Hours** 1 - 12

**Terms Offered** All

**SENG 999 - Dissertation Research**
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 dissertation written under the supervision of a departmental professor.

**Credit Hours** 1-12

**Terms Offered** All

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**Statistics**

**STAT 521 - Applied Statistical Data Analysis**
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).

**Credit Hours** 5

**Terms Offered** Spring – Distance Learning only

**STAT 525 - Applied Statistics for Managers I**
This course covers descriptive statistics, probability theory and statistical inference. Descriptive statistics covers both numerical and graphical techniques to illustrate data. Probability theory covers 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.

**Credit Hours** 4

**Terms Offered** Fall

**STAT 535 - Applied Statistics for Managers II**
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).

**Credit Hours** 4

**Prerequisites** STAT 525

**Corequisite** STAT 535L

**Terms Offered** Winter

**STAT 535L - Applied Statistics for Managers II Lab**
Lab associated with STAT-535.

**Credit Hours** 0

**Prerequisites** STAT 525

**Corequisite** STAT 535
Terms Offered Winter

STAT 583 - Introduction to Probability and Statistics
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.
Credit Hours 4
Prerequisites None
Terms Offered Fall, Winter, Summer

STAT 586 - Probability Theory for Communication and Control
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.
Credit Hours 4
Terms Offered Fall

STAT 587 - Applied Probability and Statistical Analysis
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.
Credit Hours 4
Terms Offered Fall

STAT 601 - Theory of Probability
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.
Credit Hours 4
Prerequisites STAT 583 and either MATH 509 or MATH 511
Terms Offered Fall

STAT 602 - Mathematical Statistics
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.
Credit Hours 4
Prerequisites STAT 601
Terms Offered Winter

STAT 641 - Analysis of Variance
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).
Credit Hours 3
Prerequisites STAT 602, STAT 696 and either MATH 521 or MATH 621
Corequisite STAT 641L
Terms Offered Spring

STAT 641L - Analysis of Variance Lab
Lab associated with STAT-641.
Credit Hours 1
Prerequisites STAT 602, STAT 696 and either MATH 521 or MATH 621
Corequisite STAT 641
Terms Offered Spring

STAT 642 - Computational Statistics
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.
Credit Hours 4
Prerequisites STAT 602
Terms Offered Spring

STAT 643 - Nonparametric Statistics
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.
Credit Hours 4
Prerequisites STAT 583 and STAT 602
Terms Offered Winter

STAT 644 – Categorical Data Analysis
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.
Credit Hours 4
Prerequisites STAT 696 and either STAT 583 or STAT 602
Terms Offered Winter

STAT 645 - Bayesian Inference
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 Carol (MCMC).
Credit Hours 4
Prerequisites STAT 602
Terms Offered Winter

STAT 687 - Mathematics of Reliability Theory I
Reliability models, reliability estimation, exponential and Weibull models, sequential life testing, Bayesian reliability in testing and design, goodness-of-fit tests, accelerated testing, reliability growth models.
Credit Hours 4
Prerequisites STAT 602
Terms Offered Summer

STAT 694 - Design of Experiments
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.
Credit Hours 4
Prerequisites STAT 696 or MATH 521 or MATH 523 or MATH 621 or MATH 672
Terms Offered Summer
STAT 696 - Applied General Linear Models
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.

**Credit Hours** 4
**Prerequisites** STAT 583
**Corequisite** STAT 696L
**Terms Offered** Fall

STAT 696L - Applied General Linear Models Lab
Lab associated with STAT-696.

**Credit Hours** 0
**Prerequisites** STAT 583
**Corequisite** STAT 696
**Terms Offered** Fall

STAT 699 - Master's Level Special Study
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.

**Credit Hours** 1-12
**Terms Offered** As needed

STAT 799 - Thesis Research
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 department 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.

**Credit Hours** 1-12
**Terms Offered** All

STAT 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.

**Credit Hours** 1-12
**Terms Offered** All

STAT 999 - Dissertation Research
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.

**Credit Hours** 1 - 12
**Prerequisites** Approval of Research Advisor
**Terms Offered** All
Faculty List

AKERS, BENJAMIN F.
Associate Professor of Mathematics
B.S., Pennsylvania State University; M.A.,
Ph.D., University of Wisconsin - Madison

ARMSTRONG, ANDREW M. MAJ
Assistant Professor of Statistics
B.S., Michigan Technological University; M.S.,
University of Texas at San Antonio; M.S.,
Ph.D., Air Force Institute of Technology

AHNER, DARRYL K.
Associate Professor of Operations Research
B.S., United States Military Academy; M.S.,
Rensselaer Polytechnic Institute; Ph.D., Boston
University

ANDERSON, JASON R. LT COL
Assistant Professor of Logistics and Supply
Chain Management
B.S., United States Air Force Academy; M.S.A.,
Central Michigan University; M.S., Air Force
Institute of Technology; Ph.D., Air Force
Institute of Technology

AYRES, BRADLEY J.
Visiting Assistant Professor of Systems
Engineering
B.S., University of Missouri; M.A., Webster
University; M.S., Air Force Institute of
Technology; Ph.D., MIS, Florida State
University

BADIRU, ADEDEJI B.
Professor of Systems Engineering
B.S., M.S., Tennessee Technological University;
Ph.D., University of Central Florida

BAILEY, WILLIAM F.
Associate Professor Emeritus of Physics
B.S., United States Military Academy; M.S.,
The Ohio State University; Ph.D., Air Force
Institute of Technology

BAKER, WILLIAM P.
Associate Professor of Mathematics
B.A., M.A., University of California - Irvine;
Ph.D. Northwestern University

BARTLETT, KEVIN B.
Adjunct Assistant Professor of Atmospheric
Sciences
B.S., University of California Los Angles; M.S.,
Air Force Institute of Technology; Ph.D.,
University of Albany

BECKER, DAVID J. MAJ
Assistant Professor of Electrical Engineering
B.S.E.E., M.S.E.E., Ph.D. Air Force Institute of
Technology

BEMROSE, TRAVIS J. MAJ
Assistant Professor of Mathematics
B.S., University of Idaho; M.S., University of
Texas at San Antonio; Ph.D. University of
Missouri-Columbia

BETANCES, JOAN A. MAJ
Assistant Professor of Electrical Engineering
B.S., Walla Walla University; B.S., Antillean
Adventist University; M.S., Ph.D., Air Force
Institute of Technology

BETTINGER, ROBERT A. MAJ
Assistant Professor of Aerospace Engineering
B.S., United States Air Force Academy; M.A.,
American Public University; M.S., Ph.D., Air
Force Institute of Technology

BEVINS, JAMES B. CAPT
Assistant Professor of Nuclear Engineering
B.S., University of Tennessee; M.S. Air Force
Institute of Technology; Ph.D., University of
California, Berkley

BICKLEY, ABIGAIL A.
Research Assistant Professor of Nuclear
Engineering
B.A., Dartmouth College; Ph.D. University of
Maryland

BORGHETTI, BRETT J.
Associate Professor of Computer Science
B.S., Worcester Polytechnic Institute; M.S., Air
Force Institute of Technology; Ph.D., University
of Minnesota
BOSE-PILLAI, SANTASRI
Research Assistant Professor of Engineering Physics
B.E., Jadavpur University; M.S., New Mexico State University; Ph.D., New Mexico State University

BREITBACH, TIMOTHY W. MAJ
Assistant Professor of Logistics and Supply Chain Management
B.A., University of Notre Dame; M.S., Air Force Institute of Technology; Ph.D., Massachusetts Institute of Technology

BROOKS, ERIC L. MAJ
Assistant Professor of Statistics
B.S., University of South Carolina-Aiken; M.S., Rochester Institute of Technology; Ph.D., Air Force Institute of Technology

BRUZZESE, JOHN R.
Adjunct Assistant Professor of Engineering Physics
B.S., M.S., Ph.D., The Ohio State University

BULUTOGLU, DURSUN A.
Associate Professor of Statistics
B.S., University of Maryland, College Park; M.A., Ph.D., University of California, Berkeley

BURGGRAF, LARRY W.
Professor of Chemical and Engineering Physics
B.S., Olivet Nazarene; M.S., The Ohio State University; M.A., University of West Florida; Ph.D., University of Denver

BURGI, KENNETH W. MAJ
Assistant Professor of Optical Engineering
B.S., M.S., Michigan Technological University; Ph.D., Air Force Institute of Technology

BUTLER, SAMUEL D. MAJ
Assistant Professor of Physics
B.S., Brigham Young University; M.S., Ph.D., Air Force Institute of Technology

CAIN, STEPHEN C.
Associate Professor of Electrical Engineering
B.S., University of Notre Dame; M.S., Michigan Technological University; Ph.D., University of Dayton

CANCIONI, AARON J. CAPT
Assistant Professor of Electrical Engineering
B.S., Air Force Academy; M.S., Ph.D., Air Force Institute of Technology

CASEY, DANIEL J. M.
Assistant Professor of Computer Science
B.S., United States Air Force Academy; M.S., Southern Methodist University; Ph.D., Air Force Institute of Technology

CAYLOR, MICHAEL J.
Research Assistant Professor of Engineering Physics
B.S., M.S., Ph.D., University of Notre Dame; M.S., Florida Institute of Technology

CHAMPAGNE, LANCE E.
Assistant Professor Operations Research
B.S., Tulane University; M.S., Ph.D., Air Force Institute of Technology

CHANDRAHALIM, HENGKY
Assistant Professor of Electrical Engineering
B.S., Ohio State University; M.E., M.S., Ph.D., Cornell University

CLINTON, JUSTIN A.
Assistant Professor of Nuclear Engineering
B.S., Ph.D., Rensselaer Polytechnic Institute

COBB, RICHARD G.
Professor of Aerospace Engineering
B.S., Pennsylvania State University; M.S., Ph.D., Air Force Institute of Technology

COLLINS, PETER J.
Professor of Electrical Engineering
B.S., Bethel College; M.S., The University of Minnesota; Ph.D., Air Force Institute of Technology
COLOMBI, JOHN M.
Associate Professor of Systems Engineering
B.S., University of Lowell; M.S., Ph.D., Air Force Institute of Technology

COX, AMY LT COL
Assistant Professor of Systems Engineering
A.A., Defense Language Institute; B.S., University of Cincinnati; M.S., Air Force Institute of Technology; Ph.D., The George Washington University

COX, BRUCE A. LT COL
Assistant Professor of Operations Research
B.S., Worcester Polytechnic Institute; M.S., Virginia Commonwealth University; Ph.D., Georgia Institute of Technology

CROWE, DARRELL S. MAJ
Assistant Professor of Aerospace Engineering
B.S., Texas A&M University; M.S., Ph.D., Air Force Institute of Technology

CUNNINGHAM, WILLIAM A.
Professor of Logistics and Supply Chain Management
B.S.B.A., Missouri Southern University; M.S., Oklahoma State University; Ph.D., University of Arkansas

CURRO, JOSEPH A. CAPT
Assistant Professor of Electrical Engineering
B.S., Clarkson University; M.S., Ph.D., Air Force Institute of Technology

DECKRO, RICHARD F.
Professor of Operations Research
B.S., University at Buffalo; M.B.A., D.B.A., Kent State University

DEXTER, MICHAEL L. MAJ
Assistant Professor of Nuclear Engineering
B.S., University of Nebraska at Omaha; M.S., Ph.D., Air Force Institute of Technology

DEYOUNG, MARK E. MAJ
Assistant Professor of Computer Engineering
B.S., M.S., Ph.D., Virginia Tech

DRYLIE, SCOTT T. MAJ
Assistant Professor of Cost Analysis
B.S., Montana State University; M.S., Air Force Institute of Technology; Ph.D., George Mason University

DUAN, XIAOFENG FRANK
Adjunct Associate Professor of Physics
B.S., M.S., Sichuan University; Ph.D., Southern Illinois University

EISMANN, MICHAEL T.
Adjunct Assistant Professor of Engineering Physics
B.S., Thomas More College; M.S., Georgia Institute of Technology; Ph.D., University of Dayton

ELSHAW, JOHN J.
Assistant Professor of Systems Engineering
B.S., University of Akron; M.B.A., Regis University; Ph.D., Purdue University

EMMONS, DANIEL J. II, MAJ
Assistant Professor of Physics
B.S., San Diego State University; M.S., Ph.D., Air Force Institute of Technology

ENINGER, ROBERT M. LT COL
Assistant Professor of Industrial Hygiene
B.S., United States Air Force Academy; M.S., University of Texas; M.S., Purdue University; Ph.D., University of Cincinnati

FASS, R. DAVID
Assistant Professor of Systems Integration and Cost Analysis
B.A., University of New Mexico; M.B.A., University of New Mexico; Ph.D., New Mexico State University

FERDINANDUS, MANUEL R. MAJ
Assistant Professor of Optics
B.S., Seattle University; M.S., Rochester Institute of Technology; Ph.D., University of Central Florida
FICKUS, MATTHEW C.
Professor of Mathematics
B.S., M.S., University of Maryland, Baltimore County; Ph.D., University of Maryland, College Park

GAY, CHRISTOPHER A. LT COL
Assistant Professor of Systems Engineering
B.S., Delta State University; M.S., Naval Postgraduate School; Ph.D., University of Virginia

FIORINO, STEVEN T.
Associate Professor of Atmospheric Physics
B.S., Ph.D., The Florida State University; B.S., M.S., The Ohio State University

GEYER, ANDREW J. LT COL
Deputy Department Head and Assistant Professor of Statistics
B.S., North Dakota State University; M.S., Ph.D., Air Force Institute of Technology

FORD, THOMAS C.
Assistant Professor of Systems Engineering
B.S., Brigham Young University; M.S., Wright State University; Ph.D., Air Force Institute of Technology

GILES, NANCY C.
Professor of Physics
B.S., The University of North Carolina at Chapel Hill; Ph.D., North Carolina State University

FRANKE, MILTON E.
Professor Emeritus of Aerospace Engineering
B.M.E., University of Florida; M.S.M.E., University of Minnesota; Ph.D., The Ohio State University

GOLTZ, MARK N.
Professor Emeritus
B.S., Cornell University; M.S., University of California Berkley; Ph.D., Stanford University

FRANZ, ANTHONY L. LT COL
Assistant Professor of Physics
B.S., United States Air Force Academy; M.S., Air Force Institute of Technology; Ph.D., University of Illinois at Urbana-Champaign

GRAHAM, SCOTT R.
Assistant Professor of Computer Engineering
B.S., Brigham Young University; M.S., Air Force Institute of Technology; Ph.D., University of Illinois at Urbana-Champaign

FREELS, JASON K. MAJ
Assistant Professor of Systems Engineering
B.S., Auburn University; M.S., Air Force Institute of Technology; Ph.D., Texas A&M University

GREENDYKE, ROBERT, B.
Associate Professor of Aerospace Engineering
B.B.A., Baylor University; B.S., M.S., Ph.D., Texas A&M University

FREEMAN, JACOB A. LT COL
Assistant Professor of Systems Engineering
B.S., Brigham Young University; M.S., Air Force Institute of Technology; Ph.D., Virginia Tech

GRIMAILA, MICHAEL R.
Professor of Systems Engineering and Department Head
B.S., M.S., Ph.D., Texas A&M University

GROSS, KEVIN C.
Associate Professor of Engineering Physics
B.S., M.S., Wright State University; Ph.D., Air Force Institute of Technology

GUNAWARDENA, SANJEEV
Research Assistant Professor of Electrical Engineering
B.S., B.S.E.E., M.S.E.E., Ph.D., Ohio University
HARPER, WILLIE F. JR.  
*Professor of Environmental Engineering and Science*  
B.S., University of California, Los Angeles;  
M.ENG., Cornell University; Ph.D., University of California, Berkeley

HARTSFIELD, CARL  
*Assistant Professor of Aerospace Engineering*  
B.S., Georgia Institute of Technology; M.S., Air Force Institute of Technology; Ph.D., Naval Post Graduate School

HAVRILLA, MICHAEL J.  
*Professor of Electrical Engineering*  
B.S., M.S., Ph.D., Michigan State University

HAWKS, MICHAEL R.  
*Research Assistant Professor of Engineering Physics*  
B.S., Michigan State University; M.S., Ph.D., Air Force Institute of Technology

HAZEN, BENJAMIN T. MAJ  
*Associate Professor of Logistics and Supply Chain Management*  
B.S., Colorado Christian University; M.A., Gonzaga University; M.B.A., California State University; Ph.D., Auburn University

HENGGEHOLD, ROBERT L.  
*Professor Emeritus of Physics*  
B.A., Thomas More College; M.S., Ph.D., University of Cincinnati

HERR, NICHOLAS C. MAJ  
*Assistant Professor of Material Science*  
B.S., United States Air Force Academy; M.S., Ph.D., Air Force Institute of Technology

HESS, JOSHUAH A. CAPT  
*Assistant Professor of Aerospace Engineering*  
B.S., Virginia Polytechnic and State University;  
M.S., Ph.D., Air Force Institute of Technology

HILL, RAYMOND R.  
*Professor of Operations Research*  
B.S., Eastern Connecticut State University;  
M.S., Air Force Institute of Technology; Ph.D., The Ohio State University

HOBBS, EDWARD L. LT COL  
*Assistant Professor of Nuclear Engineering*  
B.S., East Central University; M.S., Air Force Institute of Technology; Ph.D., University of New Mexico

HODSON, DOUGLAS D  
*Associate Professor of Computer Engineering*  
B.S., Wright State University; M.S., M.B.A., University of Dayton; Ph.D. Air Force Institute of Technology

HOGSED, MICHAEL R. LT COL  
*Assistant Professor of Engineering Physics*  
B.S., Baylor University; M.S., Oklahoma State University; Ph.D., Air Force Institute of Technology

HOISINGTON, ANDREW J. LT COL  
*Assistant Professor of Environmental Engineering*  
B.S., The University of Michigan; M.S., Ph.D., The University of Texas

HOPKINS, FRANK K.  
*Adjunct Professor of Electrical Engineering*  
B.S., Northern Kentucky University; M.S., Ph.D., University of Cincinnati

HOPKINSON, KENNETH M.  
*Professor of Computer Science, Interim Department Head*  
B.S., Rensselaer Polytechnic Institute; M.S., Ph.D., Cornell University

JACKSON, JULIE A.  
*Associate Professor of Electrical Engineering*  
B.S., Wright State University; M.S., Ph.D., Ohio State University
JACQUES, DAVID R.  
Professor of Systems Engineering  
B.S., Lehigh University; M.S., Ph.D., Air Force Institute of Technology

JOHNSON, ALAN W.  
Professor of Logistics and Supply Chain Management  
B.S., Montana State University; M.S., Air Force Institute of Technology; Ph.D., Virginia Polytechnic Institute and State University

JOHNSON, KIRK W. LT COL  
Assistant Professor of Aerospace Engineering  
B.S., Worcester Polytechnic Institute; M.S., Air Force Institute of Technology; Ph.D., Texas A&M University

JOO, SEONG-JONG  
Associate Professor of Logistics and Supply Chain Management  
B.S., Korea Air Force Academy; M.B.A., Saint Louis University; Ph.D., Saint Louis University

JORDAN, JEREMY D. LT COL  
Assistant Professor of Statistics  
B.A., Aurora University; M.S., Ph.D., Air Force Institute of Technology

KEDZIORA, GARY S.  
Adjunct Assistant Professor of Physics  
B.S., University of Minnesota; Ph.D., The Ohio State University

KELLY, TONY D.  
Adjunct Assistant Professor of Nuclear Engineering  
B.S., California State University; M.S., University of Nebraska-Lincoln; Ph.D., Air Force Institute of Technology

KOMIVES, JEFFREY MAJ  
Assistant Professor of Aerospace Engineering  
B.S., Purdue University; M.S., Air Force Institute of Technology; Ph.D., University of Minnesota

KOSCHNICK, CLAY LT COL  
Assistant Professor of Systems Engineering  
B.S., United States Air Force Academy; M.S., Georgia Institute of Technology; Ph.D., University of Florida

KUNZ, DONALD L.  
Professor of Aerospace Engineering  
B.S., Syracuse University; M.S., Ph.D., Georgia Institute of Technology

LAIR, ALAN V.  
Department Head and Professor of Mathematics  
B.A., North Texas State University; M.S., Ph.D., Texas Tech University

LAMONT, GARY B.  
Professor of Electrical and Computer Engineering  
B.S., M.S., Ph.D., University of Minnesota Institute of Technology

LANGHALS, BREN T.  
Assistant Professor of Information Resource Management  
B.S., United States Air Force Academy; M.S., Air Force Institute of Technology; Ph.D., University of Arizona

LAURVICK, TOD V. MAJ  
Assistant Professor of Electrical Engineering  
B.S., Michigan Technological University; M.S., Ph.D., Air Force Institute of Technology

LEISHMAN, ROBERT C.  
Research Assistant and Professor of Autonomy  
B.S., Utah State University; M.S., Ph.D., Brigham Young University

LEWIS, C. DAVID II, MAJ  
Adjunct Assistant Professor of Physics  
B.S., B.A., Duke University; M.S., Ph.D., Air Force Institute of Technology

LEWIS, DOUGLAS R.  
Adjunct Assistant Professor of Biodefense  
B.S., United States Air Force Academy; M.S., Pennsylvania State University; Ph.D., George Mason University
LIEBST, BRADLEY S.  
*Professor and Head, Department of Aeronautics and Astronautics*
B.S., Wichita State University; M.S., Ph.D., Massachusetts Institute of Technology

LIEVSAY, JAMES R. MAJ  
*Assistant Professor of Electrical Engineering*
B.S., United States Air Force Academy; M.S., Air Force Institute of Technology; Ph.D., University of Oklahoma

LINGENFELTER, ANDREW J. CAPT  
*Assistant Professor of Aerospace Engineering*
B.S., University of Nebraska – Lincoln; M.S., University of Florida; Ph.D., Air Force Institute of Technology

LONG, DAVID S.  
*Assistant Professor of Systems Engineering*
B.S., North Dakota State University; M.S., California State University, Northridge; Ph.D., Massachusetts Institute of Technology

LOPER, ROBERT D. JR.  
*Assistant Professor of Physics*
B.S., University of Dayton; M.S., University of Texas at Dallas; M.T.S., United Theological Seminary; Ph.D., Air Force Institute of Technology

LUNDAY, BRIAN J  
*Associate Professor of Operations Research*
B.S., United States Military Academy; M.S., University of Arizona; Ph.D., Virginia Polytechnic Institute

LUTZ, JESSE J.  
*Research Assistant Professor of Chemistry*
B.S., Grand Valley State University; Ph.D., Michigan State University

MAGNUS, AMY L.  
*Research Assistant Professor of Mathematics*
B.S., Rochester Institute of Technology; M.S., Ph.D., Air Force Institute of Technology

MARCIKAH, MICHAEL A.  
*Professor of Physics*
B.S., St. Joseph’s College; B.S.E.E., University of Missouri-Columbia; M.S.E.E., Ph.D., Air Force Institute of Technology

MARTIN, RICHARD K.  
*Professor of Electrical Engineering*
B.S., University of Maryland; M.S., College Park; Ph.D., Cornell University

MATHEWS, KIRK A.  
*Professor Emeritus of Nuclear Engineering*
B.S., California Institute of Technology; M.S., Ph.D., Air Force Institute of Technology

MCELWAINE, ERIC G.  
*Assistant Professor of Environmental Engineering*
B.S., Kigali Institute of Science and Technology; M.S., University of Missouri-Columbia; Ph.D., Purdue University

MCCLORY, JOHN W.  
*Associate Professor of Nuclear Engineering*
B.S., Rensselaer Polytechnic Institute; M.S., Texas A &M University; Ph.D., Air Force Institute of Technology

MCCRAE, JACK E.  
*Research Assistant Professor of Engineering Physics*
B.S., Massachusetts Institute of Technology; M.S., Ph.D., Air Force Institute of Technology

MEOLA, JOSEPH  
*Adjunct Assistant Professor of Engineering Physics*
B.S., M.S., University of Dayton; Ph.D., The Ohio State University

MERKE, LAURENCE D.  
*Assistant Professor of Computer Science*
B.S., Rensselaer Polytechnic Institute; M.S., Ph.D., Air Force Institute of Technology
MEYER, DAVID W.  
*Adjunct Assistant Professor*  
B. S., The Ohio State University; M.S., Naval Postgraduate School

MILLER, MICHAEL E.  
*Associate Professor of Systems Integration*  
B.S., M.S., Ohio University; Ph.D., Virginia Polytechnic Institute and State University

MILLS, ROBERT F.  
*Professor of Electrical Engineering*  
B. S., Montana State University; M. S., Air Force Institute of Technology; Ph.D., University of Kansas

MORRILL, DANA F., MAJ  
*Assistant Professor of Mathematics*  
B.S., Weber State University; M.S., Ph.D., Air Force Institute of Technology

MULLINS, BARRY E.  
*Professor of Computer Engineering*  
B.S., M.S., Ph.D., Virginia Polytechnic Institute and State University

NAVA, OMAR A. MAJ  
*Assistant Professor of Atmospheric Science*  
B.S., United States Air Force Academy; B.S., Naval Postgraduate School; M.S., Southern Methodist University; M.S., Air Force Institute of Technology; Ph.D., University of California Los Angeles

NUNNALLY, BEAU A., MAJ  
*Assistant Professor of Statistics*  
B.S., Virginia Tech; M.S., Ph.D., Air Force Institute of Technology

NYKL, SCOTT L.  
*Assistant Professor of Computer Science*  
B.S., University of Wisconsin-Platteville; M.S., Ph.D., Ohio University

O’DAY, BUCKLEY E. COL  
*Adjunct Assistant Professor of Nuclear Engineering*  
B.S., United States Military Academy; M.I.M., University of Maryland University College; M.S., Air Force Institute of Technology; Ph.D., Massachusetts Institute of Technology

OXLEY, MARK E.  
*Professor of Mathematics*  
B.S., Cumberland College; M.S., Purdue University; Ph.D., North Carolina State University

PACHTER, MEIR N.  
*Professor of Electrical Engineering*  
B.S., M.S., Ph.D., Israel Institute of Technology

PALAZOTTO, ANTHONY N.  
*Distinguished Professor Aerospace Engineering*  
B.S., New York University; M.S., Brooklyn Polytechnic Institute; Ph.D., New York University

PERRAM, GLEN P.  
*Professor of Physics*  
B.S., Cornell University; M.S., Ph.D., Air Force Institute of Technology

PETERSON, GILBERT L.  
*Professor of Computer Engineering*  
B.S., M.S., Ph.D., University of Texas at Arlington

PETROSKY, JAMES C.  
*Professor of Nuclear Engineering*  
B.A., Millersville University of Pennsylvania; M.S., Ph.D., Rensselaer Polytechnic Institute

PIERCE, SCOTT J. MAJ,  
*Assistant Professor of Electrical Engineering*  
B.S.E.E., Brigham Young University; M.S.E.E., Ph.D., Air Force Institute of Technology

PITZ, GREGORY A.  
*Adjunct Assistant Professor of Applied Physics*  
B.S., M.S., Wright State University; Ph.D., Air Force Institute of Technology
POLANKA, MARC D.  
Professor of Aerospace Engineering  
B.S., University of Dayton; M.S., Stanford University; Ph.D., University of Texas

QUINN, DENNIS W.  
Professor Emeritus of Mathematics  
B.S., M.S., Ph.D., University of Delaware

RAQUET, JOHN F.  
Professor of Electrical Engineering  
B.S., United States Air Force Academy; M.S., Massachusetts Institute of Technology; Ph.D., University of Calgary

REEDER, MARK F.  
Professor of Aerospace Engineering  
B.S., West Virginia University; M.S., Ph.D., The Ohio State University

REITH, MARK G. LT COL  
Assistant Professor of Computer Science  
B.S., University of Portland; M.S., Air Force Institute of Technology; Ph.D., University of Texas at San Antonio

REYNOLDS, DANIEL E.  
Assistant Professor Emeritus of Statistics  
B.A., University of Rochester; M.S., Air Force Institute of Technology; M.S., Wright State University

RICE, CHRISTOPHER A.  
Research Assistant Professor of Engineering Physics  
B.S., Cedarville University; M.S., Ph.D., Air Force Institute of Technology

RIES, HEIDI R.  
Dean for Research and Professor of Physics  
B.S., M.S., The Ohio State University; Ph.D., Old Dominion University

RITSCHEL, JONATHAN D.  
Assistant Professor of Cost Analysis  
B.B.A., University of Notre Dame; M.S., Air Force Institute of Technology; Ph.D., George Mason University

RUGGLES-WREN, MARINA B.  
Professor of Aerospace Engineering  
B.S., Polytechnic Institute of New York; M.S., Ph.D., Rensselaer Polytechnic Institute

RUSNOCK, CHRISTINA F. MAJ  
Adjunct Associate Professor of Systems Engineering  
B.A., Claremont McKenna College; M.S., Air Force Institute of Technology; M.S., Ph.D., University of Central Florida

RUTLEDGE, JAMES L. LT COL  
Associate Professor of Aerospace Engineering  
B.S., M.S., University of Texas at Austin; Ph.D., Air Force Institute of Technology

SCHUBERT KABBAN, CHRISTINE M.  
Associate Professor of Statistics  
B.S., University of Dayton; M.B.A., M.S., Wright State University; Ph.D., Air Force Institute of Technology

SHATTAN, MICHAEL B. LT COL  
Assistant Professor of Nuclear Engineering  
B.S., United States Military Academy; M.S., Massachusetts Institute of Technology; Ph.D., University of Tennessee

SCHULDT, STEVEN J. MAJ  
Assistant Professor of Engineering Management  
B.S., University of Illinois; M.S., Air Force Institute of Technology; Ph.D., University of Illinois

SLAGLEY, JEREMY M.  
Assistant Professor of Industrial Hygiene and Environmental Sciences  
B.S., United States Military Academy; M.S., University of Iowa; Ph.D., West Virginia University

SPENCER, MARK  
Adjunct Assistant Professor of Optical Sciences and Engineering  
B.S., University of Redlands; M.S., Ph.D., Air Force Institute of Technology
STEWARD, BRYAN J.
Research Assistant Professor of Optical Engineering
B.S., University of Arizona; M.S., Ph.D., Air Force Institute of Technology

STUBBS, JOHN F. LT COL
Assistant Professor of Environmental Engineering and Sciences
B.S., North Carolina State University; M.S., Ph.D., Air Force Institute of Technology

TEMPLE, MICHAEL A.
Professor of Electrical Engineering
B.S., Southern Illinois University-Edwardsville; M.S.E., SIUE., Ph.D., Air Force Institute of Technology

TERZUOLI, ANDREW J. JR.
Associate Professor of Electrical Engineering
B.S., Polytechnic Institute of Brooklyn; M.S., Massachusetts Institute of Technology; Ph.D., Ohio State University

THAL, ALFRED E. JR.
Associate Professor of Engineering Management
B.S., Texas Tech University; M.S., Air Force Institute of Technology; Ph.D., University of Oklahoma

THOMAS, LEVI M. MAJ
Assistant Professor of Aerospace Engineering
B.S., United States Air Force Academy; M.S., Air Force Institute of Technology; A.A., Defense Language Institute; Ph.D., Purdue University

TORVIK, PETER J.
Professor Emeritus of Aerospace Engineering and Engineering Mechanics
B.A., Wright State University; B.S., M.S., Ph.D., University of Minnesota

TOURNAY, ROBERT C. LT COL
Assistant Professor of Atmospheric Science
B.S., University of Maryland; M.S., Naval Postgraduate School; Ph.D., Colorado State University

TSENG, H. ROSE MAJ
Assistant Professor Atmospheric Science
B.S., Ph.D., University of California- Los Angeles; M.S., M.S., Naval Postgraduate School

TUTTLE, RONALD F.
Associate Professor of Engineering Physics
B.S., M.S., Ph.D., University of Missouri

UBER, RICHARD P. CAPT
Assistant Professor of Mathematics
B.G.S., University of Nebraska Omaha; M.S., Texas A&M University; Ph.D., Air Force Institute of Technology

WAGNER, TORREY J. LT COL
Assistant Professor of Systems Engineering
B.S., University of Minnesota; M.S., Loughborough University; Ph.D., Air Force Institute of Technology

WALKER, MICHAEL M. MAJ
Assistant Professor of Aerospace Engineering
B.S., United States Air Force Academy; M.S., Air Force Institute of Technology; M.B.A., Amberton University; Ph.D., The Ohio State University

WEEKS, DAVID E.
Professor of Physics
B.A., Colgate University; M.S., Georgia Institute of Technology; Ph.D., University of Arkansas

WHITE, EDWARD D. III
Professor of Statistics
B.S., University of Tampa; M.A.S., Ohio State University; Ph.D., Texas A&M University

WIESEL, WILLIAM E. JR.
Professor of Astronautical Engineering
B.S., University of Massachusetts; M.S., Ph.D., Harvard University

WILSON, TERRY
Adjunct Assistant Professor
B.S., University of Florida; M.S., Ph.D., Air Force Institute of Technology
WOLF, PAUL J.
Associate Dean of Academic Affairs
B.S., Regis College; M.S., Ph.D., Air Force Institute of Technology

WOOD, AIHUNA W.
Professor of Mathematics
B.S., Peking University; M.S., Ph.D., University of Connecticut