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AIR FORCE INSTITUTE OF TECHNOLOGY

GRADUATE SCHOOL OF ENGINEERING AND MANAGEMENT

Wright-Patterson Air Force Base, Ohio

AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

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PREFACE

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 five of these program areas and Doctoral studies in any area of departmental activity. The Master of Science programs in Aeronautical Engineering, 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.

This brochure provides an introduction to the Department of Aeronautics and Astronautics, Air Force Institute of Technology. It is intended to serve as a guide for students and faculty advisors in the preparation of education plans for graduate study in Aeronautical Engineering, Astronautical Engineering, Materials Science, and Space Systems.

The requirements and curricula specified in this edition of the brochure apply to all full-time students and to all part-time students admitted to the Master level degree programs in Aeronautical Engineering (GAE), Astronautical Engineering (GA), Materials Science (GMS), and Space Systems (GSS) during the period of 1 May 2009 to 30 April 2010. Course descriptions and schedules are also provided in this brochure. Additional information on courses, programs, and admissions may be found in the AFIT catalog and the applicable department and program brochures.

Further questions regarding the departmental Master level degree programs should be referred to the Department of Aeronautics and Astronautics, AFIT/ENY, as indicated below:

Mail: AFIT/ENY
2950 HOBSON WAY
WRIGHT-PATTERSON AFB OH 45433-7765

Phone: Commercial (937) 255-3069 or DSN 785-3069

Office: Bldg 640, Room 346
(AFIT Graduate School of Engineering and Management)

CHAPTER 1: INTRODUCTION

The graduate program in Aeronautical Engineering initiated in September of 1951. Since the passage of Public Law 733 by the 83rd Congress (1954), degrees have been authorized for conferral by the Commander of Air University on persons who meet all requirements established by the Air Force Institute of Technology. Programs within the Institute were first accredited by the Engineer's Council for Professional Development (ECPD) in 1955. The North Central Association of Colleges and Schools now accredits the Institute through the doctoral level. The Graduate School of Engineering and Management's program in Graduate Systems Engineering was the first one in the country that was accredited at the advanced level by the Accreditation Board for Engineering and Technology (ABET, formerly ECPD). Programs in Graduate Astronautical Engineering and in Graduate Aeronautical Engineering are also accredited by ABET. The programs in Graduate Space Systems and Materials Science are accredited through the North Central Association of Colleges and Schools.

At one time, the resident School of Engineering contained the Department of Mechanical Engineering, the Department of Aeronautical Engineering, and the Mechanics Department. In 1969, these were reorganized in two departments: the Aero-Mechanical Department, which gave emphasis to various aspects of the mechanics of fluids (e.g., aerodynamics, heat transfer, propulsion, and fluidics) and the Department of Mechanics, which gave emphasis to solid mechanics, aircraft structures, astrodynamics, and flight vehicle mechanics. A system engineering activity was added to the Department of Mechanics in the 1970s. In 1977, these two departments were merged into the present single entity. This placed administrative control for three related curricula in aeronautics, astronautics, and systems engineering in the single department. In 1995, responsibility for the Space Operations Program was transferred to the department. In 2001, the department added the Aerospace and Information Operations Program. In 2002, a decision was made by the SECAF and the SECNAV to close the Aeronautical Engineering Department of the Naval Post Graduate School and begin sending all naval officers that require graduate education in aeronautical engineering to AFIT. The first naval officers to participate in that program took courses in winter 2003. In 2002, a decision was made by SECAF and CSAF to send some Air Force majors selected as candidates for intermediate service school to AFIT for a masters degree and professional military education in-residence credit. Therefore, the Department of Aeronautics and Astronautics has developed a new graduate program in systems engineering (with specializations in Airborne Systems, C4ISR Systems, and Space Systems) to accommodate the Intermediate Development Education (IDE) (formerly Intermediate Service School) students. In 2003, the department combined the Space Operations and Aerospace with Information Operations Programs into Space Systems Program. In 2007, the Systems Engineering programs were transferred to the Dept of Systems and Engineering Management.

The programs of the resident Graduate School of Engineering and Management are a major factor in graduate education in aeronautical and astronautical engineering in the United States. This scale of operation enables students in the resident Graduate School of Engineering and Management to select from a wider variety of courses and research topics than would be available in smaller institutions. No programs leading to degrees in mechanical engineering or engineering mechanics are currently available, but students with interest in these disciplines may pursue them as a concentration within the Aeronautical Engineering Program.

The mission of the AFIT Department of Aeronautics and Astronautics is to provide high-quality aerospace graduate education and to conduct world-class defense focused research. The vision of the department is to achieve national recognition as the premier aerospace engineering department for producing defense-focused graduates and research.

Three major areas of expertise can be identified within the Department. These are: (1) Fluid Mechanics and Energy Transmission, (2) Solid Mechanics and Structures, and (3) Dynamics, Systems, and Controls.

(1) The Fluid Mechanics and Energy Transmission Division provides courses and opportunities for research in aerodynamics, (compressible, incompressible, viscous and computational), propulsion (air-breathing, rocket, and non-chemical), and heat transfer (convection, conduction, and radiation).

(2) The Solid Mechanics and Structures Division provides course offerings and research programs covering such topics as applied mechanics (elasticity, plasticity, and continuum mechanics), structures (stability, shells, and finite element methods), structural dynamics (mechanical vibrations, wave propagation, and aeroelasticity), and structural materials (fracture mechanics, composite materials, and fatigue).

(3) The Dynamics, Systems, and Controls Division provides courses and research activities in aircraft flight mechanics (performance, stability, and control), astrodynamics (orbital mechanics and optimal trajectories) spacecraft attitude dynamics, systems (design and modeling of large scale systems, and weapons analysis), and robotics (manipulators, remote systems, and man-in-the-loop control).

As is true of the entire resident school, the faculty of the Department is approximately 50 percent military and 50 percent civilian. Approximately 10 percent of the AFIT students are officers from other services or allied countries or DoD civilians.

Full-time programs leading to the Master of Science degree are typically six quarters long. Each student entering the department is assigned a class advisor who provides counseling in the selection of courses and in research opportunities within the department. The student selects a research topic and thesis advisor in the 2nd quarter and from that point on is expected to work closely with that member of the faculty both in research and in finalizing the plan of study.

Part-time students seeking a Master’s degree are advised by a single member of the department to become a candidate in one of the degree programs and to select a thesis advisor. From that point on, the thesis advisor guides the thesis research and recommends courses for the student. In administrative matters, the class advisor oversees the progress of the student throughout the program.

An advisory committee is appointed to assist each doctoral student in planning a program of study and developing a research area.

Each curriculum within the department is developed, monitored, and evaluated by a curriculum committee, selected by the department head. These committees provide the means for developing modifications in course offerings and research opportunities needed to support curricular requirements, and conversely, to provide the mechanism whereby developments in the sub-disciplines can be quickly reflected in curricular changes. The school and academic departments are headed by the dean of the Graduate School of Engineering and Management and the department heads, respectively. The academic departments are listed below along with their Master of Science (MS) degree programs:

Aeronautics and Astronautics (AFIT/ENY)
-- Graduate Aeronautical Engineering (GAE)
-- Graduate Astronautical Engineering (GA)
-- Graduate Materials Science (GMS - with ENP)
-- Graduate Space Systems (GSS)

Electrical and Computer Engineering (AFIT/ENG)
-- Graduate Computer Engineering (GCE)
-- Graduate Computer Systems (GCS)
-- Graduate Electrical Engineering (GE)
-- Graduate Electro-Optics (GEO - with ENP)

Engineering Physics (AFIT/ENP)
-- Graduate Applied Physics (GAP)
-- Graduate Electro-Optics (GEO - with ENG)
-- Graduate Nuclear Engineering (GNE)
-- Graduate Materials Science (GMS - with ENY)

Mathematics and Statistics (AFIT/ENC)
-- Graduate Applied Mathematics (GAM)

Operational Sciences (AFIT/ENS)
-- Graduate Operations Research (GOR)
-- Graduate Logistics Management (GLM)
-- Graduate Mobility Management (GMO)

Systems and Engineering Management (AFIT/ENV)
-- Graduate Cost Analysis (GCA)
-- Graduate Engineering Management (GEM)
-- Graduate Environmental Engineering and Science (GES)
-- Graduate Information Resource/Systems Management (GIS/GIR)
-- Graduate Strategic Purchasing (GSP)
-- Graduate Systems Management (GSM)
-- Graduate Systems Engineering (GSE)

Administrative processes for the institute are provided in AFIT Instructions (AFIT-I). Processes specific to the Graduate School of Engineering and Management are laid out in a series of EN Operating Instructions (ENOI). These ENOIs cover a wide variety of topics in detail and are referenced in this document. The ENOIs are available on the AFIT Intranet.

CHAPTER 2: ADMISSION AND REGISTRATION PROCEDURES

2.1 Admission to AFIT

United States citizens wishing to attend graduate-level classes at AFIT, whether full-time or part time, must first be admitted to the Graduate School of Engineering and Management. General requirements for admission are explained in the AFIT Catalog and on the AFIT web page. The application itself can be completed on line at the AFIT web site, or by mailing the completed application form, available on line as a PDF file. With the exception of officers in selected foreign military service who are sponsored by their government, foreign nationals are not eligible to attend AFIT and will not be admitted.

Air Force personnel seeking an assignment to AFIT to obtain a graduate degree will be evaluated for eligibility only--the prospective officer student must also request assignment to AFIT through their assignment team at HQ AFPC; the prospective enlisted student must apply to HQ Air Staff. Sister Service members presently must also be evaluated for academic eligibility. All other qualified students will fall into one of the four following admission categories: unconditional admission as a degree-seeking student, conditional admission as a degree-seeking student; unconditional admission as a non-degree seeking student; conditional admission as a non-degree seeking student. Students who are conditionally admitted (either degree seeking or non-degree seeking) for academic reasons may have that condition removed at the discretion of the department. Students who are conditionally admitted due to missing admissions documents (normally transcripts and/or GRE scores) must resolve deficiencies by providing missing documents and become unconditionally admitted by the end of the first quarter of study. Students admitted in non-degree status may request a change of status and be fully admitted into a degree program. Consult the AFIT Catalog for details.

Students may transfer up to 12 credit hours of graduate credit from other accredited institutions. These 12 hours of credit may consist of courses taken before, during, or after residence at the graduate school, but may not include any course submitted for any other degree. All courses transferred must carry a “B” or better, and a thesis written under the direction of another school may not be transferred. The faculty advisor, the department head, and the Academic Standards Committee must approve transfer credits. 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. EN Operating Instruction 36-104 has additional information.

Students admitted in non-degree status may request a change of status and be fully admitted into a degree program. Students seeking a change of status must meet all the requirements of the program they wish to enter. A maximum of 12 credit hours earned while in non-degree seeking status can be applied to a degree program.

Admission to the Graduate School of Engineering and Management does not guarantee admission to a specific degree program within the Department of Aeronautics and Astronautics.

Additional requirements for admission to specific programs are described in the next section.

2.2 Department of Aeronautics and Astronautics Program Admission Requirements

The general requirements for admission to graduate programs within the Department of Aeronautics and Astronautics are as follows:

a. An ABET-accredited degree with appropriate major (except for the space systems program). Students with other prior degrees will be evaluated individually. A few students with other prior degrees, but with 36 credits in the engineering sciences and design, are approved each year for admission to graduate study in aeronautical and astronautical engineering.

b. A cumulative GPA of 3.0 (on a 4.0-point basis) in that degree. Students who do not meet this requirement will be considered on an individual basis. In general, students who have a GPA above 2.8 and a “B” average on the critical upper division engineering science courses may expect to be admitted. Applicants for graduate work in astronautical or systems engineering are expected to have a "B" average in all mathematics attempted, beginning with the calculus.

c. Minimum scores on the GRE of 500 (verbal) and 600 (quantitative) are a requirement for admission to any of the graduate programs of the Graduate School of Engineering and Management. The Department may waive this requirement, but applicants should be aware that those admitted each year to the Department of Aeronautics and Astronautics have average GRE scores above the national averages for aeronautical engineers. Applicants are also encouraged to take the advanced test in engineering. An above average score may offset marginal grades.

d. Entrance to the graduate Aeronautical or Astronautical Engineering Programs requires a baccalaureate degree, which contains at least one course each in statics, dynamics, mechanics of materials, fluid mechanics, thermodynamics, circuits, a capstone design course, and suitable laboratory experience in the application of engineering principles. The applicant must also have 48 hours in mathematics (through differential equations) and basic science; one year of calculus-based physics; a course in chemistry and a course in computer programming. Normally, entrants will have a prior ABET-accredited degree in aerospace or mechanical engineering, or in engineering mechanics. Exceptions are made, however, subject to the above. For example, prior work in civil or materials engineering may qualify for a concentration in structures; prior study of chemical engineering may qualify for a program in propulsion; and students with degrees in electrical engineering may wish to concentrate in flight mechanics and controls. A student who lacks an ABET-accredited engineering degree will be admitted only if a review of records shows that all deficiencies can be removed including any deficiencies in the humanities and social sciences.

e. The Graduate Materials Science Program requires applicants to have an undergraduate degree in an engineering discipline or the physical sciences.

f. The Space Systems Program is much more interdisciplinary in nature than the other programs, and does not require an undergraduate engineering degree. A prospective student’s undergraduate program should include three quarters of calculus-based physics, and mathematics including calculus and differential equations.

2.3 Part-Time Master's Degree Program

It is possible to earn an MS degree as a part-time student (course load less than 12-quarter hours per quarter). After admission in degree-seeking status and successful completion of 12 credit hours within the Graduate School of Engineering and Management, the student may apply in writing for candidacy in a graduate program (ref. ENOI 36-134). The request for candidacy must include an approved education plan, developed with the aid of the student's academic advisor. The student should apply for candidacy at least one year prior to graduation.

After admission to candidacy, the part-time student must complete at least eight-quarter hours of graduate credit in four consecutive quarters. This requirement must be reflected on the education plan, which will be reviewed annually by the department. All academic work taken to fulfill program requirements, including transfer courses, must be completed within 26 consecutive quarters (6 1/2 years).

2.4 Course Registration and Credit

Students are responsible for registering for classes. A normal course load for degree-seeking students attending AFIT full-time is 12 to 16 quarter hours. Non-degree-seeking students will typically register for no more than eight-quarter hours.

Registration for all students is accomplished during the open registration period, which normally begins by Monday of the third week of the quarter preceding the course offering, and extending to Friday of the first week of the quarter in which the course is offered. Students will receive various notifications advising them of registration dates. Registration is accomplished on line by logging onto WebAdvisor and entering their courses through the registration screen. Students who do not have access to WebAdvisor must complete the AFIT Drop/Add Request Form. This form is available in the ENY office, on-line, and the Registrar's Office. Students are responsible for resolving all resultant scheduling conflicts and ensuring that they have the approval of their academic advisor.

Once a quarter begins, the student can drop courses only by submitting a properly completed Drop/Add Request Form to the Registrar's Office. Students may drop courses through week two of the quarter without academic record. Any student who drops a course during week three through the end of week five will receive the grade of "W". Students dropping courses week six through the end of week seven will receive a grade of “WP” or “WF”.

CHAPTER 3: DEGREE AND ABET REQUIREMENTS

3.1 General MS Degree Requirements

All of the MS degrees offered under the GA/GAE/GMS/GSS programs must adhere to the general requirements for the MS degree established by the AFIT Graduate School of Engineering and Management. A summary of these requirements follows. For more complete information and for the final authority on these requirements, the reader should consult Graduate School of Engineering and Management Operating Instructions (ENOI) 36-135, “Requirements for the Master of Science Degree,” and ENOI 36-135, “Degree Requirements for Two Masters' Degrees.” The 6-quarter MS program normally includes a minimum of 72-quarter hours. The requirement for 72 hours may be waived only by approval of the department head and the dean. The general MS requirements are:

(1) Up to 12-quarter hours of graduate course work with a grade of "B" or better may be transferred in accordance with ENOI 36-104.

(2) The minimum residence requirement is three quarters as a full-time student (ENOI 36-135).

(3) The student must have attained a grade point average of at least 3.0 for all graded courses included in the student's approved program. At least 36 of the quarter hours of courses submitted for the degree must have been completed in residence (ENOI 36-135).

(4) As part of graduate credit for the GA/GAE/GMS/GSS degrees, the student must complete 12 credit hours of thesis research. The results of this research must be reported in an oral presentation and in a written document. A thesis grade of "C-" or better is required (ENOI 36-104, ENOI 36-135). (GSS students see note at the end of Chapter 3 concerning "Thesis".)

(5) The 48 hours of graduate credit for the degree must satisfy the applicable program requirements. See Chapter 4 and/or Appendix G for program requirements.

(6) Degree requirements must be met within five years after the graduation of the student's class section (ENOI 36-135).

(7) No student is considered to have satisfactorily completed an approved program if there is an unresolved grade of "U," "F" or "I" in any course (ENOI 36-104).

(8) The student must be recommended for the degree by the Faculty Council of the Graduate School of Engineering and Management before the degree will be awarded (ENOI 36-135).

3.2 ABET Requirements

The Graduate Aeronautical Engineering (GAE) and Graduate Astronautical Engineering (GA) Degree Programs at AFIT are accredited at the basic level by the Accreditation Board of

Engineering and Technology (ABET). Students requesting the degree of Master of Science in one of these programs must satisfy all ABET curriculum requirements at this basic level. This requires that the student either enter the program with an accredited aeronautical or astronautical degree, or supplement his/her AFIT degree program with the course work necessary to fulfill the ABET requirements. Basic criteria include 48-quarter hours of mathematics and basic science, 72-quarter hours of engineering topics including 24-quarter hours of engineering design, and 24-quarter hours of humanities and social sciences. Hours taken in these areas as part of an under-graduate program will be credited against these requirements.

The Graduate Space Systems (GSS) Degree Program was developed to meet the needs of the Air Force for managers who could analyze space-related systems and make informed decisions on their development, use, and deployment. The North Central Association of Colleges and Schools accredits this program. This is a highly interdisciplinary program, including elements of astronautical engineering, systems engineering, operational analysis, and other branches of engineering and management. While the program is new enough that it does not yet have a "peer group" in the general technical community, the same standards of achievement and scholarship expected of any AFIT major are applied to the GSS program.

The Graduate Materials Science program (GMS) has not been ABET accredited.

NOTE: Students in the GSS program may have the opportunity to participate in a group design project in lieu of an individual thesis.

CHAPTER 4: PROGRAM GUIDE

4.1 Graduate Aeronautical Engineering (GAE)

Mission statement: *Produce graduates who are technically well prepared for their subsequent duties and responsibilities as aeronautical engineers in DoD organizations.*-

4.1.1 Introduction

The Graduate Aeronautical Engineering (GAE) program is a fully accredited program at AFIT leading to a Master of Science degree in Aeronautical Engineering. The GAE 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. Most students (Air Force and Navy quota as well as Air Force Test Pilot School (AFTPS)) enter as a class in September, fall quarter. Other students enter in quarters as shown in the table below. Program duration is program dependent and is shown in the table below. The courses are principally taught by the faculty of the Department of Aeronautics and Astronautics.

TYPICAL PROGRAM LENGTH FOR AERO PROGRAMS

Program	Length (mos.)	Start Qtr	Grad Qtr
AF Quota	18	Fall	Spring
AF TPS	15[1]	Fall/Winter	Winter/Summer
Navy Quota	18-24	Fall	Summer
Navy TPS	15 or 18[2]	Winter/Summer	Spring/Fall[2]
Navy IGEP[3]	12	Summer	Spring
Other (Civ., FNs, etc.)[4]	18-24	Fall (typical)	Varies

Notes:

1. Air Force Test Pilot School students complete 15 months in residence and graduate at the end of the winter/summer quarter following their one-year test pilot school program.

2. Navy Test Pilot School pilots complete 15 months in residence and graduate at the completion of their one-year test pilot program. Naval Flight Officers (NFO) complete 18 months in residence. Both the pilots and NFOs graduate after they complete their Navy test pilot school training program at the Navy Test Pilot School located in Patuxent River Maryland.

3. Navy Immediate Graduate Education Program (IGEP), for new Navy Ensigns

4. Includes foreign nationals (FN), civilians in DAGSI programs, and special DoD programs.

4.1.2 Educational Objectives

1. *Our graduates will be prepared to make direct contributions as a practicing engineer in the area of aeronautical engineering.*

2. *Our graduates will have the technical expertise to communicate, evaluate, monitor and administer aeronautical research and development programs.*

3. *Our graduates will understand how to approach and solve new technological challenges to meet the needs of the Air Force and other DoD organizations.*

4.1.3 Program Elements

(1) Core Aeronautical Engineering
(2) Mathematics (2)
(3) Specialty Sequences (2)
(4) Independent Investigation
(5) Electives
(6) 48 graduate quarter hours, minimum

(1) Core Aeronautical Engineering

CORE AERONAUTICS 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. The department offers courses in five aeronautics disciplines: 1) aerodynamics (any "AERO XXX" course), 2) aircraft stability and control, 3) air breathing or rocket propulsion, 4) structures/materials and 5) air weapons (offered in the air weapons sequence). The department requires that a master's student take at least one department-offered course from three of the five disciplines. The courses can be taken as part of a specialty sequence, as part of the ABET core or simply as elective courses.

ABET CORE Certain general program outcomes and professional components for Aeronautical Engineering are specified by the Accreditation Board for Engineering Technology (ABET). Specific course topics are determined by the lead society for ABET, the American Institute of Aeronautics and Astronautics (AIAA). The ABET general criteria are largely satisfied in any undergraduate engineering program while the specific topics are usually covered only in an aerospace or aeronautics undergraduate program. Prior to beginning the GAE program, the student with his/her faculty advisor's assistance, based on undergraduate transcripts will identify any deficiencies in the general/specific core aeronautical engineering areas. Students identified as having core aeronautics deficiencies can satisfy the requirements by taking appropriate courses from the list below. ABET general program requirements include competency in designing and conducting aeronautical (wind tunnel)-based experiments, which can be satisfied by taking AERO 517 Fluid Measurements Lab. ABET also requires a design experience and AIAA further specifies design of an aeronautical system, component or process. Either AERO 685 Aerospace Systems Design or MENG 733 Air-breathing Engine Design will satisfy the design requirement. Completion of the following courses satisfies both general and specific ABET guidelines:

a. Aerodynamics: (1) AERO 533 Incompressible Aerodynamics and
(2)AERO 536 High Speed Aerodynamics (Both are required).
b. Flight Mechanics/Stability & Control: MECH 529 Dyn. and Control of Flight Vehicles
c. Structures: MECH 545 Aerospace Structural Analysis
d. Propulsion: MENG 501 Aerospace Propulsion
e. Materials: MATL 545 Mechanical Properties of Materials

f. Design: AERO 685 Aerospace Systems Design, MENG 733 Airbreathing Engine Design, or Rotorcraft System Design (listed as AERO 699 in WI 2010)
g. Aeronautical Lab: AERO 517 Fluid Measurements Lab

Students with a Bachelor of Science in Aeronautical Engineering have sufficient background so that most or all of these courses can be waived. Such students should consider an accelerated program and early graduation. Students with other undergraduate degrees frequently lack this background.

(2) Mathematics

The second element of the GAE curriculum is mathematics. 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 Mathematics department or one course from the Mathematics department plus a second course approved by the Aeronautics department. Such approved second courses can also be used simultaneously in satisfying other degree requirements, such as in sequences.

Department-approved Math substitute courses:

AERO 551	Numerical Methods for CFD
MECH 620	Systems Optimization
MECH 622	Functional Optimization and Optimal Control
MECH 712	Nonlinear Oscillations
ASYS 525	Linear Systems Analysis
ASYS 625	Non-Linear Systems Analysis and Control

The particular math courses each student takes are based upon background and area of specialization. Nearly all students take math courses that cover topics in advanced calculus, complex variables, Fourier series and boundary value problems, linear algebra, numerical methods, and probability/statistics. MATH courses popular among students in the Graduate Aeronautical Engineering program include (but are not limited to) MATH 508, MATH 509, MATH 511, MATH 513 and MATH 521.

(3) Specialty Sequences

The third element of the Graduate Aeronautical Engineering curriculum is comprised of the specialty sequences. Each student is required to take two such 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-graduation assignments.

<u>Air Force Ed Codes:</u> Full-time Air Force military students entering AFIT are assigned an advanced level education specialty code (Ed Code). This code reflects the current requirements and availability of officers in each specialty. The system of Ed Codes is used by the Air Force to determine both the number of students and the type of advanced level education for each student. For such Air Force students, one sequence is normally dedicated to meeting Air Force requirements for specialized education, while the second sequence is left to the student's choice.

Over the last few years, Air Force quota students have been entering the GAE program with the following Ed Codes:

Ed Code	Specialty
4AAY	Aeronautical Engineering - Aerodynamics
4ABY	Aeronautical Engineering - Air Weapons
4AGY	Aeronautical Engineering – Structural Analysis
4AEY	Aeronautical Engineering – Air-breathing Propulsion
4AFY	Aeronautical Engineering - Stability and Control
4AYY	Aeronautical Engineering - General
4B*Y	Aerospace Engineering
4MBY	Mechanical Engineering – Structural Dynamics
4MFY	Mechanical Engineering – Structural Materials
4MYY	Mechanical Engineering - General

For the specialty codes listed above, Air Force students must take at least one sequence in the associated specialty. (Under "Course Sequences," each Ed Code is identified with its required sequence.)

Air Force students with the educational code 4AYY (Aeronautical Engineering-General) are free to choose their primary sequence from the list shown under "Course Sequences." Students with 4MYY (Mechanical Engineering-General) must choose at least one of the following sequences: Propulsion, Structural Analysis, or Structural Materials.

Air Force students with the educational code 4B*Y (Aerospace Engineering) choose their program (GA or GAE) and their sequences after consultation with their advisor and the supervisor of their next assignment.

In all cases, the second sequence (student's choice) may be taken in an area outside the Ed Code specialty. Students also may select their second sequence from those listed with other programs, such as "Advanced Astrodynamics," (GA program).

(4) Independent Investigation

The fourth element of the Graduate Aeronautical Engineering program is an independent investigation of a problem of current DoD interest, conducted and documented by the student, with supervision of the faculty. The investigation is presented as a formal thesis and the thesis carries 12 credit hours.

Navy TPS students are only required to satisfactorily complete a flight test report that is evaluated by Navy TPS faculty, and which is accepted in lieu of the thesis. However, completion of the flight test report carries no course credit hours.

Chapter 7 explains the thesis polices procedures, and requirements for AFIT and the Department of Aeronautics and Astronautics.

(5) Electives

Students have the opportunity to take supporting courses and elective courses and seminars covering current technical developments and DoD projects. Electives are also used to make up for undergraduate deficiencies and failed courses, prepare for future assignments, increase depth in a specialty, develop an additional specialty, or pursue individual interests by taking courses not normally found in an aeronautical engineering program. One area of growing importance in DoD is Systems Engineering. Some students may consider taking electives in this area, e.g., SENG 520 and/or SENG 620, or pursuing a certificate in Systems Engineering, a group of five courses including a capstone course that can be replaced with Aircraft Design or Engine Design. ENV administers the Certificate program.

Aeronautical Engineering Course Sequences

Ed Code	**Sequence**
4AAY	Aerodynamics
4AAY	Computational Fluid Dynamics
4AEY	Air Breathing Propulsion
4AFY	Aircraft Stability and Control (recommended for TPS students)
None	Control and Optimization Theory
None	Digital Avionics Applications and Design
4MBY	Aeroelasticity
4AGY	Structural Analysis
4MBY	Vibration Damping and Control
4MFY	Structural Materials
4ABY	Air Weapons
None	Systems Engineering
None	Finite Element Analysis

4.1.4 Sample Program—18 Month GAE Thesis Student

Master of Science in Aeronautical Engineering
September - March (18 Months)[1]

Short Term Review (4 weeks)
Mathematics
Dynamics
Aeronautics
Computers

1st Quarter Fall		**Credit Hours**
AERO 698	Graduate Seminar in Aeronautics and Astronautics	1
XXXX xxx	MATH I	4
XXXX xxx	Core/Elective	3-4
XXXX xxx	Core/Elective	3-4
XXXX xxx	Core/Elective	3-4
		14-17
2nd Quarter Winter		
XXXX xxx	MATH/Math Substitute	4
XXXX xxx	Core/Elective	3-4
XXXX xxx	Core/Sequence I/Elective	3-4
XXXX xxx	Core/Sequence II/Elective	3-4
		13-16
3rd Quarter Spring		
XXXX xxx	MATH/Elective	3-4
XXXX xxx	Sequence I	4
XXXX xxx	Sequence II	4
XXXX xxx	Elective/Core	2-4
		13-16
4th Quarter Summer		
AERO 799	Thesis Research	2-4
XXXX xxx	Sequence I/Elective	4
XXXX xxx	Sequence II/Elective	4
XXXX xxx	Core/Elective	4
		14-16

5th Quarter Fall		**Credit Hours**
AERO 799	Thesis Research	3-7
XXXX xxx	Sequence I/ Elective/Core	3-4
XXXX xxx	Sequence II/ Elective/Core	3-4
		9-15
6th Quarter Winter		
AERO 799	Thesis Research	3-6
XXXX xxx	Elective	3-4
XXXX xxx	Core/Sequence	3-4
		9-14
	TOTALS	**72-94**

Program Notes

1. This program layout is typical for a full-time 18-month student. For longer programs, additional department approved electives may be taken. In such programs, the thesis research is typically accomplished in the final three quarters.

2. In addition to curriculum requirements specified for the degree, a minimum course load of 12-credit hours per quarter (average) is required for full-time DoD students.

3. Technical electives may be selected from any program in the Graduate School of Engineering and Management.

4. A student lacking adequate preparation in humanities and social sciences must use electives to correct these deficiencies in order to earn the ABET designated degree. Taking courses at other DAGSI Universities can satisfy these deficiencies and other enhancements.

4.1.5 Special Programs

4.1.5.1 **Air Force and Navy Joint AFIT/Test Pilot School (TPS) Programs**

A special program is offered in the department in which the participating students are awarded dual diplomas: (1) an MS in Aeronautical Engineering from AFIT, and (2) a diploma from the United States Air Force Test Pilot School (AFTPS) or the United States Navy Test Pilot School (NTPS). The special joint AFIT/TPS program is only available to students who have been selected for admission to TPS. Degree requirements: same as listed in section 1.1.3 with the exception of the thesis requirement for Navy TPS students (See below).

Air Force TPS: Each year the Air Force TPS Selection Board selects two or more Air Force officers for this combined program. The selected students enter AFIT residency in September or January, and in five quarters (15 months) complete their AFIT course work. The Air Force students also complete a large portion of the thesis requirement while in residence. The students leave in December/June without their AFIT degree and enter TPS at Edwards AFB starting in January/July. While at TPS the students design and fly a flight test program that is subsequently incorporated into their MS thesis. Upon successful completion of the 1-year program at TPS and a successful defense of their AFIT thesis, the students are awarded the MS Degree in Aeronautical Engineering.

Navy Special Requirement: Navy TPS students must take ASYS 590 (Aircraft Survivability), CSCE 581 (Fundamentals of Avionics), and SENG 520 (Systems Analysis for Design). Non-aero undergraduates must take AERO 685 (Aerospace System Design) to fulfill design requirements. MENG 733 (Airbreathing Engine Design) can be taken, but will not fulfill the requirement.

Sample Program--Air Force TPS Program
Aeronautical Engineering
(15 Months)

Short Term Review (4 weeks)
September/December/June
Mathematics
Dynamics
Aeronautics
Computers

1st Quarter		**Credit Hours**
AERO 698	Graduate Seminar (Fall/Summer qtrs only)	1
XXXX xxx	MATH I	4
XXXX xxx	Core/Elective	3-4
XXXX xxx	Core/Elective	3-4
XXXX xxx	Core/Elective	3-4
		14-17

2nd Quarter		
XXXX xxx	MATH/Math substitute	4
XXXX xxx	Sequence I	4
XXXX xxx	Core/Sequence II/Elective	3-4
XXXX xxx	Core/Elective	3-4
		14-16

3rd Quarter		
AERO 799	Thesis Research[1]	3-4
XXXX xxx	Sequence I	3
XXXX xxx	Sequence II	4
XXXX xxx	Elective/Core	2-4
		12-15

4th Quarter		
AERO 799	Thesis Research[1]	3
XXXX xxx	Sequence I	4
XXXX xxx	Sequence II/Elective	3-4
XXXX xxx	Elective	3-4
		13-15

5th Quarter

		Credit Hours
AERO 799	Thesis Research[1]	3
XXXX xxx	Elective/Core	3-4
XXXX xxx	Sequence II/Elective/Core	3-4
		9-11

NAVAL FLIGHT OFFICER (NFO) ONLY
6th Quarter

XXXX xxx	Elective	3-4
XXXX xxx	Elective	3-4
XXXX xxx	Elective	3-4
XXXX xxx	Elective (Optional)	(3-4)
		9-12
	TOTALS	**60-74**
	(NFO Only)	**72-86**

Program Notes

1. Thesis credits are for the Air Force program only and are continued in the AF TPS program. At completion of the GAE program, 12 credit hours are awarded for the thesis. Naval officers will substitute a sequence course or technical elective.

2. In addition to curriculum requirements specified for the degree, a minimum course load of 12-credit hours per quarter (average) is required for full-time DoD students.

3. Technical electives may be selected from any program in the Graduate School of Engineering and Management.

4.2 Graduate Astronautical Engineering (GA)

4.2.1 Introduction

The Graduate Astronautical Engineering (GA) program is designed to provide astronautical engineering specialists for the Air Force. Astronautical engineering is dedicated to the design, testing, and development of spacecraft, missiles, launch vehicles, and related systems. In the traditional program, students enter as a class in September and graduate in 18 months. This ABET accredited program leads to a Master of Science in Astronautical Engineering.

4.2.2 Program Educational Objectives

This program provides the student with a broad education in the scientific and engineering disciplines associated with Astronautical engineering. Our Program Educational Objectives are to provide graduates who:

1) Make direct contributions to the area of astronautical engineering as practicing engineers.

2) Successfully evaluate, monitor, and administer astronautical research and development projects.

3) Use their AFIT education to approach and solve new technological challenges to meet the needs of the Department of Defense.

4.2.3 Program Outcomes

1) Graduates of the GA program will be able to apply sound engineering principles to solve Air Force and Department of Defense problems.

2) Graduates of the GA program will be able to communicate technical information, via oral presentations and written documents, to a wide range of audiences, including engineering professionals and senior military officers.

3) Graduates of the GA Program will 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.

4) Graduates of the GA program will be prepared to describe and discuss significant aspects of the space environment and their effect on Earth-orbiting spacecraft.

5) Graduates of the GA program will be able to model spacecraft attitude dynamics and synthesize control laws to control spacecraft attitude. Graduates will understand transformations due to coordinate frame translation and rotations.

6) Graduates of the GA program will 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.

7) Graduates of the GA program will be prepared to describe essential features of rocket propulsion including: performance parameters, propellant types, rocket staging, and fluid mechanics as it pertains to rocket propulsion.

8) Graduates of the GA program will be able to conduct basic analyses of space structures including deformation from tension, torsion, shear, and bending.

9) Graduates of the GA program will have a 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.

4.2.4 Program Elements

The GA curriculum is built around five principal elements:

(1) Core Courses
(2) Mathematics
(3) Specialty Sequences
(4) Thesis
(5) Elective Courses

Full time quota officers are required to complete an average of 12 credit hours per quarter over the duration of their program. Typical master's programs are six quarters, so students should plan to complete a minimum of 72 credit hours, including 12 hours of thesis credit. Students who are not DoD sponsored full time quota students may complete the degree with as few as 48 graduate credit hours, but it should be recognized that this case presumes an appropriate undergraduate degree (ABET accredited degree in astronautical or aerospace engineering).

(1) 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 these 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 take at least one graduate course related to orbital mechanics (MECH 532, MECH 731, or MECH 732) and at least one graduate course related to spacecraft attitude dynamics (MECH 632). These classes can be used to simultaneously meet other degree requirements. Credit minimums still apply, so an additional elective may be necessary in this case. 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.

The core astronautical engineering courses include:

<u>All GA Students:</u>

a) A course in orbital mechanics; ONE of the following courses:
    a. MECH 532 – Introductory Space Flight Dynamics
    b. MECH 731 – Modern Methods Of Orbit Determination
    c. MECH 732 – Advanced Astrodynamics
b) A course in spacecraft attitude determination and control;
   MECH 632 – Intermediate Space Flight Dynamics

<u>Other courses to satisfy ABET Requirements (as applicable)</u>

a. A course in dynamics; MECH 521 - Intermediate Dynamics
b. A course in linear systems analysis; ASYS 525 - Linear Systems Analysis
c. A course in feedback control systems; ASYS 565 - Control and State Space Concepts
d. A course in sensor systems; PHYS 521 - Space Surveillance
e. A course in space environment; PHYS 519 - Space Environment
f. A course in telecommunications; EENG 571-Satellite Communications
g. A course in space-related design; ASYS 631 – Spacecraft Systems Engineering
h. A course in rocket propulsion; MENG 530 – Rocket Propulsion

(2) Mathematics

The second element of the GA curriculum is 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. Other math classes suited to the GA program include MATH 521 – Linear Algebra, and MECH 712 Nonlinear Oscillations/MATH 605 Nonlinear Ordinary Differential Equations. Students planning on taking MECH 731 who have not had an undergraduate probability course may consider taking a graduate course in probability such as and STAT 527 – Introduction to Probability.

(3) Specialty Sequences

The third element of the GA curriculum is comprised of the specialty sequences. A specialty sequence, three or more courses in length, is an integrated presentation of a specific technical specialty. Each program must contain two specialty sequences.

For Air Force Students: Each full-time Air Force student entering AFIT is assigned an advanced level education specialty code (Ed Code). One of the specialty sequences required for the degree must match the academic specialty code assigned to the student. The second may be in any technical area. This code reflects the current requirements and availability of officers in each specialty. The system of Ed Codes is used by the Air Force to determine both the number of students and the type of advanced level education for each student. Over the last few years, students have been entering the GA program with the following Ed Codes:

Ed Code	**Specialty**	**Required Primary Sequence**
4B*Y	Aerospace Engineering	any
4ECY	Astronautical Engineering - Guidance and Control	Mechanics and Control of Space Structures Advanced Astrodynamics Vibration Damping and Control Control & Optimization Theory Aerospace Navigation
4EDY	Astronautical Engineering – Instrumentation	Aerospace Navigation
4EEY	Astronautical Engineering - Rocket Propulsion	Rocket Propulsion
4EFY	Astronautical Engineering - Space Facilities	Space Facilities
4EGY	Astronautical Engineering – Structures	Structural Analysis Structural Materials Vibration Damping and Control
4EYY	Astronautical Engineering - General	any

Other Recommended Sequences for Graduate Astronautical Engineering Students

Astrodynamic Re-entry
Space Navigation
Estimation
Space Vehicle Design

The second sequence is not required to match the education code, and students may select the second sequence from those listed with other programs/departments, subject to the approval of their academic advisor. Chapter 6 is a list of all specialty sequences offered annually by the Department of Aeronautics and Astronautics.

(4) Thesis

The fourth element of the GA program, the thesis, is an independent investigation of a problem of current DoD interest, conducted and documented by the student, with supervision by the faculty. Theses by previous GA students have been theoretical, experimental, and/or numerical. Topics for these theses are sometimes suggested by Air Force organizations.

Chapter 7 explains the thesis policies, procedures, and requirements for AFIT and the Department of Aeronautics and Astronautics.

(5) Elective Courses

Electives may be used to establish another specialty area, to take courses particularly pertinent to the student's next assignment, or for any other academically sound purpose. Any student with deficiencies in the social sciences and humanities or other areas must use electives to eliminate these deficiencies in order to qualify for the ABET accredited degree. The minimum credit hours permitted for full time Air Force quota officers in a 6-quarter program are 72. The minimum credit hours permitted in a 7-quarter program is 84.

Schedule permitting, a course in space vehicle design and test is highly recommended for all GSS students. This will provide a hands-on experience in the design and test of spacecraft and selected space subsystems. The recommended course is ASYS632.

4.2.5 Sample Program—18 Month GA Thesis Student

Master of Science in Astronautical Engineering
September - March (18 Months)

Short Term Review (4 weeks)	**September**	
Mathematics		
Dynamics		
Computers		
Astronautics		
1st Quarter		**Credit**
Fall		**Hours**
AERO 698	Graduate Aero & Astro Seminar	1
PHYS 519[1]	Space Environment	4
ASYS 525[1]	Linear Systems Analysis	4
MECH 521[1]	Intermediate Dynamics	4
MATH I[2]		4
		17
2nd Quarter		
Winter		
ASYS 565[1]	Control and State Space Concepts	4
MECH 532[1]	Introductory Space Flight Dynamics	4
XXXX xxx	Sequence I	4
XXXX xxx	Sequence II	4
		16
3rd Quarter		
Spring		
MATH II[2]		4
MECH 632	Intermediate Space Flight Dynamics	4
XXXX xxx	Sequence I	4
XXXX xxx	Sequence II	4
		16
4th Quarter		
Summer		
AERO 799	Independent Study (Thesis)	2-4
XXXX xxx	Sequence I	4
XXXX xxx	Sequence II	4
		10-12
5th Quarter		
Fall		
AERO 799	Independent Study (Thesis)	4-8
XXXX xxx	Core Course[1]/Elective	0-4
		4-12
6th Quarter		
Winter		
PHYS 521[1]	Space Surveillance	4
EENG 571[1]	Satellite Communications	4
AERO 799	Independent Study (Thesis)	2-4
		10-12
	TOTALS	**73-85**

1. See Section 4.2.3 (1)

2. See Section 4.2.3 (2)

This sample program is for a full-time AF quota student in an 18-month program.
NOTE: While it is possible to build a program with an approximately even load of 12 credits per quarter, students are strongly encouraged to “front load” coursework in the first three quarters of their program (16-17 credits) to free up time for thesis work in the second half of their program.

4.3 Graduate Space Systems (GSS)

4.3.1 Introduction

The Graduate Space Systems (GSS) 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 officers' 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. Full-time quota students enter as a class in September and are scheduled to graduate in March, approximately 18 months later. 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.

There are three different Academic Specialty Codes (ASCs) associated with this program: 4TSY Space Systems; OYRY Space Operations, General; OYRI Space Operations, Information Operations. The OYRI designation is the code used for Vigilant Scholar students (selected by AFSPC for the Vigilant Scholar program). All students must complete the GSS core, while the specialty sequence is tailored to meet ACS requirements as discussed in Sect 4.3.4.

4.3.2 Program Educational Objectives

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:

1) Make direct contributions to the area of space systems engineering and space science as a practicing engineer.

2) Successfully evaluate, monitor, and administer space systems research and development projects.

3) Use their AFIT education to approach and solve new technological challenges to meet the needs of the Department of Defense.

4.3.3 Program Outcomes

1. 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. Required courses are ASYS 530 Introduction to Space Programs and Operations ***or*** *ASYS 535 Military Space Systems and Applications (note: ASYS535 is restricted to US only with a TS/SCI clearance, all others should enroll in ASYS530).*

2. *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. Required course is MECH 532 Introduction to Spaceflight Dynamics*.

3. *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. Required course is EENG 571 Satellite Communications*.

4. *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. Required course is PHYS 519 Space Environment*.

5. *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. Required course is PHYS 521 Space Surveillance*.

6. *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 project. Required course is ASYS 631 Spacecraft Systems Engineering*.

4.3.4 Program Elements

The GSS curriculum is comprised of the following elements, which are discussed in greater depth below.

(1) Mathematics
(2) Core Courses
(3) Specialty Sequence
(4) Elective Courses
(5) Thesis

(1) 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 for the degree. The recommended course is MATH 509 Mathematical Methods in the Physical Sciences. Additional math courses may be needed as prerequisites for other classes.

(2) 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 as follows:

a. MECH 532 - Introductory Space Flight Dynamics
b. EENG 571 - Satellite Communications
c. PHYS 521 - Space Surveillance
d. PHYS 519 - Space Environment
e. ASYS 631 - Spacecraft Systems Engineering
f. ASYS 535 - Military Space Systems and Applications (US TS/SCI only)
   or ASYS 530 - Introduction to Space Programs and Operations

Additional ASC specific "core" courses:

OYRY: CSCE 525 Introduction to Information Warfare
Plus one of the following:
OPER 501 Quantitative Decision Making
OPER 510 Deterministic Operations Research
OPER 543 Decision Analysis

OYRI (Vigilant Scholar): SMGT 543 Systems Acquisition Mgt*
(*Note: SMGT 543 can be waived for students APDP Level II certified in PM or SPRDE.)

(3) Specialty Sequence

The third element of the GSS curriculum is a three-course specialty sequence. This sequence is intended to provide depth in order to support the thesis effort and/or follow-on assignment requirements. As such, the sequences are different for each of the three ASCs as shown below. The courses comprising the sequences are available from each of the departments responsible for the sequence. The ENY sequences are listed in Chapter 6. An unofficial list of the AFIT sequences is found at L:\students\eny students\EN Sequences\Ensequences.htm. Course offerings should always be verified with those posted by the department offering the course. ENY offerings are listed in Appendix G.

4TSY (and 4ISY): These students are expected to take two technical depth specialty sequences in areas of space engineering or science. The sequences must be approved by the curriculum advisor. Many sequences require prerequisites. Some suitable sequences are:

Sequence
Astrodynamics (ENY)
Astrodynamic Re-entry (ENY)
Advanced Astrodynamics (ENY)
Aerospace Robotics (ENY)
Control and Optimization Theory (ENY)
Mechanics and Control of Space Structures (ENY)
Rocket Propulsion (ENY)
Space Navigation (ENY)
Space Vehicle Design (ENY)
Structural Analysis (ENY)

Structural Materials (ENY)
Communication Systems (ENG)
Navigation Systems (ENG)
Radar Systems (ENG)
Laser and Electro-Optic Systems (ENG)
Stochastic Estimation and Control (ENG)
Target Recognition (ENG)
Signal Processing (ENG)
Space Environment (ENP)

OYRY: These students are permitted to take a sequence outside of the engineering and science fields, such as those having a stronger management or operational emphasis, as consistent with customer needs. Some suitable sequences (in addition to 4TSY suggestions above and OYRI suggestions below) are:

Sequence
Applied Statistics (ENS)
Deterministic Operations Research (ENS)
Probabilistic Operations Research (ENS)
Operational Modeling (ENS)
Simulation (ENS)
Applied Decision Analysis (ENS)
Computer Networks (ENG)
Database Systems (ENG)
Research and Development Management (ENV)
Information and Knowledge Integration (ENV)

OYRI (Vigilant Scholar): These students are required to develop an expertise in the collection, management, dissemination, and control of information. One of the following must be completed:

Sequence
Information Assurance Sequence (ENG)
Information Operations (ENS)
Information and Knowledge Integration (ENV)

(4) Elective Courses (Full-time students)

For full-time quota students, the minimum credit hours permitted in the six-quarter program are 72. These additional classes will be used to satisfy prerequisites for the specialty sequence, support thesis research, support follow-on assignments, or support the student's career goals and interests.

Schedule permitting, a course in space vehicle design and test is highly recommended for all GSS students. This will provide a hands-on experience in the design and test of spacecraft and selected space subsystems. The recommended course is ASYS632.

Schedule permitting, a course in GPS is highly recommended for all GSS students. This will provide a theoretical and practical understanding of the operations and utility of the Global Positioning System (GPS). The recommended course is EENG 533 Navigation Using the Global Positioning System. The associated lab course, EENG 536 is also recommended.

Schedule permitting, a course in systems engineering is highly recommended for all GSS students. This will provide a coherent framework for engineering design of complex systems and the development of DoD tools that are important to the successful design of space systems. The recommended course is SENG 520 Systems Analysis and Design.

(5) Thesis

The final element of the GSS program, 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 serving as the thesis advisor. For those students with thesis advisors in the Department of Aeronautics and Astronautics, Chapter 7 explains the thesis policies, procedures, and requirements.

4.3.5 Degree Options

If the student has the appropriate background (e.g. an ABET accredited undergraduate degree), he or she may pursue a degree other than the Master of Science (Space Systems). These alternatives are listed in the table below. These options are available to provide flexibility for full-time quota students who must satisfy the Space Systems Ed Code requirements (4TSY, OYRY, OYRI) but prefer to obtain one of these degrees. To qualify for one of these degrees, the student must satisfy the requirements of the degree *in addition to* the requirements of their ASC for the GSS program. Students that opt for degrees offered outside of the Department of Aeronautics and Astronautics will be co-advised by the GSS advisor and the advisor of the degree-granting program. The advisor of the degree-granting program will be responsible for completing the AFIT Form 69 to ensure graduation requirements are met. The GSS advisor will provide oversight to ensure that the requirements of the GSS program are met. Note that pursuing many of the degrees requires course loads beyond the 72-hour minimum for quota students. See the GSS advisor for additional details.

M.S. Degree Granted	**Coordinating Dept.**	**Additional Entry Requirements**
Mathematics	ENC	BS Mathematics
Electrical Engineering	ENG	BS Electrical Eng
Comp Science or Comp Systems	ENG	BS Comp Sci or Equiv
Computer Engineering	ENG	BS Comp Eng or BS Elec Eng
Engineering Physics	ENP	BS Physics
Operations Research	ENS	--
Logistics	ENS	--

Research & Development Management	ENV	--
Aeronautical Engineering	ENY	BS Astro, Aero or Mech Eng.
Astronautical Engineering	ENY	BS Astro, Aero or Mech Eng.
Systems Engineering	ENV	Any ABET accredited BS

4.3.6 Sample Program—18 Month GSS Thesis Student

Master of Science (Space Systems)
September - March (18 Months)

Short Term Review (4 weeks)
- Mathematics
- Dynamics
- Computers
- Astronautics

		Credit Hours
1st Quarter Fall		
AERO 698	Graduate Aero & Astro Seminar	1
ASYS 535	Military Space Systems and Applications[2]	1
MATH 509	Mathematical Methods in the Physical Sciences	4
PHYS 519	Space Environment	4
SENG 520	Systems Analysis and Design (or elective)	4
XXXX XXX	Specialty Sequence/Elective	3-4
		17-18
2nd Quarter Winter		
MECH 532	Introductory Space Flight Dynamics	3
EENG 571	Satellite Communications[1]	4
ASYS 535	Military Space Systems and Applications[2]	1
XXXX XXX	Specialty Sequence/Elective	3-4
XXXX XXX	Specialty Sequence/Elective	3-4
		14-16
3rd Quarter Spring		
AERO 799	Independent Study (Thesis)	0-4
ASYS 535	Military Space Systems and Applications[2]	1
XXXX XXX	Specialty Sequence/Elective	3-4
XXXX XXX	Specialty Sequence/Elective	0-4
		4-13
4th Quarter Summer		
AERO 799	Independent Study (Thesis)	2-4
ASYS 631	Spacecraft Systems Engineering	4
XXXX XXX	Specialty Sequence/Elective	3-4
XXXX XXX	Specialty Sequence/Elective	0-4
		9-16

5th Quarter
Fall

AERO 799	Independent Study (Thesis)	2-6
XXXX XXX	Specialty Sequence/Elective	3-4
XXXX XXX	Specialty Sequence/Elective	0-4
		5-14

6th Quarter
Winter

AERO 799	Independent Study (Thesis)	2-6
PHYS 521	Space Surveillance[1]	4
XXXX XXX	Specialty Sequence/Elective	0-4
		6-14
	TOTALS	**72-91**

1. It is recommended that some members of the GSS class switch this class with EENG 571/PHYS 521 (both are required courses) so that there is a mix of expertise for the design project in ASYS 631.

2. US only, TS/SCI required. This is a single 3-credit course divided over three quarters (all three quarters must be taken unless given special permission by instructor).

4.4 Graduate Certificate Program in Space Systems

4.4.1 Introduction

For those students not enrolled in the Space Systems (GSS) or Astronautical Engineering (GA) degree programs, AFIT offers a Graduate Space Systems Certificate Program (GSSC). 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.

The courses required to earn the Graduate Certificate are:

a. MECH 532—Introductory Space Flight Dynamics
b. PHYS 519—The Space Environment
c. ASYS 631—Spacecraft Systems Engineering
d. An applications course (choose ONE of the following):
    a. OENG 530—Fundamentals of IR and MASINT Technology
    b. EENG 571—Satellite Communications
    c. SS3616—Military Satellite Communications (offered via NPS DL)

These courses provide a common breadth of knowledge and the basic building blocks for all Air Force and DoD Space Systems Engineers. The core courses are 4 credit hours each, and the application courses are 3-4 credit hours, so that the certificate program consists of 15-16 credits.

4.4.2 Program Educational Objectives

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:

1. 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.

2. A graduate will have a thorough understanding of orbital mechanics and the space environment and how these can affect the spacecraft mission.

3. A graduate will have an understanding of a specific application of space vehicles.

4.5 Graduate Materials Science (GMS)

4.5.1 Introduction

The Graduate Materials Science (GMS) program leads to the degree of Master of Science (Materials Science). Students normally enter as a class in September and are scheduled to graduate in March after 18 months. The 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.

4.5.2 Educational Objectives

The goal of the GMS 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 GMS program prepares students for a range of Air Force positions. It demands that the students develop a detailed understanding in specialty areas while ensuring that they are also well educated across all areas of materials science and engineering.

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

1. *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).*

2. *An in-depth knowledge in one specialty area.*

3. *Experience in conducting and documenting an independent investigation, a thesis, on a problem of Air Force interest.*

4.5.3 Program Elements

The GMS program is normally 6 quarters in length. The equivalent of 5 quarters of study is devoted to course work and 1 quarter of study to thesis research. The program provides preparation in thermodynamics and kinetics of materials, mechanical, electronic and optical properties of materials, material characterization, material selection and processing, and mathematics. Also, each student is 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 GMS curriculum is built around five principal elements:

(1) Basic Materials Core
(2) Mathematics
(3) Specialty Sequence
(4) Thesis
(5) Elective Courses

(1) Basic Materials Core

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. The courses making up the core are:

MATL 545	Mechanical Properties of Materials
MATL 525	Thermodynamics and Kinetics of Materials
MATL 560	Electronic, Magnetic, and Optical Properties of Materials
MATL 680	Materials Characterization
MATL 685	Materials Selection and Processing

All students are required to take this set of five core courses; however, if a student can demonstrate successful completion of a similar course a waiver may be granted. Students who find that most or all of the core requirements can be waived should consider an accelerated program and early graduation. Students with undergraduate degrees in areas other than materials science frequently lack this background.

(2) Mathematics

The second element of the GMS curriculum is 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.

(3) Specialty Sequence

The third element of the GMS curriculum consists of the 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.

Each full-time Air Force military student entering AFIT is assigned an advanced- level education specialty code (Ed Code). This code reflects the current requirements and availability of officers in each specialty. The system of Ed Codes is used by the Air Force to determine both the number of students and the type of advanced-level education for each student.

Students will enter the GMS program with the following Ed Codes:

Ed Code	**Specialty**
4FAY	Materials Science and Engineering-Structural Materials
4FBY	Materials Science and Engineering-Electronic and Optical Materials
4FYY	Materials Science and Engineering-General

For these listed specialty codes, students must take one sequence in that specialty. (Under "Course Sequences," each Ed Code is identified with its required sequence.) Students with the educational code 4FYY (Materials Science and Engineering-General) are free to choose their primary sequence from the list shown under "Course Sequences."

(4) Thesis

The fourth element of the GMS program, 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.

(5) Elective Courses

Opportunities to take supporting courses and elective courses are provided. Included also are seminars covering current technical developments and Air Force projects. Electives are used to make up for undergraduate deficiencies and failed courses, prepare for future assignments, increase depth in a specialty, develop an additional specialty, or pursue individual interests in taking courses not normally found in a materials science and engineering program.

4.5.4 Administrative

This program is of a multidisciplinary nature and will be updated, changed and/or modified in consultation with Materials and Manufacturing Directorate, Air Force Research Laboratory. The curriculum committee will consist of at least one member from the Department of Aeronautics and Astronautics, one from the Department of Engineering Physics, and the one from the Materials and Manufacturing Directorate of the Air Force Research Laboratory. Students with Ed Codes of 4FAY and 4FBY will be the responsibility of ENY and ENP, respectively, and will accordingly follow the rules and regulations of these departments. Students with the Ed Code 4FYY will initially report to the chairman of the GMS Curriculum Committee, who will assign these students to either ENY or ENP depending upon whether their interest and background is in the area of Structural (ENY) or Non-Structural (ENP) materials. For all GMS students, a form

69 will be signed by the Head of both the Department of Aeronautics and Astronautics and the Department of Engineering Physics.

4.5.5 Sample Program—18 Month GMS Thesis Student

Master of Science in Materials Science
September - March (18 Months)

Short Term Review (4 weeks)
Mathematics
Physics
Computers

		Credit Hours
1st Quarter Fall		
AERO 698	Graduate Aero & Astro Seminar	1
XXXX xxx	MATH I[3]	4
MATL 560	Electronic, Magnetic and Optical Materials	4
XXXX xxx	Sequence/Elective/Prerequisite	4
XXXX xxx	Sequence/Elective/Prerequisite	4
		17
2nd Quarter Winter		
XXXX xxx	MATH II[3]	4
MATL 680	Materials Characterization	4
XXXX xxx	Sequence/Elective	4
XXXX xxx	Sequence/Elective	4
		16
3rd Quarter Spring		
MATL 525	Thermodynamics and Kinetics of Materials	4
XXXX xxx	Sequence/Elective	4
XXXX xxx	Sequence/Elective	4
XXXX xxx	Elective	4
		16
4th Quarter Summer		
MATL 799	Thesis Research	2-4
XXXX xxx	Sequence/Elective	4
XXXX xxx	Sequence/Elective	4
XXXX xxx	Sequence/Elective	4
		14-16
5th Quarter Fall		
MATL 799	Thesis Research	4-7
MATL 545	Mechanical Properties of Materials	4
XXXX xxx	Sequence/Elective	4
		12-15
6th Quarter Winter		
MATL 799	Thesis Research	3-6
MATL 685	Materials Selection and Processing	4
XXXX xxx	Sequence/Elective	4
		11-14
	TOTAL	**72-74**

Note: This program is intended to be typical for a full-time Air Force quota student.

Program Notes

1. The purpose of this curriculum guide is to assist the student and advisor in defining the best possible curriculum for each student. The above-listed curriculum guide represents a typical course load expected of full-time, 18-month, Air Force quota students. Some of these curriculum requirements are alterable if adequate justification exists.

2. The specific program requirements for Materials Science are:

   a. Core courses in Materials Science: MATL 545, MATL 525, MATL 560, MATL 680, and MATL 685
   b. At least one graduate mathematics course
   c. One sequence, which may be determined by student's Ed Code
   d. Twelve credit hours work of thesis
   e. In addition to curriculum requirements specified for the degree, a minimum course load of 12-credit hours per quarter (average) is required for full-time Air Force quota students. For purposes of reducing latter quarter course loads, programs containing an overload (more than four courses) in the first 3 quarters may be approved in certain cases.

3. Recommended courses are MATH 511 - Methods of Applied Math I; MATH 513- Methods of Applied Math II; STAT 527 - Introduction to Probability; STAT 537 - Introduction to Statistics; and MATH 508 - Numerical Methods.

Ed Code	**Sequence**
4FAY	Structural Materials[1]
4FBY	Electronic and Optical Materials[2]

1. Prerequisite to this sequence is an advanced undergraduate course on mechanics of materials.
2. Prerequisite to this sequence is PHYS 531 - Electromagnetism and PHYS 655 - Quantum Mechanics I.

CHAPTER 5: RESIDENT PHD PROGRAM

5.1 Introduction

Students are admitted to study leading toward the PhD degree in Aeronautical, Astronautical, or Space Systems, with concentration in one of the three major divisions of the Department of Aeronautics and Astronautics. 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. Typical selections are shown below:

Fluid Mechanics	Solid Mechanics	Dynamics Systems & Control	
4AAY	4AGY	4AFY	4THY
4AEY	4EGY	4EGY	4TIY
4EEY	4EYY	4ECY	4TJY
4EYY	4AYY	4EDY	4TKY
4AYY	4MYY	4EYY	4TYY
4MYY	4MFY	4AYY	4THY
4ISY	4FAY	4MYY	4TIY
	4FYY	4TSY	OYRY
	4ISY		OYRI

Typically, a PhD degree program in the Department consists of two phases: phase one is a course work and examination period of six academic quarters, and phase two is dedicated to research. During phase one, all requirements for admission to candidacy (course work, examinations, and approval of research prospectus) are met. During phase two, usually lasting 18-24 months, 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.

A doctoral specialty may be pursued in any of the areas of concentration within the Department. Specialty coursework generally consists of one or more graduate sequences, augmented by the more advanced courses, which are offered for doctoral students. Students interested in a doctoral program should discuss those interests with a member of the department who is actively engaged in research in an area of interest to the student. Students are encouraged to explore offerings of the Dayton Area Graduate Studies Institute (DAGSI) as a means of enhancing their programs.

A collection of policy letters, prepared by the doctoral council will be provided to each student on admission, and are to be followed in planning and completing the program.

5.2 Admission Criteria

Admission to the PhD program is made by the Department following policies set down by the AFIT Doctoral Council. There is no set formula for admission, but the following are target minimum criteria:

- a quality BS program with grades averaging at least 3.00,
- a quality MS program with grades averaging at least 3.50,
- the successful completion of a MS thesis (desirable),
- GRE scores of at least 1200 (quantitative-verbal combined), and
- endorsement by the student's MS faculty, especially by the MS thesis advisor.

5.3 Types of Programs

5.3.1 Regular Programs (Fully-Funded)

Each year, assignments directly into the PhD programs are sought for a few of the most outstanding AFIT graduates of the resident MS programs. Volunteers who have qualified for admission by applying annually through Admissions (AFIT/ENER) fill the remainder of the annual quota.

5.3.2 Civilian Long-term, Full-time Training

Civilian employees sponsored by their organization may use AFIT for full-time, long-term training programs. Candidates are encouraged to precede their full-time assignment with a period of part-time study and to consider developing an arrangement whereby the research for the dissertation may be conducted "on the job" after returning to their own organization.

5.3.3 Civilian Employees of AFMC

A special program for civilian employees of Wright Laboratories has been developed. The AFIT/AFMC PhD program consists of three phases: part-time course work, full-time course work for one year, and dissertation research at or for the sponsoring laboratory. The entry requirement includes a master's degree in engineering or science either from AFIT or elsewhere. During the part-time phase the student will take one or two courses per academic term. These courses should be selected in conjunction with the part-time advisor as part of an overall plan. Procedures for enrolling and registering as a part-time student are given elsewhere in this document.

The student may progress to the full-time phase when three conditions are met.

a. First, the student can complete the remaining courses and examinations (including the defense of prospectus) in one year (12 months) of full-time schooling. To increase the probability of meeting this requirement, the Department of Aeronautics and Astronautics normally requires candidates for admission to the full-time phase to have completely satisfied one of two segments (mathematics, specialty core) completely.

b. Second, the student has identified, been accepted by, and received departmental approval of a prospective research advisor.

c. Finally, the sponsoring AFMC organization agrees to release the student for full-time study.

At the end of one year of full-time study, the student is expected to have formed a research committee and successfully proposed and defended a research prospectus to that committee. The chairman of the research committee will be a full-time member of the AFIT faculty. The prospectus will have the approval of the chief scientist of the student's laboratory as well as of the committee. At that time the student may be formally admitted to candidacy for the PhD degree. The student will return to the laboratory to complete the research. It is expected that the research will require two years of full-time effort. It is important that AFIT/AFMC PhD students not be assigned other duties during the research phase.
NOTE: This program may be extended to employees of other scientific and engineering organizations at Wright-Patterson AFB.

5.4 Requirements

5.4.1 Coursework and Examinations

The PhD academic course work requirements are at least 36 hours to include: (a) a minimum of 24 hours in the major area and (b) 12 quarter hours in mathematics. Additionally, the students must successfully complete: (a) a specialty examination in the major area and, (b) a defense of the prospectus, which may include further examination over the major.

5.4.2 Residence

The residence requirement of three quarters of full-time study is to be met within a four-quarter period.

5.4.3 Research and Dissertation

At least 48 hours of supervised research must be completed under the supervision of an approved chairman, who must be a full-time faculty member in the Graduate School of Engineering and Management. A prominent laboratory scientist or other scientist or engineer may be a member of the committee, but members of the full-time AFIT or DAGSI faculty must constitute a majority of the committee. Finally, a suitable dissertation must be completed, defended and accepted. In selecting a research topic, students who are fully funded officers must insure that the research subject is appropriate to the assigned educational code. Admission to candidacy must be approved no later than four years from the beginning of the first course in approved program and graduation no later than four years after admission to candidacy.

5.4.4 Policies and Procedures

A complete list of policies and procedures can be found (a) in the Doctoral Council Policy Letters located at the AFIT Homepage and (b) in the ENY Department Supplement, “Doctoral Committee Policies”, available in the Department main office.

CHAPTER 6: SPECIALTY SEQUENCE DESCRIPTIONS

Each graduate program requires the completion of at least two approved specialty sequences. A wide variety is available to meet certain Air Force education requirements and to permit the development of programs tailored to meet special requirements. Certain sequences are approved for the various curricula. Others may be approved by the department to meet a special educational requirement. Those sequences, which are offered annually, are described on the following pages. In several cases, more advanced courses (primarily intended for doctoral students) are available as electives to students who have completed sequence requirements. The academic advisor may allow or disallow certain sequences for certain majors/backgrounds. Specialty sequences currently available in ENY as well as those identified as part of a program for ENY students in Chapter 4 are:

Advanced Astrodynamics
Aerodynamics
Aeroelasticity
Aerospace Navigation
Air Breathing Propulsion
Air Weapons
Aircraft Stability and Control
Astrodynamic Re-entry
Astrodynamics
C4ISR Systems
Computational Fluid Dynamics
Control and Optimization Theory
Digital Avionics Applications and Design
Electronic and Optical Materials
Estimation
Finite Element Analysis
Mechanics and Control of Space Structures
Optimization
Reliability
Rocket Propulsion
Space Facilities
Space Navigation
Space Systems
Space Vehicle Design
Structural Analysis
Structural Materials
Systems Engineering
Vibration Damping and Control

Advanced Astrodynamics

Courses in this sequence prepares students to do orbital mission analysis, re-entry, and orbit determination by using techniques of orbital analysis developed through special and general perturbations, and considers nonlinear resonance and the effects of the geopotential, air drag, and lunisolar perturbations. Courses in basic orbital mechanics are prerequisites to this sequence.

MECH 732	**-**	**Advanced Astrodynamics**	**WI**
MECH 637	**-**	**Astrodynamic Re-entry**	**SP**
MECH 731	**-**	**Modern Methods of Orbit Determination**	**SU**

Aerodynamics

Prepares students to perform the computations needed to determine aircraft performance characteristics, e.g., lift, drag and aerodynamic coefficients. Emphasis is given to the mathematical modeling and solution of flow problems peculiar to external aerodynamics. Knowledge of perfect fluid theory and compressible aerodynamics is presumed. Choose two courses to take with AERO 520 to complete the three-course sequence

AERO 520	**-**	**Viscous Flow Theory (Required)**	**FA**
AERO 579	**-**	**Theory of Gases for Aerodynamics and Propulsion**	**WI**
AERO 622	**-**	**Introductory Hypersonics**	**SP**
AERO 627	**-**	**Turbulence**	**WI**

Aeroelasticity

This sequence of courses is intended to provide students with a background in the analysis of systems that are simultaneously subjected to dynamic, structural, and aerodynamic loads. It is particularly relevant for those students wishing to pursue careers in aircraft model and flight test. Students are expected to have taken courses in aerodynamics, dynamics, and structures at least at the undergraduate level.

MECH 500 -	**Fundamentals of Solid Mechanics**	**FA**
or MECH 545	**Aerospace Structural Analysis**	**WI/SU**
MECH 515 -	**Theory of Vibrations**	**WI/SU**
or MECH 610	**Continuous Vibration**	**SP**
MECH 662 -	**Introduction to Aeroelasticity**	**SP**
or AERO 610	**Rotorcraft Aeromechanics**	**WI**

Aerospace Navigation

The purpose of the Navigation Systems sequence is to provide the student with the necessary background to enable an individual to design, analyze, test, and evaluate modern navigation components and systems to meet current Air Force requirements. Throughout the sequence, the emphasis is placed on advanced components and systems, implementation methods accounting for sensor limitations, computer limitations, and on algorithms. Primary emphasis is on inertial navigation systems, the Global Positioning System (GPS), and integrated navigation systems combining the two.

EENG 533	**-**	**Navigation of Global Positioning Systems**	**WI**
EENG 534	**-**	**Fundamentals of Aerospace Components & Systems**	**WI**
EENG 635	**-**	**Inertial Guidance & Control of Aerospace Vehicles**	**SP**
EENG 633	**-**	**Advanced GPS Theory and Applications (Recommended)**	**SU**
EENG 735	**-**	**Navigation Systems Analysis & Integration (Recommended)**	**SU**

Air Breathing Propulsion

This sequence of courses equips the student for preliminary analysis and design of ramjet and gas turbine type propulsion devices. It is intended for those who will be assigned in the areas of engine development, procurement, and/or evaluation as well as those responsible for the propulsion system aspects of flight vehicle development, application, and maintenance. The student should have a background in thermodynamics and gas dynamics.

MENG 633	**-**	**Fundamentals of Combustion**	**FA**
MENG 732	**-**	**Advanced Turbomachinery**	**SP**
MENG 733	**-**	**Air Breathing Engine Design**	**SU**
AERO 579	**-**	**Theory of Gases for Aerodynamics and Propulsion (Optional)**	**WI**

Air Weapons

This sequence prepares students for research and development activities in the field of weapons systems engineering. A background including such undergraduate core subjects as dynamics, mechanics of materials and fluid mechanics is presumed.

ASYS 563		**Terminal Effects and Delivery of Conventional Weapons (Required)**	**FA**
ASYS 590	**-**	**Aircraft Survivability (Required)**	**SP**
OPER XXX	**-**	**Selected Course from Dept of Operational Sciences***	
EENG 502	**-**	**Radio Frequency Systems***	**WI**
EENG 533	**-**	**Navigation using GPS***	**WI**
CSCE 525	**-**	**Introduction to Information Warfare***	**SP/SU/FA**
NENG 597	**-**	**Nuclear Weapons Effects, Technology and Non-Proliferation***	**FA**

*** or TBD, selected course with department approval**

Aircraft Stability and Control (Recommended for TPS Students)

This sequence enables the student to model the dynamics and aerodynamics of flight vehicles, to determine flight vehicle response to initial conditions, random and control inputs and to design flight control systems using both classical and modern control theory. Basic courses in aircraft stability and linear systems are required as prerequisites to the sequence.

ASYS 565	**-**	**Control and State Space Concepts**	**WI**
or ASYS 545		**Linear Systems Analysis for Control (Navy TPS only)**	**WI**
MECH 628	**-**	**Aircraft Control**	**SP**
MECH 629	**-**	**Aircraft Handling Qualities**	**SU**

Astrodynamic Re-entry

This sequence provides the student with an understanding of the dynamics of vehicles/objects entering a planetary atmosphere. Students also gain insight into the related areas of heat transfer, high-speed aero, and/or trajectory optimization.

MECH 637	**-**	**Astrodynamic Re-entry**	**SP**
MENG 571	**-**	**Fundamentals of Heat Transfer**	**WI**

Choose one of the following:

MECH 622	**-**	**Functional Optimization and Optimal Control**	**SP**
AERO 536	**-**	**High Speed Aerodynamics**	**SU/WI**
AERO 622	**-**	**Introductory Hypersonics**	**SP**

Astrodynamics

This sequence provides the student with an understanding of the dynamics of space vehicles. Students also gain insight into the issues of orbit design and orbit determination.

Choose 3 of the following (must include MECH 637 and/or MECH 731):

MECH 521	**-**	**Intermediate Dynamics**	**FA**
MECH 532	**-**	**Introductory Space Flight Dynamics**	**FA/WI**
MECH 632	**-**	**Intermediate Space Flight Dynamics**	**SP**
MECH 637	**-**	**Astrodynamic Re-Entry**	**SP**
MECH 731	**-**	**Modern Methods of Orbit Determination**	**SU**

C4ISR Systems

Design of military C4ISR systems have interrelated aspects of basic communications, information warfare and software intensive system architecture. The C4I Systems program is designed to develop technical expertise in a broad background in C4I systems, providing a technical foundation to better understand, develop, acquire, manage and employ the advanced military C4I systems used by the Department of Defense.

CSCE 525	**-**	**Introduction to Information Warfare**	**SP/SU/FA**
EENG 571	**-**	**Satellite Communications**	**WI**
EENG 651	**-**	**C4I Systems**	**SP**

Computational Fluid Dynamics

Computational methods for solving equations of motion for fluid mechanics and their various special cases are addressed. For this sequence, the student should have some knowledge of linear algebra and a good background in FORTRAN and compressible flow.

AERO 551	**-**	**Numerical Methods for Computational Fluid Dynamics**	**FA**
AERO 652	**-**	**Computational Fluid Dynamics**	**WI**
AERO 753	**-**	**Adv Computational Fluid Dynamics**	**SP**
AERO 543	**-**	**Adv Computational Modeling for Aerodynamics (Optional)**	**FA**

Control and Optimization Theory

This sequence enables the student to formulate and solve a broad class of optimization problems related to the design and control of aerospace systems. Variational calculus and Pontryagin's Maximum Principle have direct application in optimization for aircraft flight performance and in spacecraft and robot trajectory planning. Modern optimal control based on these principles finds use in the multivariable control requirements of aerospace systems. Robust control techniques make it possible to ensure stability and some measure of performance in the face of uncertainty, and non-linear control methods offer alternatives to the traditional method of linearization and gain scheduling. Prerequisite for the sequence is a basic course in linear systems analysis. MATH 521 (Linear Algebra) is a recommended elective that complements this sequence. Only one optimization course can be used to satisfy the requirements of this sequence. Choose two courses to take with ASYS 565 to complete this sequence.

ASYS 565	**-**	**Control and State Space Concepts (Required)**	**WI**
ASYS 765	**-**	**Robust Control**	**SP**
or EENG 765		**Stochastic Estimation and Control**	
ASYS 625	**-**	**Non-Linear Systems Analysis and Control**	**SU**
MECH 620	**-**	**Systems Optimization**	**WI**
or MECH 622		**Functional Optimization & Optimal Control**	**SP**

Digital Avionics Applications and Design

This sequence will give the student a background in digital avionics applications in both military and civilian applications. Topics include binary number systems, microprocessor architectures as well as the avionics systems typical of F-22 or B-777 architecture. The sequence also covers the theory and operation of coupling avionics design with GPS.

CSCE 581	**-**	**Fundamentals of Avionics**	**FA**
CSCE 681	**-**	**Digital Avionics II**	**WI**
EENG 533	**-**	**Navigation Using GPS**	**WI**

Electronic and Optical Materials

This sequence provides a foundation in chemical and physical properties of materials that are important to electronics and optics applications. The sequence is most beneficial to those who will be modeling, analyzing or conducting experiments related to electrical or optical aerospace systems.

MATL 620	**-**	**Chemistry of Materials**	
PHYS 670	**-**	**Introduction to Solid State Physics**	
MATL 672	**-**	**Optical Properties of Materials**	**SU**

Estimation

Provides a rigorous treatment of the design of control systems for aerospace vehicles that are subject to measurement noise, random disturbances, and parameter uncertainty that cannot be modeled adequately by deterministic methods. Includes the design and digital implementation of Kalman filters, adaptive and nonlinear filters, and stochastic digital controllers.

EENG 765	**Stochastic Estimation & Control I**	**WI**
EENG 766	**Stochastic Estimation & Control II**	**SP**
EENG 768	**Stochastic Estimation & Control III**	**SU**

Finite Element Analysis

This sequence is designed to give the student a background in the use and practical application of finite element analysis as it applies to structural materials. The sequence is most beneficial to those who will be assigned to analysis groups, which use finite element methods to model structures for either static or dynamic applications. Students will be capable of developing finite element computer codes or modifying and supplementing existing codes to solve current problems. The prerequisites for the sequence are a good background in matrix algebra, analysis of simple structural members, and computer programming.

MECH 542	**-**	**Intro to Fin Elem Anal & Computer-Aided Design**	**WI**
MECH 642	**-**	**Finite Element Methods for Structural Analysis I**	**SP**
MECH 644	**-**	**Finite Element Methods II**	

Mechanics and Control of Space Structures

Prepares students to analyze the dynamics and control of both rigid and flexible spacecraft.

MECH 515	**-**	**Theory of Vibrations**	**WI/SU**
ASYS 765	**-**	**Robust Control**	**SP**
MECH 722	**-**	**Control of Flexible Spacecraft**	

Optimization

Optimization provides the tools and techniques necessary to develop balanced designs, which are subject to one or more constraints.

OPER 510	**-**	**Deterministic Operations Research**	**WI**
OPER 610	**-**	**Linear Programming and Network Flows**	**SP**
OPER 612 **or MECH 620**	**-**	**Nonlinear Programming** **Systems Optimization**	 **WI**
OPER 613	**-**	**Integer Programming**	**SU**
OPER 615	**-**	**Large-scale System Optimization**	
MECH 622	**-**	**Functional Optimization & Optimal Control**	**SP**

Reliability

This sequence enables the student to identify and model mathematically the reliability of functional types of operational systems. These statistically based courses explore applications to components and systems, which demonstrate various operations failure, and restoration distributions. Courses in probability and statistics are prerequisites for the sequence.

	SENG 585	**-**	**Reliability Theory in Systems Design**	**WI**
	SENG 685	**-**	**Reliability Engineering**	**SP**
	SENG 687	**-**	**Advanced Topics in Reliability**	**SU**
	or STAT 537 – Introduction to Statistics			
or				
	STAT 687	**-**	**Mathematics of Reliability Theory I**	**SU**
	STAT 697	**-**	**Mathematics of Reliability Theory II**	
	OPER 746	**-**	**Topics in Advanced Reliability**	

Rocket Propulsion

This sequence of courses is intended to provide students with a background in propulsion and energy systems as required for R&D assignments in rocket and missile systems. A course including high-speed internal flows is required as a prerequisite or may be waived by permission of the instructor.

MENG 633	**-**	**Fundamentals of Combustion**	**FA**
MENG 530	**-**	**Chemical Rocket Propulsion**	**WI**
MENG 531	**-**	**Space Propulsion and Power Systems**	**SP**

Space Facilities

This sequence of courses provides graduate astronautical students, in the space facilities specialty, the necessary background for their roles in the development of large permanent space facilities. This sequence is approved for students with a 4EFY Ed Code only.

MENG 530	**-**	**Chemical Rocket Propulsion**	**WI**
MECH 515	**-**	**Theory of Vibrations**	**WI/SU**
MENG 531	**-**	**Space Propulsion and Power Systems**	**SP**

Space Navigation

This sequence provides understanding of current methods of determining the location of aerospace vehicles. Knowledge of orbit mechanics is a necessary prerequisite.

EENG 533	**-**	**Navigation Using the Global Positioning System**	**WI**
MECH 731	**-**	**Modern Methods of Orbit Determination**	**SU**

And one of the following

EENG 534	**-**	**Fundamentals of Aerospace Instruments and Navigation Systems**	**WI**
EENG 633	**-**	**Advanced GPS Theory and Applications**	**SU**
EENG 765	**-**	**Stochastic Estimation & Control I**	**WI**
ASYS 765	**-**	**Robust Control**	**SP**

Space Systems

This sequence is designed to give students broad knowledge of past and current space systems. It will also provide an in depth understanding of how typical spacecraft subsystems are designed and integrated into an operational vehicle. This sequence is only for non-GSS and non-GA students:

ASYS 631	**-**	**Spacecraft Systems Eng**	**SP**

and two of the following:

ASYS 530	**-**	**Intro Space Ops -or- ASYS 535 - Mil Space App**	**FA**
MECH 532	**-**	**Introductory Spaceflight Dynamics**	**FA/WI**
MECH 632	**-**	**Intermediate Spaceflight Dynamics**	**SP**
PHYS 519	**-**	**Space Environment**	
PHYS 521	**-**	**Space Surveillance**	
EENG 571	**-**	**Satellite Communications**	**WI**
EENG 533	**-**	**Navigation Using the Global Positioning System**	**WI**

Space Vehicle Design

This sequence is designed to give students in-depth knowledge of all aspect of spacecraft design and test. The sequence combines analytical design with laboratory tests of spacecraft systems.

ASYS 631	**-**	**Spacecraft Systems Eng**	**SP**
ASYS 632	**-**	**Satellite Design and Test**	**SU**
		and one of the following:	
MECH 719	**-**	**Vibration Damping and Control**	**FA**
MECH 542	**-**	**Introduction to Finite Element Analysis and Computer-Aided Design**	**WI**

NOTE: GSS students should choose both MECH 542 and MECH 719.

Structural Analysis

This sequence prepares students to perform detailed analysis of complex aerospace structures. For the following four-course sequence, the student must take at least three courses of the five. However, any course used as part of one sequence may not be counted in another sequence.

MECH 500	**-**	**Fundamentals of Solid Mechanics**	**FA**
MECH 600	**-**	**Elasticity**	**WI**
MECH 601	**-**	**Introduction to Time-Dependent Material Behavior**	**SU**

Structural Materials

This sequence of courses provides a treatment of advanced topics in modern aerospace materials and material-related design problems. The approach taken is that of mechanics rather than metallurgy. MATL 545 may replace MECH 500 or MECH 545 if these courses are part of a different sequence.

MECH 500	**-**	**Fundamentals of Solid Mechanics**	**FA**
or MECH 545		**Aerospace Structural Analysis**	**WI/SU**
MECH 541	**-**	**Mechanics of Composite Materials**	**WI**
MECH 601	**-**	**Introduction to Time-Dependent Material Behavior**	**SU**
and/or			
MECH 605	**-**	**Fracture Mechanics**	**SP**
MATL 545	**-**	**Mechanical Properties of Materials (Optional)**	**WI/SU**

Systems Engineering

This sequence provides a coherent framework for engineering design of complex systems and develops several tools that are important to the design process. In addition to the four core courses listed below, a capstone design project or suitable substitute will qualify the student for a Graduate Certificate in Systems Engineering. Students interested in completing the Graduate Certificate program should consult the curriculum chair for Systems Engineering.

SENG 520	**-**	**Systems Analysis for Design**	**SU/FA**
CSCE 590	**-**	**Engineering Software Intensive Systems**	**FA/SP**
SENG 640	**-**	**System Architecture**	**FA/WI**
SENG 610	**-**	**System Engineering Process and Management (Optional)**	**WI/SP**

Vibration Damping and Control

This sequence prepares students to analyze structural vibrations and design effective and efficient vibration suppression schemes using either passive or active means, preparing students for R&D assignments in either air or space technology. Courses in basic dynamics and linear systems are prerequisites for this sequence.

ASYS 565	**-**	**Control and State Space Concepts**	**WI**
MECH 515	**-**	**Theory of Vibrations**	**WI/SU**
MECH 719	**-**	**Vibrations Damping and Control**	**FA**
MECH 610	**-**	**Continuous Vibration (optional)**	**SP**

NOTE: GAE students are required to take ASYS 565. GA students are required to take MECH 500. GMS, GSE, and GSS students are required to take ASYS 565.

CHAPTER 7: THESIS

7.1 Thesis Topic and Faculty Advisor Selection

Thesis topic selection is an important choice in your AFIT program. Full time thesis students will attend the short course review before the fall quarter to help you become familiar with the department faculty and the research topics available. Due to a shortage of students needed to perform funded research, you may be required to select a funded topic. The time to make your selection of a thesis advisor is during the winter quarter. You must submit a topic selection statement signed by your advisor and yourself by the end of the 10th week of the winter quarter. This statement is a one-line identification of your general topic and the faculty advisor. A sample/template of the statement is located on the L: drive, ENY Student folder, THESIS TOPIC Ltr folder. A printed copy signed by the student, thesis advisor, and Department Head will be turned in to the Department Education Technician.

7.2 Preparation of the Prospectus

Once you have chosen a topic and a faculty member has agreed to be your thesis advisor, your next task is to prepare a prospectus. Generally, this is done by the end of the 2nd week of the spring quarter but must be completed before the beginning of the 1st quarter for which the student Ed Plan has AERO 799 credit. Out-of-department theses need to be enrolled for that department's AERO 799 equivalent. The prospectus is used for several purposes: assignment of advisory committee, allocation of laboratory resources, and the safety review of experimental theses. A template is located on the L: drive, ENY Student folder, PROSPECTUS folder. Completion of the prospectus is electronically sent to the thesis advisor and if accepted the advisor will forward it to a Department Education Technician.
The memorandum should include the following information:

a. Your name

b. Tentative title

c. Name of thesis advisor

d. A short description, to include what you propose to do, how you propose to do it, and the nature and utility of the anticipated results

e. Required support, i.e., laboratory facilities and/or computers

f. Suggested committee members

g. Sponsor name and organization (if any)

h. Sequences/Options

7.3 Thesis Advisory Committee

There are two faculty members besides your advisor on your thesis committee. All three vote on your thesis grade. Sponsors and other people related with the thesis research may be non-voting readers. Committee members may be from other departments, but, if so, the members should be asked to initial the prospectus to indicate their willingness to serve on your committee.

7.4 Progress Reporting

You will be required to report your progress to your thesis committee on a regular basis. Your advisor will delineate this requirement.

7.5 General Thesis Information

7.5.1 Style and Format

"A Style Guide for Theses and Dissertations," is published by AFIT and available for students on the AFIT website or a paper copy available in the Research Department. The style guide explains in detail all mandatory requirements to be met. Your thesis advisor may impose additional stylistic requirements.

In particular, you will need to pay as much attention to the clarity and margins of your figures and computer listings as you do to the thesis text. All must pass the standards of the Defense Technical Information Center, and if not sufficiently legible, the thesis will not be accepted for distribution.

7.5.2 Classified Theses

If you use any information that will cause your thesis to have other than unlimited distribution, coordinate carefully with your thesis advisor (and sponsor if you have one). Classified (up to Secret) MS theses are permitted.

7.5.3 Thesis Designator

The thesis advisor's Department Education Technician will assign a thesis designator for each thesis. The typical thesis designator is of the form **AFIT/***PROG***/ENY/***YY-MNN*, where *PROG* is replaced by the appropriate program designator (i.e., GA, GAE, GMS, or GSS) and *YY-MNN* denotes graduation year and month, and sequence number of your thesis (e.g., 06M-12.) The **ENY** denotes that your thesis advisor is a faculty member of the Department of Aeronautics and Astronautics (AFIT/ENY) and that you have registered for the course AERO 799. This will be different for out-of-department theses. Note: GSS students who conduct a group study will submit their "group design study" in final thesis format.

7.5.4 Thesis Due Dates

TIMELINE FOR GRADUATES

ITEM	PROGRAM WEEK	POINT OF CONTACT	09J-DATE(s) (Estimated)
Thesis topic and Advisor selected- turn in memo with signatures	2nd qtr- week 1	Department Education Technician	3 Oct 08
Prospectus submitted to Thesis Advisor electronically	2nd qtr - week 6	Department Education Technician	7 Nov 08
Thesis Designator number assigned	4th qtr – week 1	Department Education Technician	3 Apr 09
Draft of Thesis to Advisor	4th qtr – week 6	Advisor	8 May 09
Draft of thesis to readers	4th qtr – week 7	Readers	15 May 09
Thesis Presentation Day	4th qtr – week 9	Department Education Technician	28 May 09
Original Thesis, all copies & forms submitted	4th qtr – week 10	Department Education Technician	9 Jun 09
End of program review	4th qtr – week 11	Department Education Technician	15-17 Jun 09
GRADUATION	4th qtr – week 12	Student Services/Department Education Technician	18 Jun 09

ITEM	PROGRAM WEEK	POINT OF CONTACT	2010M -DATE(s) (Estimated)
Thesis topic and Advisor selected- turn in memo with signatures	2nd qtr-week 6	Department Education Technician	9-13 Feb 09
Prospectus submitted to Thesis Advisor electronically	3rd qtr –week 2	Department Education Technician	8 Apr 09
Thesis Designator number assigned	6th qtr – week 1	Department Education Technician	8 Jan 10
Blue Dart submitted to PA	6th qtr – week 2	Submit to PA then to AU Dept Ed Tech	15 Jan 10
Draft of Thesis to Advisor	6th qtr – week 6	Advisor	12 Feb 10
Draft of thesis to readers	6th qtr – week 7	Readers	19 Feb 09
Thesis Presentation Day	6thqtr – week 9	Department Education Technician	3-5 Mar 10
Original Thesis, all copies & forms submitted	6th qtr – week 10	Department Education Technician	16 Mar 10
End of program review	6th qtr – week 11	Department Education Technician	17-19 Mar 10
GRADUATION	6th qtr – week 12	Student Services/Department Education Technician	25 Mar 10

ITEM	PROGRAM WEEK	POINT OF CONTACT	2011M -DATE(s) (Estimated)
Thesis topic and Advisor selected- turn in memo with signatures	2nd qtr-week 6	Department Education Technician	12 Feb 10
Prospectus submitted to Thesis Advisor electronically	3rd qtr –week 2	Department Education Technician	9 Apr 10
Thesis Designator number assigned	6th qtr – week 1	Department Education Technician	7 Jan 11
Blue Dart submitted to PA	6th qtr – week 2	Submit to PA then to AU Dept Ed Tech	14 Jan 11
Draft of Thesis to Advisor	6th qtr – week 6	Advisor	11 Feb 11
Draft of thesis to readers	6th qtr – week 7	Readers	18 Feb 11
Thesis Presentation Day	6thqtr – week 9	Department Education Technician	3-4 Mar 11
Original Thesis, all copies & forms submitted	6th qtr – week 10	Department Education Technician	17 Mar 11
End of program review	6th qtr – week 11	Department Education Technician	22 Mar 11
GRADUATION	6th qtr – week 12	Student Services/Department Education Technician	24 Mar 11

7.5.5 Grade Determination/Incomplete

The grade on the thesis is a collective decision reached by the entire committee. Your faculty advisor will give you your thesis grade. If you do not complete your thesis in time, you will receive the grade of "Incomplete" and will not graduate with your section. Further, before leaving AFIT you will be required to develop a schedule, approved by the thesis advisor and department head, for completion with new dates. Failure to develop such a schedule will lead to the grade of "F" being assigned at the end of the 6th week of the following quarter.

7.5.6 Thesis Grading Guidelines

Student Name: ___________________________Grade: _____

Committee Member: _________________________

Date: ___________

Factor	A	A-	B+	B	≤**B-**
Technical Accuracy	Extremely rigorous and accurate	Accurate work	Questionable accuracy	Minor inaccuracies	Significant inaccuracies
Contribution to Field	Innovative and important	Significant	Some relevance	Little relevance	No relevance
Initiative/Independence	Go-getter	Significant self-directed progress and ideas	Works well under supervision	Required close supervision	Extremely close supervision
Level of Effort	Dedicated and very hard working	Hard working	Significant effort	Some effort	Little effort
Problem Difficulty/Scope	Difficult problem and/or many issues addressed	Significant problem	Straightforward problem with little risk	Easy problem	Comparable to a class project
Publishable	Journal	Conference			
Thesis Document/Defense	-Very clear, concise, complete, organized -Exceptionally strong understanding	-Clear, concise, complete, organized -Demonstrates good understanding	-Sometimes unclear & difficult to follow -Understanding appears tenuous	-Poorly expressed ideas, incomplete -Some lack of understanding	-Muddled and disorganized -Major lack of understanding
Editing (First Draft)	Minor Modification	Some Reworking	Significant Reworking	Extensive Reworking	Deficient

CHAPTER 8: FACULTY

8.1 Faculty Summary

Fluid Mechanics and Energy Transmission

- Branam
- Franke
- Greendyke
- Hartsfield
- Huffman
- King
- Lofthouse
- Polanka
- Reeder

Dynamics, Systems, and Controls

- Ayres
- Caylor
- Cobb
- Decker
- Harmon
- Hicks
- Kunz
- Liebst
- Shearer
- Swenson
- Wiesel

Solid Mechanics and Structures

- Black
- Mall
- Palazotto
- Ruggles-Wrenn
- Torvik

8.2 Adjunct Faculty

Dr. Philip S. Beran
BS, MS, PhD
Adjunct Associate Professor
AFRL/RB

Maj. Paul Blue
Adjunct Instructor
BS, MS
US STRATCOM

Dr. Larry W. Byrd
BS, MS, PhD
Adjunct Assistant Professor
AFRL/RB

Dr. Jose A. Camberos
BS, MS, PhD
Adjunct Assistant Professor
AFRL/RB

Dr. Robert Canfield
BS, MS, PhD
Adjunct Professor
Virginia Tech University

Dr. Michael J. Caylor
BS, MS, PhD
Adjunct Professor
AFIT/EN

Dr. Thomas A. Eason III
BS, MS, PhD
Adjunct Professor
AFRL/RB

Dr. Geoff E. Fair
BS, MS, PhD
Adjunct Assistant Professor
AFRL/RX

Dr. Michael J. Flanagan
BS, MS, PhD
Adjunct Assistant Professor
AFRL/RZ

Dr. Tommy J. George
BS, MS, PhD
Adjunct Assistant Professor
AFRL/TEFF

Dr. William Gray
BS, MS, PhD
Adjunct Instructor
USAF Test Pilot School

Dr. Randall S. Hay
BS, MS, PhD
Adjunct Assistant Professor
AFRL/RXLN

Dr. Michael Heil
BS, MS, PhD
Adjunct Assistant Professor
Ohio Aerospace Institute

LtCol Jorris
BS, MS, PhD
Adjunct Assistant Professor
USAF Test Pilot School

Dr. Ray Maple
BS, MS, PhD
Adjunct Assistant Professor
Hawker Beechcraft

Maj. Shad Reed
BS, MS, PhD
Adjunct Assistant Professor
AFRL/RZ

Lt. Col. Michael J. Shepherd
BS, MS, PhD
Adjunct Assistant Professor
USAF Test Pilot School

Dr. Edward W. Swim
BS, MS, PhD
Adjunct Assistant Professor
US Military Academy (West Point)

Dr Nate Titus
BS, MS, PhD
Adjunct Assistant Professor
Aerospace Corp.

8.3 Faculty Biographies

Ayres, Bradley J.
Visiting Professor, 255-3355 x3422

BS, Chemical Engineering, University of Missouri, Columbia, 1982; M.A., Procurement and Acquisition Management, Webster University, St. Louis, 1991; M.S., Software Systems Management, Air Force Institute of Technology, 1992; Ph.D., Business Administration specializing in MIS, Florida State University, 2003. Dr. Ayres' research interests include institutional theory and applying organizational theory and organizational behavior to systems engineering management. His is a member of the Project Management Institute and the International Council on Systems Engineering.
E-mail = Bradley.Ayres.Ctr@afit.edu

Black, Jonathan T.
Assistant Professor of Aerospace Engineering, 255-3636 x4578

BS Industrial Engineering, University of Illinois at Urbana-Champaign, 2001; MS Mechanical and Aerospace Engineering, Joint Institute for Advancement of Flight Sciences (joint NASA Langley Research Center and George Washington University program), 2003; PhD Mechanical Engineering, University of Kentucky, 2006. Dr. Black's research interests include lightweight and inflatable aerospace structures, structural and nonlinear dynamics, noncontact measurement systems, and computational structural mechanics. His dissertation work involved using novel measurement and modeling techniques to characterize the static and dynamic behavior of new, stiff, self-supporting lightweight membrane aerospace structures. E-mail = Jonathan.Black@afit.edu.

Branam, Richard D., Lt Col, USAF
Assistant Professor of Aerospace Engineering, 255-3636 x7485

BS, Aerospace Engineering, The Ohio State University, 1993; MS, Aeronautical Engineering, Air Force Institute of Technology, 1997; PhD, Aerospace Engineering, The Pennsylvania State University, 2005. Major Branam's primary research areas of interest are rocket propulsion, satellite propulsion and hypersonics. Current research includes investigation of vehicle aspects and performance through numerical techniques to include conventional computation fluid dynamics as well as molecular dynamic simulations and other available tools. The research compares experimental results with models and explore techniques and procedures for improving both model and vehicle performance. Major Branam has published several conference and journal articles. He is a Member of AIAA. Email: richard.branam@afit.edu

Caylor, Michael J.
Assistant Professor of Aerospace Engineering, 255-3636 x7104

BS, Univ of Notre Dame, 1981; MS, Univ of Notre Dame, 1983; PhD, Univ of Notre Dame, 1993. Dr. Caylor's research interests include astrodynamics, rocket propulsion, and space systems. His previous assignments include Associate Dean of the AFIT Graduate School, Small Satellite Program Manager and Director of Labs and Research within the Astronautics

Department at the USAFA, Sector Chief of the Weapons Systems Sector in AFRL Headquarters, and as a technical program manager within the AFRL Directed Energy Directorate. Email = michael.caylor@afit.edu

Cobb, Richard G.
Assistant Professor of Aerospace Engineering, 255-3636 x4559

BS, the Pennsylvania State University, 1988; MS, Air Force Institute of Technology, 1992; PhD, Air Force Institute of Technology, 1996. Dr. Cobb's research interests include dynamics and control of flexible space structures, vibration isolation and control, system identification techniques and applied applications of optimal control theory. His dissertation addressed development of system identification and structural damage identification techniques for space applications using measured vibration data. He is a member of Tau Beta Pi and a Senior Member of AIAA. E-mail = Richard.Cobb@afit.edu.

Decker, Douglas D., Lt Col, USAF
Assistant Professor of Aerospace Engineering, 255-3636

B.S., University of Kansas, 1987; M.S., Air Force Institute of Technology, 1994; Ph.D., Air Force Institute of Technology, 2004. Lt Col Decker's research interests include optimal control, optimization, applications of optimal control (especially to propulsion systems), cooperative control of unmanned air vehicles, search theory, and orbital mechanics. He is a member of Sigma Gamma Tau, Tau Beta Pi, and AIAA. E-mail = Douglas.Decker@afit.edu.

Franke, Milton E.
Professor Emeritus of Aerospace Engineering, 255-3636 x4720

BME, University of Florida, 1952; MSME, University of Minnesota, 1954; PhD, The Ohio State University, 1967. Research interests include fluid transmission lines, thrust vector control, high-lift aerodynamics, circulation control, fluidics, acoustics, cavity oscillations, thrust augmenting ejectors, aircraft bombing systems, heat transfer, electrostatic cooling, boundary layers, space propulsion, and engineering systems. Dr. Franke has authored or co-authored over 100 technical articles. He holds five patents and was the recipient of the AFIT Charles A. Stone Award in 1986 and the AFIT Bernard A. Schriever Award in 1993. Dr. Franke is a retired colonel, US Air Force Reserve. He served as Vice President for Communications of ASME (1990-1992), Vice President for Systems and Design of ASME (1993-1996), and Vice Chair, Council on Engineering of ASME (1995-1996). He currently chairs a committee of the Board of Governors of ASME. He is a Fellow of ASME, and an Associate Fellow of AIAA. E-mail = Milton.Franke@afit.edu

Greendyke, Robert B.
Associate Professor of Aerospace Engineering, 255-3636 x4567

B.B.A., Baylor University, 1979; B.S., Texas A&M University, 1986; M.S., Texas A&M University, 1988; Ph.D., Texas A&M University, 1998. Dr. Greendyke's research interests are in the field of Computational Fluid Dynamics with specialties in hypersonics re-entry flows, rarefied gas dynamics, plasma flows, and molecular computational methods. He has published over 30 conference papers, journal articles, technical reports, and book chapters. Previous to employment at AFIT, Dr. Greendyke was first a contract Research Scientist at NASA Langley Research Center's Aerothermodynamics Branch. After NASA, he taught for seven years at the University of Texas at Tyler where he was twice voted "Professor of the Year" in the College of Engineering and Computer Sciences, and also named an Associate Fellow of the AIAA. Email = robert.greendyke@afit.edu

Harmon, Frederick G., Lt Col, USAF
Assistant Professor of Aeronautical Engineering, 255-3636 x7478

BS, Electrical Engineering, Embry-Riddle Aeronautical University, 1992; MS, Electrical Engineering, Air Force Institute of Technology, 1996; PhD, Mechanical Engineering, University of California-Davis, 2005. Lt Col Harmon's research interests include the cooperative control of multiple unmanned aerial vehicles, autonomous vehicle guidance and control, bio-inspired control and technologies, nonlinear control, alternative energy systems, hybrid-electric technology, and fuel cell technology. His previous assignments were in research labs, intelligence organizations, and flight test squadrons (USAF TPS graduate). Lt Col Harmon is a member of AUVSI, AIAA, and IEEE. E-mail: frederick.harmon@afit.edu

Hartsfield, Carl R., Lt Col, USAF
Assistant Professor of Aerospace Engineering, 255-3636 xXXXX

BS Aerospace Engineering, Georgia Institute of Technology, 1991; MS Aeronautical Engineering, Air Force Institute of Technology, 2001; PhD Astronautical Engineering, Naval Postgraduate School, 2006. Prior to his assignment to AFIT, Lt Col Hartsfield was assigned to the National Reconnaissance Office, managing the development of adjunct payloads for overhead National Asset programs. Lt Col Hartsfield's previous research includes radioactive isomers as a power source for jet aircraft and mixing and combustion in rocket exhaust plumes. Lt Col Hartsfield is a member of Sigma Gamma Tau. E-mail = Carl.Hartsfield@afit.edu.

Huffman, Richard E., Lt Col, USAF
Assistant Professor of Aerospace Engineering, 255-3636x7490

BS Aeronautical and Astronautical Engineering, Purdue University, 1994; MS Aeronautical Engineering, AFIT, 1995; PhD Aerospace Engineering, University of Illinois at Urbana-Champaign 2007. Maj Huffman's research interests include the improvement of aircraft survivability and advances in weapon design as well as experimental research into combustion and plasma phenomena. Previous research has included feasibility of airborne gravity gradiometers for use in covert navigation, the effect of plasma on turbulence in free shear layers, and the flow field characteristics of supersonic wrap-around fins used in missile control. Maj Huffman is a USAF TPS graduate and was assigned to F-22 flight test as ops lead for weapon separation testing. Maj Huffman is a member of Tau Beta Pi, and senior member in the AIAA. E-mail = richard.huffman@afit.edu

Hicks, Kerry D., Lt Col, USAF
Assistant Professor of Aerospace Engineering, 255-3636 x4568

BS Aeronautical and Astronautical Engineering, University of Illinois, 1985; MS Astronautical Engineering, Air Force Institute of Technology, 1986; PhD Astronautical Engineering, Air Force Institute of Technology, 1989. Lt Col Hicks' research interests include astrodynamics, re-entry dynamics, and electric space propulsion with emphasis on numerical solutions and mathematical modeling. He has published several conference papers and journal articles as well as DoD publications. He is a member of Tau Beta Pi and a Senior Member of AIAA. E-mail = Kerry.Hicks@afit.edu

King, Paul I.
Professor of Aerospace Engineering, 255-3636 x4628

BSME, Arizona State University; MS Astronautics, Air Force Institute of Technology; PhD, Oxford University, England. Dr. King's research interests in turbomachinery, scramjets and pulse detonation engines include experiments, computations and simulations of components and full engine performance. Dr. King has served as a consultant for NASA Lewis Research Center and has conducted funded research for NASA, for the Air Force Weapons Laboratory and for AFOSR. Professor King has also served on the faculty of the US Air Force Academy and Cleveland State University. E-mail = Paul.King@afit.edu

Kunz, Donald L.
Associate Professor of Aerospace Engineering, 255-3636 x4548

BS, Aerospace Engineering, Syracuse University, 1971; MS, Aerospace Engineering, Georgia Institute of Technology, 1972; PhD, Aerospace Engineering, Georgia Institute of Technology, 1976. Dr. Kunz’s research interests include rotorcraft dynamics, vibrations, and loads, structural dynamics, aeroelasticity, multibody dynamics, smart structures, and computational structural mechanics. He has published more than 60 journal articles, conference papers, and technical reports. Prior to coming to AFIT, Dr. Kunz worked at the US Army Aeroflight dynamics Directorate, McDonnell Douglas Helicopter Company, Old Dominion University, and the US Army Aviation and Missile Command. He is an Associate Fellow of AIAA; a member of AHS, and ASME; and a licensed professional engineer in the commonwealth of Virginia. E-mail = donald.kunz@afit.edu

Liebst, Bradley S.
Professor and Head, Department of Aeronautics & Astronautics, 255-3636 x4636

BS, Wichita State University, 1978; MS, Massachusetts Institute of Technology, 1979; PhD, Massachusetts Institute of Technology, 1981. Dr. Liebst's research interests include eigenstructure assignment and control, stability and control of aerospace vehicles, and passive and active control of large flexible structures. He has published over 30 articles and reports and chaired over 40 theses and dissertations. Prior to teaching at AFIT, Dr. Liebst was Assistant Professor of Aerospace Engineering for 6 years at the University of Minnesota where he was voted the 1987 Best Institute of Technology Professor. E-mail = Bradley.Liebst@afit.edu.

Lofthouse, Andrew J., Maj, USAF
Assistant Professor of Aerospace Engineering, 255-3636 x4537

BS Mechanical Engineering, Brigham Young University, 1997; MS Aeronautical Engineering, Air Force Institute of Technology, 2002; PhD Aerospace Engineering, The University of Michigan, 2008. Maj Lofthouse's research interests include all aspects of Computational Fluid Dynamics with specific interest in hypersonic reacting flows and nonequilibrium gas dynamics. He has published several conference papers and journal articles. He is a member of Tau Beta Pi and a Senior Member of AIAA. E-mail = Andrew.Lofthouse@afit.edu

Mall, Shankar
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BS, Banaras Hindu University, India, 1964; MS, Banaras Hindu University, 1966; PhD, University of Washington, 1977. Dr. Mall's research centers on composite materials, nanocomposites, MEMS, fatigue and fracture, and aerospace structures. Dr. Mall has authored over 350 papers. Dr. Mall is a Fellow of American Society of Mechanical Engineers and an Associate Fellow of AIAA. E-mail = Shankar.Mall@afit.edu.

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CHAPTER 9: RESEARCH FACILITIES

9.1 Introduction

The research laboratories of the Department of Aeronautics and Astronautics are equipped 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 three different buildings. Building 640 has 13,000 square feet of general laboratory facilities, building 644 with 5246 square feet of laboratory space housing a 44″ x 31″ wind tunnel, 5.0 kip shaker with digital controller, Simulated Satellite (SIMSAT II), vibration lab, an instrumentation lab, high pressure shock tube facility, 9.0 inch low velocity wind tunnel, and turbine cascade facility.

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 ft^3) air supply is available in Rooms 256, and 258, also 250 psi (800 ft^3) and 2500 psi (44 ft^3) are located in Rm 258 of Building 640. Rooms 256, 258, and 254 have two overhead electrical buss bar systems. The two systems include 440-volt three-phase, 220-volt three-phase.

9.2 Facilities Overview

GENERAL

Facility	**Key Components**
Computational Dynamics and Design Laboratory Bldg 640 Rm 210 B	Workstations, microcomputers, and peripherals
Systems Engineering Project Room Bldg 641 Rm 324	Computer terminals, tables, and storage
Systems Engineering Project Room Bldg 642, Library 3rd Floor *Conference Rm*	Computer terminals, tables, and storage
Laboratory Lecture and Meeting Room Bldg 644 Rm 104	Space for lectures or meetings
Technician Work Area Bldg 644 Rm L156	Technician office and work area
Instrumentation Laboratory Bldg 644 Rm L156	Room for laboratory coursework Benches, shakers, modal analyzer
Experimental Methods Bldg 644 L-156	Two feedback and control experiments four data acq. System A/D, D/A, Digital I/O

FLUID MECHANICS AND ENERGY TRANSMISSION

Facility	**Key Components**
Computational Dynamics and Design Laboratory Bldg 640 Rm 210 B	High performance computers for computational fluid dynamics
Fluid Flow Laboratory Bldg 640	12-in Low Speed Wind Tunnel
Shock Tube Laboratory Bldg 644 RM L154	4" X 8" Shock Tube
Heat Transfer, Fluid Flow, Vibration High Speed Aerodynamics Micro-Space Propulsion Testing Bldg 640 Rm 256	Supersonic Pressure Vacuum Wind Tunnel Hypersonic Blow Down Wind Tunnel Variable Mach Blow Down Wind Tunnel Space Environment Cells
Combustion Lab Bldg 640 Rm 258	Turbojet Combustor Research Facility Advanced Laser Combustion Diagnostics Atmospheric Pressure Burner Rig High Velocity Oxygen Facility
Water Tunnel Facility Bldg 644 L154	Rolling Hills Educational Water Tunnel 7″ by 10″ Test section
Low Speed Wind Tunnel Bldg 644 L154	31″ x 44″ Test section High Pressure Shock Tube
Advanced Space Propulsion Research Bldg 644 Rm L156	Space Environment Chamber Advanced Satellite Propulsion Diagnostics
Turbine Engine Demonstrator	Engine and instrumentation

DYNAMICS, SYSTEMS, AND CONTROLS

Facility	Key Components
Materials Analysis Laboratory Bldg 640 Rm 251	Equipment for Microscopic Analysis of Materials, Scanning Electron Microscope 5.0 Kip Test Stage
Computational Dynamics and Design Laboratory Bldg 640 Rm 210 F	High Performance Computers for guidance, navigation and control system design and simulation
Computer-Aided Design and Manufacturing Laboratory Bldg 640 Rm 250	Stratasys 3-D Modeling Faro's 3-D Digitizer
Systems Engineering Project Room Bldg 641 Rm 324	Space, terminals for Systems Engineering students
Spacecraft Dynamics Bldg 644 L152A	AFIT Simulation Satellite (SimSat II) D-space Controller Wireless LAN
Spacecraft Tracking Bldg 644 L155AB	WAVE Scope 4x8 optical table (floating) 4x10 optical table (floating)
Vibration Lab Bldg 644 L153AB	PSV 400 3D Scanning Vibrometer MB Dynamics 5kip shaker 36″ x 30″ x 30″ Vacuum Chamber
Vibration Laboratory Annex Bldg 640 Rm 257	HP Modal Analysis System
Autonomous Guidance, Navigation and Control (GNC) Laboratory, Bld 640, Rm 261	High-fidelity vehicle simulations with control system hardware-in-the-loop for autonomous GNC design, simulation, and pre-test checkout. Ground and air vehicles for autonomous GNC demonstrations
Pilot-in-the-loop Simulation Laboratory Bldg 640, Rm 261	High-fidelity aircraft simulations with pilot-in-the-loop control interface and synthetic vision display

SOLID MECHANICS AND STRUCTURES

Facility	Key Components
Materials Analysis Laboratory Bldg 640 Rm L155A	Equipment For Microscopic Analysis of Materials, Scanning Electron Microscope 5.0 Kip Test Stage
Material Preparation Facility Bldg 644 L152A	Buehler Cutters, Polishers and Sonic Cleaners 3D Printer
Structures and Materials Testing Laboratory Bldg 640 Rm 254	State-of-the-art Materials Testing Facilities, High Temperature Ovens Smart Structures High Frequency Test Stand

9.3 Facility Descriptions

9.3.1 General

Building No. 640
Room No. 210

Function: Computational Dynamics and Design Laboratory

Area: 1650 Square Feet

This laboratory is the site of most of the department's computational facilities. Workstations, microcomputers, and peripherals are gathered in this laboratory to support computationally oriented research by faculty and students in fluid dynamics, solid mechanics, dynamics and controls, and systems engineering. Department students have open access to some laboratory resources for classroom exercises and class projects. A summary of hardware and software available in the laboratory is provided in Chapter 10.

Building No. 641
Room No. 324

Function: Systems Engineering Project Room

Area: 250 Square Feet

This room provides the necessary space and facilities for systems engineering students working on required projects. Computer terminals, tables, and storage are provided for their use.

Building No. 642
Room No. Library 3rd Floor *Conference Room*

Function: Systems Engineering Project Rooms

Area: 250 Square Feet

This room provides the necessary space and facilities for systems engineering students working on required projects. Computer terminals, tables, and storage are provided for their use.

Building No. 644
Room No. L104

Function: Laboratory Lecture and Meeting Room

Area: 672 Square Feet

This room is primarily used for briefings during scheduled laboratory course periods. When not required for scheduled classes, the briefing area is made available for departmental, meetings, thesis projects progress reports, and design course projects.

Building No. 644
Room No. L156A

Function: Technician Work Area, Minor Instrument Repair and Storage, and Model Modifications

Area: 655 Square Feet

The technicians of the Department of Aeronautics and Astronautics have their principal office and work area in Room 255. The function of the area is to provide a work area for new systems evaluation, instrument repair, calibration, model modifications, and secure storage for valuable instruments and supplies.

Building No. 640
Room No. 247

Function: Instrumentation Laboratory

Area: Instrumentation Lab: 806 Square Feet
Preparation and Storage Room: 352 Square Feet

This room is generally used for laboratory course work involving experimental fluid and solid mechanics. The fixed facilities include laboratory benches with multiple electrical outlets. These benches are used for preliminary instrumentation setup and calibration and also have four designated experimental mechanics workstations established. These four workstations consist of the following equipment.

a. Electrodynamic Shakers: Small electrodynamic shakers ranging from 10 to 50 pounds of force capacity with power amplifiers and can be driven by the function generator .

b. Free vibration demonstration rigs, used in experimental mechanics and instrumentation courses.

c. Modal Analyzers: Two modal analyzers are available for sharing between the four workstations. These modal analyzers are capable of providing auto- and cross-correlation and coherence functions as well as the system frequency response functions with the associated animated mode shapes as products of a modal analysis of a structural system.

d. Agilent LabPack Workstations: The Agilent LabPack Workstation is a single package unit that includes an oscilloscope, digital-multimeter, function generator, frequency counter and a DC power supply module.

e. Dell PC Computers: The Dell PC computers are LabPack models with analog-to-digital and digital-to-analog circuit boards included for digital data acquisition and control experiments.

f. Calibration Workstation: Several standards are available for instrument calibration they include; thermocouples, AC/DC and resistance standards, SPL calibrator, accelerometer standard and dead weight tester for pressure calibration.

g. PSV-400 very quickly gathers complete, calibrated vibration data from an entire structural area. Animations of structural resonance's can be viewed immediately after a scan is completed. These "operating deflected shapes" (ODS) are usually enough to identify which parts of a structure require reinforcement or damping, or which parts of the structure are generating noise. ODS is also a very accurate approximation of the actual mode shape, if the mode is not closely coupled to adjacent modes.

9.3.2 Fluid Mechanics and Energy Transmission

Building No. 640
Room No. 210F

Function: Computational Fluid Dynamics (CFD) Laboratory

Area: Approximately a 400 Square feet section Room 142

This laboratory is the site of computational hardware and software focused on the development testing and applications of CFD algorithms.

Building No. 640
Room No. 258

Function: Combustion Laboratory and Fluid Flow Test Facility

Area: 1099 Square Feet

a. 12 Inch Low Speed Wind Tunnel: A wind tunnel suitable for demonstrations and experiments at any air-speed from near zero to approximately 254 MPH is available that has a test section turbulence level below 0.25 percent. The tunnel is provided with a 5-component sting balance, which permits model positioning in both pitch and yaw. Studies may be conducted to determine forces and moments on various aerodynamics, aircraft, or non-aerodynamic models in the usable speed range of the tunnel.

b. Combustion Test Facility: An atmospheric pressure combustion test facility is suitable for demonstrations, evaluations and experiments on combustors and combustion systems. The facility has two legs of independently controllable (0-200SCFM main & 0-60SCFM cavity), heated (500F) air. Liquid and gaseous fuels may be used with overall equivalence ratios up to one and cavity equivalence ratios as high as $\phi_{cav} = 4$. The facility is fully instrumented for temperature, pressure and mass flows. Fuel-injector spray evaluation and testing is also available.

c. Data Acquisition Systems: Multi-channel data acquisition systems for logging and control of both facility and test rig are available for experiments done in the combustion test facility and the 12 inch low speed wind tunnel. A Malvern Spraytec particle size analyzer is capable of measuring particles and droplets in sizes ranging from 1.0 to 400 microns at a data rate of 2500 Hz. A full emissions test rack is capable of measuring HC, CO, CO_2, O_2, and NO_x in accordance with SAE Aerospace Recommended Practices.

d. The facility has a diagnostic system, which can provide a means to characterize specified flow fields by employing non-intrusive measuring techniques to include instantaneous Raman, Particle Image Velocimetry (PIV), Laser Induced Incandescence (LII) and Planar Laser-Induced Fluorescence (PLIF) and Laser Doppler Velocimetry (LDV). The system is a complete system with the capabilities of modular use to allow for further capabilities, specifically Coherent Anti-Stokes Raman Scattering (CARS) and Raman Spectroscopy. The Flame Calibration System provides accurate means to calibrate these advanced laser diagnostics and the use of infrared imaging for further flame characterization.

e. Atmospheric Pressure Burner Rig and High Velocity Oxygen Facility: High temperature testing of ceramic matrix composites (CMCs) as well as other advanced materials under temperature load simulating more realistic turbine engine conditions.

Building No. 640
Room No. 256

Function: High Speed Aerodynamics and Space Environment Chamber

Area: 1527 Square Feet

The AFIT High-Speed Aerodynamics Laboratory located in building 640, room 258, houses three wind tunnel facilities (Mach numbers ranging from 1.5 to 5.0), two high pressure air supply systems, and advanced laser velocimetry, hot-wire anemometry, and optical diagnostic equipment. These facilities and equipment are used to perform state of the art research in the areas of high-speed aerodynamics and propulsion.

a. Variable Mach Blow Down facility was designed and constructed by Aerolab, Incorporated. This facility has a 15.24 x 15.24 cm test section cross-section. The free stream Mach number is continuously variable over a range of 1.5 to 4.0. The run time varies from 10 to 35 seconds depending on the free stream Mach number. The stagnation pressure in this high Reynolds number facility peaks at 8.85 atm for the Mach 4.0 condition. Two Ingersoll-Rand compressors (housed in room 258) are used to fill the 22.7 m3 supply tank with aerodynamically clean and dry air (-75 °C) to a pressure of 13.6 atm. The tank recharge time is approximately 30 minutes.

b. Pressure-Vacuum Supersonic Wind Tunnel was designed and constructed in- house to perform basic research. This facility has a 6.35 x 6.35 cm test section cross-section. Currently two nozzle (M = 1.7 and 3.0) blocks are available. The facility was designed to provide a long (60.0 cm) constant pressure test section. A variable geometry wall was incorporated to control the streamwise pressure. The high pressure for this moderate Reynolds number facility is supplied by the Ingersoll-Rand system discussed above. A 12.0 m3 vacuum system is also used. At Mach 3.0, the system provides a 25-second run time. The recharge time for this system is about 5-7 minutes.

c. Hypersonic Blow Down WindTunnel was also designed and constructed in house. This facility has a 7.62 x 7.62 test section cross-section. The Mach number is 5.0. A 1.25 m3 air supply tank is charged to 170 atm with aerodynamically clean and dry air by a compressor/dryer/filter system housed in room 258. An in house designed and constructed pebble bed heater is used to heat the test air in order to prevent liquefaction of the oxygen during expansion to Mach 5.0. The stagnation temperature is maintained at 100° C by the heaters. The stagnation pressure held constant at a user-selected value in the range of 20.0 to 30.0 atm. The run times for this facility are limited by the heater system. Each of the three heaters provides about 20 to 30 seconds of constant temperature. The reheat time for the pebble beds is 1.0 to 2.0 hours.

d. Data Acquisition Systems: Multi-channel data acquisition systems for simultaneous recording of up to 20 channels are available for acquiring and processing data for experiments done in the blow down tunnel facilities. A high-speed schlieren visualization system is capable of digitally recording events at speeds of up to 16,000 frames per second. Full-model pressure and temperatures may be measured using a system, which incorporates a light source, high spatial resolution cooled CCD camera, and commercially available pressure and temperature sensitive paint. A Malvern Spraytec particle size analyzer is capable of measuring particles sizes ranging from 1.0 to 400 microns at a data rate of 2500 Hz.

e. Space Environment Cells: AFIT has two space environment cells specifically designed to test micro satellite propulsion systems such as the pulsed plasma thruster. These systems are stand alone test cells complete with multi channel data acquisition and control systems. Instrumentation includes various standard pressure and temperature sensors as well as a torsional thrust balance capable of measuring micro Newtons (10^{-6}).

Building No. 644
Room No. L152A

Function: Specimen Preparation and Polishing

Area: 270 Square Feet

The specimen preparation and polishing facility is comprised of a fume hood, Buehler Isomet 2000 cutter, Isomet low speed cutter, Phoenix 4000 sample preparation system, two Vibromet vibration polishers, Ultramet 2002 sonic cleaner, two Simpimet mounting presses. Preparation and polishing of metal matrix composites, ceramic composites, and other materials is essential in the property evaluation of new materials. This facility is an extension of the material testing facility located in Rm 254.

Building No. 644
Room No. L154

Function: Aerodynamic Test Facility and Space Environment Chamber

Area: 1980 Square Feet

The wind tunnel is an Open Circuit Wind Tunnel. It will attain a maximum airspeed of at least 230 feet/sec through a 31 "x 44" test section. The transverse velocity distribution across the test section and within the boundary layers is be within 1.0% of the mean. The turbulence measured at the test section centerline is less than 0.1% at full speed. The contraction Area Ratio is a minimum of 9.5:1. The ceiling and floor of the test section is fabricated from aluminum plate. Side doors are made of Plexiglas. These doors have gas-actuated hinges to provide easy access to the test section. A removable Plexiglas window is installed in the ceiling. A removable turntable is provided in the floor. High Pressure Shock Tube: The high-pressure shock tube is of modular construction with a rated maximum pressure of 10,000 psi. The shock tube internal diameter is 2 inches with a 1-inch wall thickness. The shock tube is composed of 10 sections each 5 feet long. Two of these sections are designed to mate with a double diaphragm section, which separates the tube into the driver, and driven sections. One of the ten sections is equipped with a set of 1/2-inch diameter windows and another special section has 1/2-inch by 8-inch windows. These are used for optical instrumentation. The primary function of the shock tube is to establish the high temperature, high pressure, and/or high velocity conditions desired for propulsion and heat transfer research.

Turbine Cascade Test Facility: Open return, angled wind tunnel for testing high-turning-angle turbine cascades. The flow is subsonic through a four-blade (three passage), low aspect ratio turbine cascade used for obtaining pressure and surface heat transfer data.

Water Tunnel Facility: The Model 0710 tunnel from Rolling Hills Research is equipped with a settling basin, flow straighteners and contoured walls on either side of the test section. Circulation is provided by a pump controlled by a variable frequency A/C motor, with mean test section velocities ranging from 0 to 5 inches per second. A tunnel wall support and dye wand are also available with the system.

Instrumentation: Instrumentation support for the wind tunnel facility includes: digital data acquisition system, several six component strain gage balance systems ranging in scale from nominally 8 lbf to 100 lbf, conventional pressure and temperature sensors, a two-channel hot-wire anemometer system, and a house air supply system for blowing studies. Models may be built using the Stratasys 3300 modeler or, alternatively, with a second Stratasys rapid modeling system. A Dantec stereo particle imaging velocimetry (SPIV) system incorporates two high resolution cameras and a dual-chamber Nd:YAG laser to interrogate flow fields for three component velocity measurements. In addition, a 3-component Dantec laser Doppler velocimetry system with a single-lens optical head can be used to measure velocity and turbulence statistics in the wind tunnel.

Space Environment Chamber: Stand alone testing and data acquisition system for advanced space propulsion testing and evaluation. The laboratory has a flight ready 200W Hall Thruster and all associated control and monitoring systems. The diagnostic systems include a microwave interferometer system for electron density measurements. The microwave interferometer system covers both Ku and Ka band of the electromagnetic spectrum. The interferometer system is on a rigid arm so it can travel in the XY directions with minimal vibrations in order to make measurements in two planes of plasma thrusters. Added to the microwave system are the infrared imaging capability and direct thrust measurements.

9.3.3 Dynamics, Systems, and Controls

Building No. 640
Room No. 250

Function: Computer-Aided Design and Manufacturing

Area: 250 Square Feet

This room is designed to provide an area to support the design of new and modified flight hardware. High-resolution computer workstations are provided as platforms for a number of computer-aided design software packages. Rapid prototyping of these computer models is available through a Stratasys fused-deposition modeling system connected directly to a workstation. Reverse engineering capability is provided through an extremely accurate, portable computer controlled measuring system. Data collection is possible on both laptop and workstation computer systems.

Function: Systems Engineering Project Room

Area: 250 Square Feet

This room provides the necessary space and facilities for systems engineering students working on required projects. Computer terminals, tables, and storage are provided for their use.

Building No. 644
Room No. L152

Function: Spacecraft Dynamics

Area: 270 Square Feet

The SIMSAT system supports satellite experimentation in areas of attitude control, precision pointing, and vibration suppression. The SIMSAT system consists of: (1) Space Electronics, Inc. Tri-Axis Spherical Air Bearing (spherical rotor, hollow shaft, mounting flanges, pedestal, and air compressor) which allows nearly frictionless three rotational degrees-of-freedom for a small scale satellite assembly, and (2) Small scale satellite assembly which consists of a Humphrey CF 75 3-axis gyroscope, 3-momentum wheels with motors and power amps, a dSPACE 32-input/32-output command and control processor, three 12-volt Power Sonic PS-12180 sealed lead-acid batteries, and a Radio LAN wireless LAN for real-time command/data transmission to/from a ground station PC running the dSPACE cockpit software. In addition to the three experiments, the lab contains two SUN Spare II workstations for numerical control/structure interaction analysis.

Building No. 644
Room No. L153

Function: Spacecraft Hardware Qualification Lab

Area: 576 Square Feet

The Spacecraft Hardware Qualification Laboratory supports prototype and flight hardware qualification testing of small satellites and satellite subcomponents. The facility is equipped for both random vibration testing and thermal/vacuum testing of flight hardware.

For vibration testing, the C40HP Electrodynamics (E-D) Shakers from MB reflects the latest in enhanced design and increased performance. The C-Series HP shakers have 2" of stroke, automatic payload re-centering, and force ratings ranging from 5,000 lbf. Classical waveforms include: half sine, saw tooth, triangle, and rectangle, user-supplied time history, i.e., the ability to perform tests from digitized time domain data, frequency Range: 1 - 4 kHz.

For Thermal/Vacuum testing, a custom built chamber by PHPK Industries can provides space environmental testing. The chamber accommodates testing of payloads of up to 200 lbs, with dimensions up to 30” x 30” x 36”. The chamber provides a vacuum environment down to $1x10^{-7}$ Torr, and computer controlled temperature ranging from -60 to + 100 deg C. The chamber is amply instrumented with thermal couples to support component testing.

As currently configured, the Spacecraft Hardware Qualification Lab is supporting hardware qualification testing of AFIT’s Rigidizable Inflatable Get-Away-Special Experiment (RIGEX) that launched on the Space Shuttle in 2008.

The Vibrations laboratory supports passive and active vibration suppression research. The facility includes an 8'x4' isolated granite backed optical table for mounting experimental fixtures in an isolated room to minimize disturbances. Standard modal test excitation/instrumentation is available. Data acquisition is provided by an HP VXI based 16 channel system or a dSpace 32-in, 32-out real-time control system. Current projects include vibration suppression of a bladed-disk assembly and a space antenna model.

Building No. 644
Room No. L155B

Function: Spacecraft Tracking

Area: 576 Square Feet

The WaveScope two-dimensional lens array divides the incoming wave front into an array of spatial samples called sub-apertures. Light from these sub-apertures is brought to a focus behind the array on a CCD camera. The lateral position of the focus spots depends on the local tilt of the wave front.

A change in the gradient of the wave front across a sub-aperture will produce a shift in the position of the spots. By measuring the shift of the spots, the gradient of the incoming wave front can be calculated.

In a conventional Shack-Hartmann sensor, when the local tilt is large enough to move the focus spot into the field of the next sub-aperture, an ambiguity arises as to the origin of the spot. This severely limits the dynamic range of the measurement. WaveScope resolves this ambiguity by moving the camera to trace the path of the spots during calibration. This is how WaveScope measures aberrations of many hundreds of waves with fractional wave accuracy. Additionally, the ability to move the camera allows imaging of the entrance pupil at the lenslet array, providing an invaluable aid in alignment.

Building No. 640
Room No. 261

Function: Autonomous Guidance, Navigation, and Control (GNC)

The Autonomous GNC Laboratory, which is a part of AFIT's Advanced Navigation Technology (ANT) Center, provides the space, computers, equipment, and vehicles required to conduct and demonstrate research in the area of autonomous guidance, navigation, and control for both ground and air vehicles. The lab includes digital control systems, hardware-in-the-loop simulations, multiple ground vehicles, and multiple air vehicles.

Building No. 640
Room No. 261

Function: Flight Control Design and Evaluation, and Development of Synthetic Vision Systems

The Pilot-in-the-loop Simulation Laboratory, which is a part of AFIT's Advanced Navigation Technology (ANT) Center, provides the space, computers, and equipment required to conduct and demonstrate research in the areas of advanced flight control, pilot-in-the-loop handling quality evaluations, and synthetic vision systems.

9.3.4 Solid Mechanics and Structures

Building No. 644
Room No. 153B

Function: Materials Analysis Laboratory

Area: 275 Square Feet

The testing facilities to perform microscopic evaluation of materials are located in this laboratory. Equipment available in this laboratory is: scanning electron microscopes, high power optical microscope, inverted microscope, and related test facilities. Test sections are available for each scanning electron microscope with load capabilities of 1.0 kip and 5.0 kip for real-time material evaluation.

Building No. 640
Room No. 254

Function: Structures and Materials Testing Laboratory

Area: 2961 Square Feet

This state-of-the-art laboratory houses numerous facilities for mechanical testing of materials and structural elements. Fourteen servo-hydraulic MTS mechanical testing machines with capacities ranging from 1.0 to 110 kip permit static and fatigue testing. A servo-hydraulic MTS tension-torsion machine is available for testing under multiaxial, combined tension-torsion loading conditions. All testing machines are equipped with MTS Test Star II digital controllers for computerized input signal generation and data acquisition. Heating chambers and temperature controllers are employed for testing at ultra-high temperatures (above 1000°C). Environmental and vacuum chambers are available for testing in controlled environment. Several MTS uniaxial and biaxial high-temperature extensometers permit accurate strain measurement. Two MTS high-frequency facilities permit testing at frequencies of up to 1000 Hz. The MTS Nano- and MTS Microforce- Testing Systems are available for testing of individual fibers and nano-composite specimens. Nano-indenter, Atomic Force Microscope and a Scanning Electron Microscope are available for micro- and nano-scale research. In addition, the laboratory includes unique facilities for automated thermo-mechanical fatigue testing, as well as a capability for crack growth measurement using the electric potential method at room and elevated temperatures. Three laser interferometric systems permit non-contact displacement measurement at room and elevated temperatures by using a laser and optical interferometry with different gage lengths. An acoustic emission test system is available for monitoring the damage growth in composite materials. Three servo-hydraulic testing machines are equipped with specially designed fretting fixtures for investigating the fretting fatigue phenomenon in jet turbine engine components.

MTS Planar Biaxial Testing Systems combine modular load frame technology, innovative control methods, advanced alignment techniques and integrated environmental chambers to effectively simulate the mixed mode loading environments of aircraft materials and components. The increasing sophistication of aircraft designs has necessitated the development of more descriptive and complex material and component models. Validating these models, however, requires very realistic simulations of airframe and turbine operating environments. Employing uniaxial testing technology for this yields less than accurate results, while full-scale tests with spinning components are expensive when evaluating design iterations. Achieving truly accurate and affordable simulation of these environments requires the use of multiaxial loading technology. The MTS Planar Biaxial Testing System employs multiaxial loading technology to apply and measure in-plane stresses in both the X and Y axes.

CHAPTER 10: COMPUTER RESOURCES

10.1 Computing At AFIT

10.1.1 Microsoft Windows Environment

10.1.1.1 General-Use Computing Labs

AFIT/EN maintains computer labs for general student use in Bldg 640 Rooms 210(B),(F),214,215,222,225. These labs are equipped with single-processor Windows 2000/XP computers, printers, and scanners.

A wide range of software is available in the general-use computer labs. Software of particular interest to ENY students includes:

Adobe Acrobat: Create pdf files

Chemkin: Numerical chemistry software

LaTeX (MikTeX + WinEDT): Powerful scientific typesetting software

Mathcad: Symbolic mathematics and plotting with an emphasis on document creation

Mathematica: Powerful symbolic mathematics and plotting software

Matlab: Powerful linear algebra software with a large number of special purpose toolboxes for dynamics and control, signal processing, and other engineering tasks

Microsoft Office suite: Word, Excel, Powerpoint, etc.

TecPlot: General purpose data plotting software

Visual Fortran: Fortran 90/95 in the Microsoft visual environment

Visual Studio (C, C++, Java, Basic): Microsoft visual software development environment

10.1.1.2 Computer Lab Software

Most of the software available in the general-use computer labs is also available on the windows workstations in the Computational Dynamics and Design Laboratory in Bldg. 640 Rm. 210. Additional software packages unique to the ENY research subjects are available on some or all of these workstations. Examples include:

ABAQUS: Finite element program for non-linear structural analysis.

AutoCAD LT is a two-dimensional (2D) design and drafting software product.

MD NASTRAN: general-purpose finite-element structural analysis program for linear and nonlinear statics, buckling, frequency and transient dynamic response, heat transfer, and aeroelastic response.

FEMAP: general-purpose finite-element structural analysis program for linear and frequency and transient dynamic response, and heat transfer response.

PATRAN: pre- and post-processor for finite element applications such as NASTRAN and ABAQUS.

STK: Module allows the user to analyze and visualize communications links among spacecraft, and between spacecraft and Earth stations.

Solid Works a mechanical design automation application that takes advantage of graphical user interface. Designers to quickly sketch out ideas, experiment with features and dimensions.

The primary purpose of these workstations is thesis research and special-purpose classroom activities. Normal class work and administrative tasks such as email should be carried out in the general use computing labs.

Note: Whenever possible, computations requiring several hours of run time should be performed on Parallel/High Performance computing resources (see below) to avoid tying up Windows workstations.

10.1.2 Unix/Linux Environment

AFIT/ENY maintains Unix/Linux engineering workstations in the Computational Dynamics and Design Laboratory. At the time of publication, there were fifteen 2.2GHz dual-processor, dual-core Opteron CentOS 4.6 Linux workstations, each with 4 GB of RAM. All Unix/Linux workstation accounts mount a common home directory, so user files are available from any workstation. Accounts on these machines are not automatically generated—they must be requested from AFIT/SC via AFIT Form 35. POC for accounts is SC AFIT/Userhelp, located in Bldg 642, Room 2200.

Unix/Linux workstations are loaded with a wide array of software tools included in the CentOS 4.6 Linux distributions. In additions, the following software applications are available on the Unix/Linux workstations and the Beowulf clusters.

Abaqus: Finite element program for non-linear structural analysis.

Compilers: Commercial (Intel, Portland Group) and open source compilers and debuggers for C, C++, Fortran 77, Fortran 90, ADA, JAVA, as well as interpreters for Python, Perl, and TCL/Tk.

Fieldview: Powerful visualization software for 3-D field data such as that generated by Computational Fluid Dynamics.

Fluent: Computational fluid dynamics (CFD) software for fluid flow modeling.

GRIDGEN: Numerical grid-generation tool suitable for two- and three-dimensional structured and unstructured grids.

MATHEMATICA: Powerful symbolic mathematics and plotting software

MATLAB: Powerful linear algebra software with a large number of special purpose toolboxes for dynamics and control, signal processing, and other engineering tasks

MPICH: implementation of the Message Passing Interface (MPI) parallel programming tools.

NASTRAN: general-purpose finite-element structural analysis program for linear and nonlinear statics, buckling, frequency and transient dynamic response, heat transfer, and aeroelastic response.

PATRAN: pre- and post-processor for finite element applications such as NASTRAN and ABAQUS.

TecPlot: General purpose data plotting software.

10.1.3 Parallel/High Performance Computing

To meet High Performance/Parallel computing requirements, AFIT/EN maintains several Linux-based Beowulf clusters. At the time of publication, these included those shown below:

Cluster	*PBS Queue*	*Nodes*	*Processors per Node*	*Processor Type*	*RAM per Node (GB)*	*Interconnection*
Tahoe	workq	64	2	2.2 GHz Opteron	4	Gigabit Ethernet
Taos	taosq	24	2	2.4 GHz Opteron	2	Gigabit Ethernet
Provo	provoq	16	2	2.2 GHz Opteron	4	Myrinet
Banff	banffq	8	2	3.0 GHz Xeon	2	Gigabit Ethernet
Aspen	aspenq	32	1	2.1 GHz Athlon	1	Gigabit Ethernet
Mammoth	N/A	3	8	2.2 GHz dual core Opteron	64	Shared Memory

All clusters share the same accounts, home directory, and software applications as the Linux workstations described above. Though not specifically defined, the general functional breakout of the clusters is as follows:

Tahoe/Taos – Large, numerically intensive parallel computations such as Computational Fluid Dynamics and Finite Element Analysis

Aspen/Banff – Parallel or serial computations that are less numerically intensive

Provo – Parallel computations that require large amounts of message passing

Mammoth – Parallel computations requiring large amounts of memory

Jobs are submitted to a cluster (with the exception of Mammoth) by means of the Portable Batch System (PBS). PBS keeps track of which nodes are in use and which are free. When jobs are submitted, the job is run on the requested cluster with the requested number of nodes, if available. If the nodes are not available, the job is held in a queue and will automatically start when the nodes become available.

NOTE: PBS has no way of tracking jobs started by logging directly into the cluster and running interactively. Because of this, PBS may start additional jobs on the same node, significantly degrading performance. As a result, direct login to the cluster computers is highly discouraged.

The AFIT parallel computing resources are intended for problems requiring less than 32 processors. Very large problems requiring more processors should be run at the ASC Major Shared Resource Center (MSRC). An account and allocation at the MSRC must be requested by your research advisor.

10.2 Computing At Home

10.2.1 Software Available for Checkout

In addition to the software contained on the student CD, the following commercial software can be checked out for installation on your home computer:

Minitab[1]
Mathematica[3]
Visual Fortran[1,2]
Mathtype[2]
MatLab[2] (Standalone version: Win/Mac/Linux)

1. *Limited Licenses Available*
2. *Available for home installation*
3. *Available for home installation – Faculty/Staff only*

10.2.2 Computing at AFIT from Home

Remote logins to the AFIT Windows network are routed through a Virtual Private Network (**VPN**) that sends all communications through the WPAFB firewalls. You first must connect to the internet through your own ISP (e.g., AOL, Earthlink.) If you do not have an ISP then you can complete an application for a base dial-up (**WPAFB RAS)** account. It takes a few days to receive the account and once you receive it you will be able to connect to the AFIT computers. Instructions for connecting to AFIT through the **VPN** are available on the student CD ROM and on the web.

Remote logins and file transfers to the AFIT Unix/Linux network are accomplished via secure shell (ssh). All remote ssh connections must be made through alpine.afit.edu or telemark.afit.edu, which are Linux Workstations. Once logged in to one of these workstations, the ENY unix/linux workstations can be reached by a second ssh to the desired machine. A windows version of ssh is included on the student CD Rom.

If your home computer is running either Linux or an X server (e.g. cygwin XFree86) under MS Windows, and you have a high-speed internet connection, then it is possible to run graphical applications on AFIT workstations while displaying on your home computer.

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APPENDIX A: SELECTED FORMS

A.1 Education Plan

This form, commonly known as an "ed plan," (WebAdvisor – Student Plan Inquiry) is used to record student's projected and actual academic programs. Each new student is required to submit an initial education plan, (ENOI 36-120) which lists all courses to be included in the academic program before the end of the first quarter of study. The plan is prepared in conjunction with the student's academic advisor and entered by the student. The proposed program must satisfy the general requirements for the MS degree and the specific requirements of the student's curriculum area and primary and secondary sequence options. The student should make sure that all prerequisites and co-requisites for all courses in the education plan are satisfied and that courses are scheduled to be offered in the desired quarter.

The education plan is subject to the approval of the student's advisor, the curriculum chair, and the department head. Any subsequent changes to this plan must be coordinated with the student's academic advisor. A major restructuring of a program may require a complete revision of the plan and formal re-coordination.

Immediately prior to graduation a final grade summary listing the grades received in all courses and the thesis title will be prepared for final approval by the department head and reviewed by the Graduate School of Engineering and Management Academic Standards Committee.

A.2 Drop/Add - Special Study Request and DAGSI Forms

Registration changes will be accomplished by the student through the on-line process or filling out the Drop/Add Form. The form is available in the Department Office. Student should fill out the form and obtain his/her academic advisor's signature, instructor's signature, and Department Head signature and hand carry it to the Registrar's office, Building 641.

DAGSI Scholarship students wishing to cross-register must complete the DAGSI forms.

When any student registers for a Special Study (AERO 699 and AERO 899) a Drop/Add Form is required. This form is used to provide the name of the special study, the course instructor, and the number of credit hours

APPENDIX B: SELECTED COURSE DESCRIPTIONS

Not all of the following courses are offered each year. See Appendix G for forecast of course offerings.

AERO 500 – Introduction to Aeronautical Engineering

Introduction to fluid mechanics, airfoil and wing aerodynamics, steady and accelerated aircraft performance, and stability and control. Permission of Instructor. Not open to graduates of an Aeronautical Engineering Program.

Prereq: Permission of Instructor

AERO 517 - Fluid Measurements Lab

An 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. Instrumentation includes oscilloscopes, anemometers (laser and hot-film/wire), pressure transducers, heat and temperature sensors, schlieren flow visualization, and other measurement systems at the discretion of the instructor.

Prereq: AERO 533 or equivalent

AERO 520 - 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.

Prereq: AERO 533 or equivalent

AERO 533 - Incompressible Aerodynamics

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

Prereq: Permission of Instructor

AERO 536 - High Speed Aerodynamics

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

Prereq: Undergraduate Thermodynamics

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 incompressible 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.

Prereq: Permission of Instructor

AERO 543 Lab

Usage of commercial and government software packages for detailed modeling and analysis of internal and external aerodynamic flow fields to include incompressible 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.

Taken in conjunction with AERO 543.
Prereq: Permission of Instructor

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.

Prereq: Permission of Instructor

AERO 579 – 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.

Prereq: Undergraduate Thermodynamics

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.

Prereq: AERO 533 or equivalent; MECH 515 (can be concurrent)

AERO 622 - Introductory Hypersonics

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

Prereq: AERO 536, AERO 579

AERO 627 – Turbulence

Order of magnitude estimates for diffusivity, dissipation, and velocity and fundamental length scales in turbulence. Reynolds time averaging and mass averaging of the Navier-Stokes equations, the closure problem, and turbulent energy and vorticity balances. Boundary-free shear flows and wall-bounded shear flows for internal and external flows. Turbulence modeling, Statistical description of turbulence, Orr-Sommerfeld analysis and the transition problem.

Prereq: AERO 520

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.

Prereq/Coreq: AERO 551 and AERO 536, or Permission of Instructor

AERO 685 – 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 core disciplines and provides students experience in applications of such disciplines to military aircraft design.

Prereq: Core Aeronautical Engineering

AERO 698 - Graduate Seminar in Aeronautics and Astronautics

Current problems and solutions in the design of Air Force aeronautical and astronautical systems are presented by representatives of USAF agencies and the aerospace industry.

AERO 699* – Helicopter Performance and Flying Qualities for Preliminary Design

Team design for performance and flying qualities of a helicopter. Design methodology focuses on modifying the design of an existing helicopter to satisfy new mission performance and flying qualities requirements. The project draws on the aeronautical core disciplines and the theory of helicopter rotor aerodynamics. The course provides students experience in applications of such disciplines to military helicopter design.

*Course to be offered in WI 2010
Prereq: Core Aeronautical Engineering, AERO 610

AERO 699 - Master's Level Independent Study

Course content determined by faculty member based on student need. Prereq: Permission of Instructor

AERO 753 – Advanced Computational Aerodynamics

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 generation; 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.

Prereq: AERO 520 and AERO 652, or permission of instructor.

AERO 799 - Independent Study

The topic for an independent study is selected from a wide variety of problems of current interest to the Air Force. The results of the study are reported in a thesis written under the supervision of a departmental faculty member and are presented in a formal oral report. Ordinarily this study extends over four quarters and no credit is given until the end of the last quarter.

AERO 899 - Doctoral Independent Study

Course content determined by faculty member based on student need.
Prereq: Permission of Instructor

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.

Prereq: Approval of Research Advisor

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, including mechanical, electrical, fluid, and thermal systems is covered. Analysis techniques include classical analysis in the continuous time, discrete time, frequency domain, and modern state space techniques for linear systems.

Prereq: Permission of Instructor

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, US space policy, military space missions, US military space organizations, and non-US space programs. Introduction to standard space mission analysis software.

Prereq: Permission of Instructor

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 US and foreign space systems and related topics of DoD interest.

Prereq: Permission of Instructor (US only, TS/SCI required). This is a single three-credit course divided over three quarters (students 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.

Prereq: Permission of Instructor (only allowed for Navy TPS officers)

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
Prereq: AERO 533, AERO 536, Permission of Instructor, US Citizens only

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.

Prereq: Linear Systems Analysis - ASYS 525 or equivalent.

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
Prereq: 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 non-linear 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. Examples will be drawn from air and space applications. Prereq: Linear systems and state space control (ASYS 525, 565 or equivalent).

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.

Prereq: MECH 532 or Permission of Instructor

ASYS 632 – Satellite Design & Test

This course provides a detailed introduction to 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.

ASYS 699 – Master's Level Independent Study

Course content determined by faculty member based on student need
Prerequisites: none
Course content determined by faculty member based on student need

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. Stability and robustness measures to the multi-input/multi-output (MIMO) multivariate systems will be covered, including multivariate pole/zero and singular value analysis. Linear Quadratic Regulator (LQR), estimator (LQE) and controller (LQG) will be presented. Modeling of uncertainty is covered, and signal and transfer function norms are used to quantify both levels of uncertainty and robustness to it. H_2 and H_∞ solution techniques are covered and relevant examples from air and space systems will be used to demonstrate applications of these techniques. Use of MATLAB® for design and simulation is emphasized.

Prereq: ASYS 565

MATL 498 - Materials Selection Seminar

Definition of material properties as they relate to load bearing structural materials. General discussion of constitutive equations and how material properties are necessary both for stress strain relationships and for limit load analyses. Presentations on the material characteristics, strengths, weaknesses, applications, problems, and current research objectives for airframe metals, high temperature metals, organic composites, metal matrix composites, carbon-carbon, viscoelastic materials.

Prereq: Strength of Material Course

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.

Prereq: Undergraduate Materials Science Course

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.

Prereq: Permission of Instructor

MATL 560 - Electronic, Magnetic and Optical Properties of Materials

Introduction to the theory and engineering applications of electronic, magnetic, and optical materials. Atomic bonding, crystal structure, crystal defects, lattice properties, diffusion, electrical properties of materials, metals, dielectrics, semiconductors, 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, superconductors, and optical devices are treated.

Prereq: Undergraduate Materials Science Course

MATL 598 - Materials and Processes Seminar

Current technologies, applications, and research issues in the materials and processes are presented by experts form the Air Force, industries and other universities.

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 use or 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.

Prereq: CHEM 590

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, configuration interaction methods, and density functional theory.

Prereq: MATL 620, PHYS 655

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.

Prereq: PHYS 670

MATL 680 - Materials Characterization

The objective of this course is to provide an integrated view of characterization as a process requiring application of many methods to extract information about a material. Two classes of methods are considered, those using particles and those using waves. Particles are grouped into photons (visible, infrared, ultraviolet, x-ray), electrons, and atoms/ions/neutrons. Frequency ranges of waves include acoustic and microwave. The challenge in characterization is to understand the probe-material-sensor interactions, because these are the drivers to characterizing the material. Only a few specific methods are covered as representatives of the several hundred methods now used.

Prereq: Undergraduate Materials Science Course

MATL 685 - Materials Selection and Processing

An introduction to methods for logical choice of materials processes for applications with emphasis on aerospace requirements. Includes methods for assessment of risk and cost with respect to requirements.

Prereq: Undergraduate Materials Science Course

MATL 699 – Master's Level Independent Study

Course content determined by faculty member based on student need.
Prereq: Permission of Instructor

MATL 701 - Research Apprenticeship

Students will work on special problems related to an individual professor's or laboratory scientist's materials 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 problems 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.

Prereq: Permission of Instructor

MATL 799 - Independent Study

The topic for an independent study in Materials Science and Engineering is selected from a wide variety of problems of current interest to the Air Force. The results of the study are reported in a thesis written under the supervision of a departmental faculty 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.

MATL 899 – Doctoral Level Independent Study

Course content determined by faculty member based on student need.
Prerequisites: Permission of Research Advisor

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-sections is analyzed by applying St. Venant's Semi-Inverse Principle.

Prereq: Undergraduate Strength of Materials

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 nonmetallic 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. This class is open to ENV systems engineering students only.

MECH 515 - Theory of Vibrations

Free and forced vibrations of damped and undamped systems with a finite number of degrees of freedom. Characteristic frequencies and mode shapes. Generalized coordinates and normal modes. Free and forced vibrations of simple continuous systems; transverse oscillations of strings, longitudinal and torsional oscillations of rods, and bending vibrations of beams.

Prereq: MECH 521 or equivalent

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.

Prereq: Undergraduate dynamics

MECH 529 - Dynamics and Control of Flight Vehicles

Aerodynamic considerations of lift, drag, and moment. Aerodynamic stability derivatives. Derivation of the aircraft equations of motion. Trim conditions and stability analysis of the linearized equations of motion.

Prereq: MECH 521 or equivalent

MECH 532 - Introductory Space Flight Dynamics

Formulation and solution of the two-body problem in three dimensions. Orbital elements, reference frames, coordinate transformations, orbit determination methods, and basic orbital maneuvers. Formulation and description of basic attitude dynamics and control concepts, including spin-, dual-spin, three-axis, and gravity gradient stabilization.

Prereq: Undergraduate dynamics or Permission of Instructor

MECH 537 – Introduction to Astrodynamic Re-entry

This course provides the student with a basic understanding of astrodynamic reentry into a planetary atmosphere. Three-dimensional equations for flight over a spherical planet are derived. The basic equations for planar entry trajectories are developed and studied with first-order analyses. Loh's Second-Order Theory, Yaroshevskii's Theory, and aerodynamic heating are introduced. Students will explore the trades made between heating, dynamic loads, etc. when designing entry trajectories. Students are expected to use MATLAB or MATHCAD for simple solutions. This course is intended for Graduate Space Systems (GSS) students and others not enrolled in Graduate Astronautical Engineering (GA).

Prereq: MATH 302 or equivalent undergraduate differential equations course.
Coreq: MECH 532 (if not previously taken)

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.

Prereq: MECH 500 or MECH 545

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

Introduce finite element analysis and computer-aided design tools for analyzing, pre-, and post-processing finite element models. Review historical development of finite element analysis and related computational tools. Demonstrate finite element process for truss elements. Program simple finite element code for trusses. Learn graphics software in AFIT computer environment to model one-, two-, and three-dimensional structures. Use pre-processor to create geometric models and associated finite element meshes. Use post-processor to generate deformed geometry, x-y plots, and contour plots. Present modeling guidelines and adaptive meshing techniques.

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.

Prereq: Undergraduate strength of materials

MECH 600 – Elasticity

A review of linear, infinitesimal continuum theory. Introduction to nonlinear elasticity. Solutions in curvilinear coordinate problems. Introduction to plate theory. Buckling and instability.

Prereq: MECH 500 or MECH 545 if taking structural materials sequence

MECH 601 - Introduction to Time-Dependent Material Behavior

The objective is to provide a fundamental background in inelastic solid mechanics. Phenomenological aspects (observed experimentally) of inelastic behavior of real engineering materials are presented and inelastic constitutive models are introduced. Topics include Kelvin-Voigt, Maxwell and Standard Linear Solid models for materials with internal variables, creep and stress relaxation, linear and nonlinear viscoelasticity, correspondence principle, and time-temperature equivalence of thermorheologically simple materials. In addition, rate-independent plasticity, viscoplasticity, yield criteria, yield surfaces, and isotropic and kinematic hardening rules are discussed.

Prereq: MECH 500 or MECH 545

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.

Prereq: MECH 500 or MECH 545 or Permission of Instructor

MECH 610 – Structural Vibrations

Vibration of continuous systems; strings, rods, bars, membranes and plates. General formulation of the eigenvalue problem. Emphsis on variational methods and approximate methods of solution. Series methods, Fourier transform methods and Green's functions.

Prereq: MECH 515 or Permission of Instructor

MECH 620 - Systems Optimization

This course covers theory and procedures for optimizing multivariable, nonlinear objective functions that measure system performance. Topics include: formulation of classical and Kuhn-Tucker optimality conditions, numerical algorithms for solving classes of problems - linear programming, gradient and evolutionary algorithms search techniques for nonlinear problems, multi-objective optimization theory, and special topics illustrated with problems in aerospace design.

Prereq: Matlab Programming

MECH 622 - Functional Optimization and Optimal Control

Variational techniques are applied to optimize linear and nonlinear dynamic systems with respect to prescribed inequality 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.

Prereq: Knowledge of linear feedback control - ASYS 565 or equivalent.

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.

Prereq: MECH 529; ASYS 565; or equivalent

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.

Prereq: MECH 529

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.

Prereq: MECH 521 and MECH 532

MECH 637 - Astrodynamic Re-Entry

Introduction to planetary atmospheres and aerodynamic forces. Equations for flight over a spherical planet. Performance in extra-atmospheric flight. Return to atmosphere. Basic equations for planar entry trajectories. Analysis of first-order planetary entry solutions. Loh's Second-Order Theory. Yaroshevskii's Theory. Chapman's Theory. Entry corridors. Unified Theory of Re-Entry. Orbit contraction due to Atmospheric Drag.

Prereq: MECH 521
Coreq: MECH 532 (if not previously taken) or permission of instructor

MECH 642 - Finite Element Methods for Structural Analysis I

Energy principles. Stiffness analysis of structural members. Formulation of structural problems using finite element methods. Analysis of trusses, frames, plane stress, and plane strain problems. The course will involve computer programming of finite elements.

Prereq: MECH 542

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 and forced response, stability, and nonlinear analysis.

Prereq: MECH 642

MECH 646 - Structural Optimization

General formulation of optimal design. Approaches to structural design and optimization. The min-max problem. Direct and indirect methods. Multicriterion optimization.

Prereq: MECH 500

MECH 662 - Introduction to Aeroelasticity

Mathematical foundations of aeroelasticity. Static aeroelastic behavior of swept and straight wings, control surface effectiveness, coupled control surface/wing torsional divergence. Free vibration and dynamic response of continuous systems. Unsteady, quasi-steady aerodynamics in subsonic and supersonic regimes. Nonconservative dynamic instability, fluttering systems.

Prereq: AERO 533 and MECH 515

MECH 699 – Master’s Level Independent Study

Course content determined by faculty member based on student need.
Prerequisites: Permission of Instructor

MECH 712 - Nonlinear Oscillations

Geometric theory of dynamical systems. Motion of single degree of freedom autonomous systems about equilibrium points. Stability of multi-degree of freedom autonomous systems, Liapunov's direct method. Nonautonomous systems, linear systems with periodic coefficients, Floquet theory. Perturbation techniques, secular terms, Linstedt's method, KBM method.

Prereq: MECH 720 or Permission of Instructor

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.

Prereq: MECH 515 and ASYS 565 or Permission of Instructor

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.

Prereq: MECH 521

MECH 728 - Advanced Flight Mechanics

Advanced topics in flight mechanics and control chosen from optimal control, discrete-data control systems, aeroelastic effects, human pilot models and nonlinear effects.
Prereq: MECH 628 and ASYS 525 or equivalent

MECH 731 - Modern Methods of Orbit Determination

Introduction to probability theory. Statistical mission assessment. Derivation of the methods of the least squares in linear and nonlinear problems. Sequential estimation methods, including numerical instabilities and time weighting. Applications to the problem of determining the updating of the orbital elements of satellites.

Prereq: MECH 532

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, periodic motion.

Prereq: MECH 521

MECH 899 – Doctoral Level Independent Study

Course content determined by faculty member based on student need
Prerequisites: Permission of Research Advisor

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.

Prereq: Undergraduate thermodynamics

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.

Prereq: Undergraduate Thermodynamics

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.

Prereq: Undergraduate Thermodynamics

MENG 571 - Fundamentals of Heat Transfer

Fundamentals of conduction, convection, and radiation heat transfer. Derivation and solution of the general heat conduction equation for one- and two-dimensional, steady and unsteady conduction problems. Both analytical and numerical solution techniques will be covered. Forced convection in laminar and turbulent flows on internal and external surfaces. Application to thermal processes in a variety of systems.
Prereq: Permission of Instructor

MENG 633 - Fundamentals of Combustion

This course is designed to provide an understanding of the fundamentals of combustion and combustion aerodynamics. Topics include: (1) Chemical thermodynamics: heats of reaction and flame temperature; (2) Chemical kinetics: rates of reaction, reaction order, chain reactions, and explosions; (3) Gas dynamics of reacting flows; (4) Deflagration and detonation of premixed gases; (5) Laminar flames, and (6) Turbulent flames.
Prereq: Undergraduate Thermodynamics, Chemistry, and Differential and Integral Calculus

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 emphasized and applied to components of satellite, propulsion, and solar energy systems.

Prerequisites: MENG 571 or equivalent

MENG 674 - Convection Heat Transfer

Differential and integral analysis of laminar and turbulent convection heat transfer. Forced convection in internal flows, including entrance regions. Forced convection in external, from low to supersonic speeds. Free convection. Applications to heat exchangers, environmental control and thermal protection systems.

Prerequisites: MENG 571 or equivalent

MENG 699 – Master's Level Independent Study

Course content determined by faculty member based on student need
Prerequisites: Permission of Instructor

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.

Prereq: Permission of Instructor

MENG 733 - Airbreathing 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.

Prereq: MENG 501 and MENG 732 or Permission of Instructor

MENG 899 – Doctoral Level Independent Study

Course content determined by faculty member based on student need.
Prerequisites: Permission of Research Advisor

APPENDIX C : ACADEMIC CALENDAR 2009-2011

AFIT operates on a quarter systems. Each quarter consists of 10 weeks of classes plus a final exam week and a break week. There are also two 4-week short terms, which are used, for preparatory courses for incoming students prior to their first regular quarter.

2009 Fall Review Session

Military Students Arrive	18 Aug
Student Orientation/In Processing	19 Aug
Review Session	31 Aug – 25 Sept
Labor Day	7 Sept

2009 Fall Quarter

Classes begin	28 Sept
Columbus Day	12 Oct
AFIT Wingman Day	5 Nov
Veteran's Day	11 Nov
Thanksgiving	26 Nov
AETC Family Day	27 Nov
Classes End	9 Dec
Finals	11 – 15 Dec 09

2010 Winter Quarter

Classes begin	4 Jan
MLK Day	18 Jan
President's Day	15 Feb
Classes End	12 Mar
Finals	15 – 18 Mar
Graduation	25 Mar

2010 Spring Quarter

Classes begin	29 Mar
Memorial Day	31 May
Classes End	4 Jun
Finals	7 – 10 Jun
Graduation	17 Jun

2010 Summer Review

Military Students Arrive	21 May
Student Orientation/In Processing	24 – 28 May
Memorial Day	31 May
Review Session	1 – 25 Jun

2010 Summer Quarter

Classes begin	28 Jun
AETC Family Day	2 Jul
Independence Day observed	5 Jul
Classes End	3 Sep
Labor Day	6 Sep
Finals	7 – 10 Sep

2010 Fall Review Session

Military Students Arrive	17 Aug
Student Orientation/In Processing	18-27 Aug
Technical Refresher Course	30 Aug – 24 Sep
Labor Day	6 Sep

2010 Fall Quarter

Classes begin	27 Sep
Columbus Day	11 Oct
AFIT Wingman Day	4 Nov
Veteran's Day	11 Nov
Thanksgiving	25 Nov
AETC Family Day	26 Nov
Classes End	8 Dec
Finals	10 – 15 Dec

2011 Winter Quarter

Classes begin	3 Jan
MLK Day	17 Jan
President's Day	21 Feb
Classes End	11 Mar
Finals	14 – 18 Mar
Graduation	24 Mar

APPENDIX D: CURRICULUM COMMITTEES AND ADVISORS

DEPARTMENT OF AERONAUTICS AND ASTRONAUTICS

CURRICULUM COMMITTEES

Effective April 2009

GROUP	GRAD AERO	GRAD ASTRO	GRAD MATERIAL SCI	GRAD SPACE SYS	DOCTORAL
Fluid Mech	Kunz* Greendyke	Huffman	Reeder	Lofthouse	King*
Solid Mech	Mall	Palazotto	Mall* Ruggles-Wrenn	Palazotto	Ruggles-Wrenn
Dynamics Systems & Controls	Shearer	Swenson* Cobb		Cobb* Wiesel	Cobb

DAGSI/PTS	TPS
King	Kunz

*** Denotes Chairman**

APPENDIX E: AWARDS AVAILABLE TO GRADUATING ENY STUDENTS

Students earning a Master’s degree within the Department of Aeronautics and Astronautics are eligible for a variety of awards. Descriptions of these awards, along with the selection criteria, are provided below.

THE MERVIN E. GROSS AWARD

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. To be eligible for consideration, a graduating student must have a cumulative grade point average of at least 3.75.

ENY BEST THESIS AWARDS

The ENY Best Thesis Award is given in recognition of the most exceptional master's thesis by graduating students of the Department of Aeronautics and Astronautics in each of the following technical categories: (1) Dynamics and Control, (2) Fluids/Heat Transfer, and (3) Materials and Structures.

AIR FORCE INSTITUTE OF TECHNOLOGY
DEAN’S AWARD

The Dean’s Award is given in recognition of the most exceptional master’s thesis by a graduating student in each academic department of the Graduate School of Engineering and Management. In the Department of Aeronautics and Astronautics, the Dean’s Award is given to the best and most exceptional master’s thesis among the three ENY Best Thesis Award winners.

AIR FORCE INSTITUTE OF TECHNOLOGY
COMMANDANT'S AWARD

The Commandant's Award is given in recognition of the most exceptional master's thesis by a graduating student of the Graduate School of Engineering and Management. The award is based on a master's thesis, which reflects exceptional defense research contributions to scientific, management, or engineering knowledge; in addition, consideration may be given to originality, resourcefulness, completeness, scope, clarity of presentation, and level of difficulty. The nature of the research (scientific versus engineering, or theoretical versus experimental) is not a consideration.

DISTINGUISHED GRADUATE RECOGNITION

The commandant of AFIT is authorized to designate as Distinguished Graduates (DG) those students who have performed in an outstanding manner in accomplishing the overall educational objectives of the Graduate School of Engineering and Management. The criteria for identifying DG achievement encompass academic scores (GPA of 3.75 or higher) and the "whole person" concept, based on professional qualities (e.g. character, integrity, leadership, fellowship, and team building), and recommendation of the department heads.

THE LOUIS F. POLK AWARD

The Louis F. Polk Award, sponsored by National Defense Industrial Association (NDIA), is given in recognition of the student who has made an advanced contribution in their professional field in direct furtherance of the objectives of NDIA. The honoree is expected to achieve the highest standards of academic and professional accomplishment during their participation in the Institute's graduate programs as demonstrated by (1) a high cumulative grade point average (GPA) in all graduate courses taken in resident AFIT programs and (2) ability to apply academic and professional theory to the solution of a significant problem of direct value to national defense through research and thesis accomplishment.

THE LT EDWIN E. ALDRIN, SR., AWARD

The Lt Edwin E. Aldrin, Sr., Award, sponsored by the Wright Memorial Chapter of the Air Force Association and authorized by AFITI 36-110, is given in recognition of the student who has displayed exceptional leadership characteristics, and demonstrated high quality academic accomplishments, military decorum and the ability to work with faculty and fellow students.

THE AIAA DAYTON-CINCINNATI GRADUATE STUDENT AWARD FOR RESEARCH EXCELLENCE

The American Institute of Aeronautics and Astronautics (AIAA) Dayton-Cincinnati Graduate Student Award for Research Excellence recognizes the outstanding MS thesis of a graduating AFIT student for making a significant contribution toward the science and technology of aeronautics or astronautics. The AFIT/ENY Best Thesis selection committee considers the ENY theses submitted for consideration for the Dean’s and Commandant’s Awards, together with theses nominated by other AFIT departments.

THE IVAN B. THOMPSON AWARD

The Ivan B. Thompson Award is given to a member of the graduating class who has shown exceptional service to the class, the School, the Air Force, and/or the local community.

DARPA INTERN PROGRAM

This program is not an award, but is a competitive internship assignment that is served during the year following Graduation. The purpose of this program is to bring officers with operational backgrounds who have the potential to be senior leaders in their Service to DARPA to expose them to the mission and operation of DARPA, and to demystify perceptions about the agency. Selectees will typically spend 3-4 months at DARPA.

APPENDIX F: SECTION COURSE REQUIREMENTS

The course requirements for qualification for the Master of Science degree are specified in the Program Guide (Chapter 4) and on the Section Course Requirements (SCR) Form, AFIT Form 69. The AFIT Form 69 for each program is provided in this appendix.

Section Course Requirements – Graduate Aeronautical Engineering (GAE)

GRADUATE SCHOOL OF ENGINEERING AND MANAGEMENT PROGRAM SUMMARY

CAT	PROGRAM REQUIREMENTS	MIN CREDIT HOURS
1	Thesis	12
2	Primary Sequence (minimum of three courses)	11
3	Second Sequence (minimum of three courses)	9
4	Two graduate Math courses or one Math plus one approved substitute (see program guide)	8
5	Core Aeronautics: One ENY course (min) from 3 of the 5 aero disciplines May be concurrent with CATs 2, 3 and 6 (see program guide)	9
6	Completion of ABET core	N/A
7	Other graduate courses as required to total at least 48 hours	N/A

PROGRAM REQUIREMENTS APPROVAL

REVISION ☐ Yes ☒ No DATE:

PROGRAM CHRM:

DEPT HEAD: DATE: 12 Apr 07

CDRC* CHMN: DATE: 20 Jul 07

DEAN: DATE: 20 Jul '07

* *Curriculum and Degree Requirements Committee Chairman*

COMPLETED PROGRAM APPROVAL

HEAD: DATE:

DEGREE RECOMMENDATIONS

		YES	NO	INITIALS
STUDENT'S FACULTY COMMITTEE	1			
	2			
	3			
ACADEMIC STANDARDS COMMITTEE	1			
	2			
	3			

STUDENT'S NAME *(Last, First, MI)*	DATE
SECTION / YEAR GAE-11 M /J /S /D	RANK

Degree Title: MS in Aeronautical Engineering

ALL COURSES TAKEN[1]

CAT	COURSE	CREDIT HOURS	INITIALS[2]

[1] TYPE OR FILL OUT IN INK. List courses corresponding with Program Requirements by categories.

[2] Courses deviating from approved Program Requirements must be initialed as approved by the Department Head.

Total number of graduate credit hours (48 min required):	If GPA ≥ 3.25 indicate PhD potential: I II III
Total number of credit hours:	[1] GPA of 3.00 required GPA:

AFIT FORM 69, Oct 2004 *(MSWord Template)* PREVIOUS EDITIONS ARE OBSOLETE

Section Course Requirements – Graduate Astronautical Engineering (GA)

GRADUATE SCHOOL OF ENGINEERING AND MANAGEMENT PROGRAM SUMMARY

CAT	PROGRAM REQUIREMENTS	MIN CREDIT HOURS
1	Thesis	12
2	Core (MECH 532 or MECH 731 or MECH 732) and (MECH632) (may be concurrent with Cat. 4 or 5)	8
3	Mathematics (two graduate MATH courses)	8
4	Major Sequence (minimum of 3 courses)	10
5	Minor Sequence (minimum of 3 courses)	10
6	Other (courses required for ABET degree - see program guide)	N/A
7	Other	N/A

PROGRAM REQUIREMENTS APPROVAL

REVISION ☐ Yes ☒ No	DATE:
PROGRAM CHRM: [signature]	9 May 08
DEPT HEAD: [signature]	DATE: 9 May 08
CDRC* CHMN: [signature]	DATE: 16 May 08
DEAN: [signature]	DATE: 22 May 08

* *Curriculum and Degree Requirements Committee Chairman*

COMPLETED PROGRAM APPROVAL

HEAD:	DATE:

DEGREE RECOMMENDATIONS

	YES	NO	INITIALS
STUDENT'S FACULTY COMMITTEE 1 2 3			
ACADEMIC STANDARDS COMMITTEE 1 2 3			

STUDENT'S NAME *(Last, First, MI)*	DATE
SECTION / YEAR GA-11M (ASTRO.ABET.MS)	**RANK**

Degree Title: Master of Science in Astronautical Engineering

ALL COURSES TAKEN[1]

CAT	COURSE	CREDIT HOURS	INITIALS[2]

[1] TYPE OR FILL OUT IN INK. List courses corresponding with Program Requirements by categories.

[2] Courses deviating from approved Program Requirements must be initialed as approved by the Department Head.

Total number of graduate credit hours (48 min required):	If GPA ≥ 3.25 Indicate PhD potential: I II III
Total number of credit hours:	[1] GPA of 3.00 required GPA:

AFIT FORM 69, Oct 2004 *(ENG MSWord Template)* PREVIOUS EDITIONS ARE OBSOLETE

Section Course Requirements – Graduate Space Systems (GSS)

GRADUATE SCHOOL OF ENGINEERING AND MANAGEMENT PROGRAM SUMMARY

CAT	PROGRAM REQUIREMENTS	MIN CREDIT HOURS
1	Thesis	12
2	Core (MATL 525, MATL 545, MATL 560 , MATL 680, and MATL 685)	20
3	Mathematics (one graduate MATH course)	4
4	Specialty Sequence (min three courses)	12

STUDENT'S NAME *(Last, First, MI)*	DATE
SECTION / YEAR: GMS - 10M (MTRLSCI.MS)	RANK

Degree Title: Master of Science (Materials Science)

ALL COURSES TAKEN[1]

CAT	COURSE	CREDIT HOURS	INITIALS[2]

PROGRAM REQUIREMENTS APPROVAL

REVISION ☐ Yes ☒ No	DATE: 9 May 08
PROGRAM CHRM: [illegible]	
DEPT HEAD: [illegible]	DATE: 9 May 08
CDRC* CHMN: [illegible]	DATE: 16 May 08
DEAN: [illegible]	DATE: 22 May 08

* *Curriculum and Degree Requirements Committee Chairman*

COMPLETED PROGRAM APPROVAL

HEAD:	DATE:

DEGREE RECOMMENDATIONS

	YES	NO	INITIALS
STUDENT'S FACULTY COMMITTEE 1 2 3			
ACADEMIC STANDARDS COMMITTEE 1 2 3			

[1] TYPE OR FILL OUT IN INK. List courses corresponding with Program Requirements by categories.

[2] Courses deviating from approved Program Requirements must be initialed as approved by the Department Head.

Total number of graduate credit hours (48 min required):	If GPA ≥ 3.25 indicate PhD potential: I II III
Total number of credit hours:	[1] GPA of 3.00 required GPA:

AFIT FORM 69, Oct 2004 *(ENG MSWord Template)* PREVIOUS EDITIONS ARE OBSOLETE

Section Course Requirements – Graduate Materials Science (GMS)

GRADUATE SCHOOL OF ENGINEERING AND MANAGEMENT PROGRAM SUMMARY

CAT	PROGRAM REQUIREMENTS	MIN CREDIT HOURS
1	Thesis	12
2	Core (ASYS530 or ASYS535, EENG571, MECH532, PHYS519, PHYS521, and ASYS631)	22
3	Mathematics (One graduate MATH or STAT course)	4
4	Specialty Sequence (minimum of 3 courses)	9
5	Other (graduate courses to total 48 hours)	N/A

PROGRAM REQUIREMENTS APPROVAL

REVISION ☐ Yes ☒ No DATE: 9 MAY 2008

PROGRAM CHRM: [signature]

DEPT HEAD: [signature] DATE: 9 May 08

CDRC* CHMN: [signature] DATE: 16 May 08

DEAN: [signature] DATE: 22 May 08

* Curriculum and Degree Requirements Committee Chairman

COMPLETED PROGRAM APPROVAL

HEAD: DATE:

DEGREE RECOMMENDATIONS

		YES	NO	INITIALS
STUDENT'S FACULTY COMMITTEE	1 2 3			
ACADEMIC STANDARDS COMMITTEE	1 2 3			

STUDENT'S NAME *(Last, First, MI)*: | DATE:

SECTION / YEAR: GSS - 11M (SPACE.MS) | RANK:

Degree Title: **Master of Science (Space Systems)**

ALL COURSES TAKEN[1]

CAT	COURSE	CREDIT HOURS	INITIALS[2]

[1] TYPE OR FILL OUT IN INK. List courses corresponding with Program Requirements by categories.

[2] Courses deviating from approved Program Requirements must be initialed as approved by the Department Head.

Total number of graduate credit hours (48 min required):	If GPA ≥ 3.25 indicate PhD potential: I II III
Total number of credit hours:	[1] GPA of 3.00 required GPA:

AFIT FORM 69, Oct 2004 *(ENG MSWord Template)* PREVIOUS EDITIONS ARE OBSOLETE

APPENDIX G: FORECAST OF COURSE OFFERINGS SUMMER 2009 - WINTER 2011

This information is provided for planning purposes and reflects the most accurate information available at the time of printing. Students should ensure the classes are being offered during the quarter they desire. Credit hour format: (hrs lecture - hrs lab) credit hrs.

AERO	SU 09	FA 09	WI 10	SP 10	SU 10	FA 10	WI 11	Title	Cr
500					X			Introduction to Aeronautics	(4-0)4
517				X				Fluid Measurements Lab	(2-6)4
520		X				X		Viscous Flow Theory	(4-0)4
533		X				X		Incompressible Aerodynamics	(4-0)4
536	X		X		X		X	High Speed Aerodynamics	(4-0)4
543	X	X				X		Advanced Computational Modeling for Aerodynamics	(3-3)4
551		X				X		Num Meth for Comp Fluid Dynamics	(4-0)4
579			X				X	Theory of Gases for Aerodynamics & Propulsion	(4-0)4
610			X				X	Rotorcraft Aeromechanics	(4-0)4
622				X				Introductory Hypersonics	(4-0)4
627			X				X	Turbulence	(4-0)4
652			X				X	Computational Fluid Dynamics	(4-0)4
685	X				X			Aerospace System Design	(4-0)4
698								Graduate Seminar Aero & Astro	(1-0)1
699[a]				X				Special Topics (Helicopter Design)	(4-0)4
753	X			X				Advanced Computational Aerodynamics	(4-0)4

ASYS	SU 09	FA 09	WI 10	SP 10	SU 10	FA 10	WI 11	Title	Cr
525	X	X				X		Linear Systems Analysis	(4-0)4
530		X				X		Introduction to Space Programs & Operations	(3-0)3
535		X	X	X		X	X	Military Space Systems and Applications	(1-0)1
545			X				X	Linear Systems Analysis for Control	(5-0)5
563		X				X		Terminal Effects and Delivery of Conventional Weapons	(4-0)4
565			X				X	Control and State Space Concepts	(4-0)4
590				X				Aircraft Survivability	(4-0)4
625	X				X			Non-linear Systems Analysis & Control	(4-0)4
631				X				Spacecraft Systems Engineering	(4-0)4
632	X				X			Satellite Design & Test	(3-3)4
765				X				Robust Control	(4-0)4

MECH	SU 09	FA 09	WI 10	SP 10	SU 10	FA 10	WI 11	Title	Cr
500		X				X		Fundamentals of Solid Mechanics	(4-0)4
505	X			X	X			Aircraft Structural Analysis & Mechanics	(4-0)4
515	X		X		X		X	Theory of Vibrations	(4-0)4
521		X				X		Intermediate Dynamics	(4-0)4
529			X				X	Dynamics and Control of Flight Vehicles	(4-0)4
532		X	X			X	X	Introductory Space Flight Dynamics	(4-0)4
537								Intro to Astrodynamic Re-entry	(4-0)4
541			X				X	Mechanics of Composite Materials	(4-0)4
542			X				X	Introduction To Finite Element Analysis And Computer-Aided Design	(3-3)4
545	X		X		X		X	Aerospace Structural Analysis	(4-0)4
600			X				X	Elasticity	(4-0)4
601	X				X			Intro to Time Dependent Material Behavior	(4-0)4
605				X				Fracture Mechanics	(4-0)4
610								Continuous Vibration	(4-0)4
620			X				X	Systems Optimization	(4-0)4
622				X				Functional Optimization & Optimal Control	(4-0)4
628				X				Aircraft Control	(4-0)4
629	X				X			Aircraft Handling Qualities	(4-0)4
632				X				Intermediate Space Flight Dynamics	(4-0)4
637	X			X				Astrodynamic Re-entry	(4-0)4
642				X				Finite Element Methods for Structural Analysis I	(4-0)4
644								Finite Element Methods for Structural Analysis II	(4-0)4
646								Structural Optimization	(4-0)4
662				X				Intro to Aeroelasticity	(4-0)4
712				X				Nonlinear Oscillations	(4-0)4
719		X				X		Vibration Damping and Control	(3-3)4
720								Analytical Mechanics	(4-0)4
722								Control of Flexible Spacecraft	(4-0)4
731	X				X			Modern Methods of Orbit Determination	(4-0)4
732			X				X	Advanced Astrodynamics	(4-0)4

MENG	SU 09	FA 09	WI 10	SP 10	SU 10	FA 10	WI 11	Title	Cr
501		X				X		Aerospace Propulsion	(4-0)4
530			X				X	Chemical Rocket Propulsion	(4-0)4
531				X				Space Propulsion and Power Systems	(4-0)4
571			X				X	Fundamentals of Heat Transfer	(4-0)4
633		X				X		Fundamentals of Combustion	(4-0)4
732				X				Advanced Turbomachinery	(4-0)4
733	X				X			Airbreathing Engine Design	(3-3)4

MATL	SU 09	FA 09	WI 10	SP 10	SU 10	FA 10	WI 11	Title	Cr
525				X				Thermodynamics and Kinetics of Materials	(4-0)4
545		X				X		Mechanical Properties of Materials	(4-0)4
560		X				X		Electronic, Magnetic, & Optical Properties of Materials	(4-0)4
662				X				Electronic Properties of Molecules and Solids	(4-0)4
672	X				X			Optical Properties of Materials	(4-0)4
680			X	X			X	Materials Characterization	(4-0)4
685			X				X	Materials Selection and Processing	(4-0)4

[a] This AERO 699 course will count as a design course for ABET accreditation. Other AERO 699 courses on different subject areas may be offered throughout the year but will not count toward the design requirement for ABET accreditation.