

# Graduate Handbook



## University of Kansas School of Engineering Department of Aerospace Engineering

Department Chairman:  
Professor Mark S. Ewing  
Administrative Office:  
2120 Learned Hall



## Introduction

The purpose of this handbook is to present in one document all material needed to plan and monitor your graduate program. The handbook includes requirements for four graduate degree programs as well as any associated rules and procedures. Background material on the faculty, staff, facilities and recent research is also included.

The Department of Aerospace Engineering offers traditional Master of Science (MSAE) and Doctor of Philosophy (PhDAE) programs which emphasize original analytical and experimental research.

In addition two unique programs are offered: the Master of Engineering (MEAE) and the Doctor of Engineering (DEAE) programs which emphasize system design and management.

All these programs provide an excellent preparation for employment in industry or in private and government laboratories. The doctoral programs also prepare for an academic career in teaching and research.

Graduate course work is available in the following areas of aerospace engineering:

- aerodynamics
- propulsion
- structures
- flight testing
- flight dynamics
- controls
- aircraft design
- spacecraft design
- orbital mechanics

Graduate courses are taught by faculty with a strong background in graduate education and in industry and government laboratory experience. All faculty are currently active in funded or unfunded research in their areas of expertise. Department research programs are typically funded by: NASA, DOD, NSF, FAA, and the Aerospace industry.

This handbook starts with an overview of the department in Section 1. Four graduate programs, MSAE, MEAE, PhDAE and DEAE are described in Sections 2 and 3. An overview of department facilities is given in Section 4. Appendix A provides descriptions for approved graduate courses.

Your special attention is called to Appendix B which summarizes important aspects of professionalism.

Dr. Mark S. Ewing  
Department Chairman

# **1. Department Overview**

## **1.1 Department History**

The current department has its origin in the formation of a Department of Aeronautical Engineering on January 2, 1941. The first degree program was the Bachelor of Science in Aeronautical Engineering (BSAE). Until that time the degree program had been an option under the Department of Mechanical Engineering.

In 1961 the name of the department was changed to Aerospace Engineering. Graduate programs leading to the MSAE and PhDAE were established soon thereafter. During 1962-1967 the departments of Mechanical Engineering and Aerospace Engineering were merged but in 1968 the department, once again, became independent under its current name.

In 1968 the MEAE was added followed in 1969 by the DEAE program. Also in 1968 approval was sought to form the Flight Research Laboratory (FRL). Approval was granted in 1969. The FRL operates as a laboratory within the Kansas University Center for Research. (KUCR) and has an annual research volume of \$1.5M-\$2.2M. The current director of the FRL is Dr. Mark Ewing who is also the Chairman of the Department of Aerospace Engineering.

In 1970 a short course program was established. The Aerospace Engineering Short Course Program is currently directed by Ms. Soma Chakrabarti and operates as a unit of the KU Continuing Education Division. This program offers more than 50 public and in-house short courses per year in the US and abroad. The program offers a wide range of courses tailored specifically to the needs of industry and government organizations.

In 1980 the department began offering several space science and engineering courses.

## **1.2 General Description of the Department**

The graduate programs build on the nationally and internationally recognized BSAE program. Many students from abroad are enrolled in the BSAE program. At the undergraduate level students can pursue minor specializations in airplane design, spacecraft design or propulsion system design as well as theoretical, computational and experimental studies in aerodynamics, propulsion, structures, control systems and flight test.

For detailed descriptions of the four graduate programs: MSAE, MEAE, PhDAE and DEAE are available in Sections 2 & 3.

## **1.3 Aerospace Engineering Faculty**

The AE faculty combines considerable experience in the aerospace industry and government laboratories with excellent academic credentials. All AE faculty members are involved in teaching undergraduate and graduate courses as well as in research and publication activities. Brief resumes for the faculty follow.

### **Ron Barrett-Gonzalez, Associate Professor of Aerospace Engineering**

Dr. Barrett joined the Department in 2005. His research areas include enhancement of transportation related technologies, design, development and testing of unusual uninhabited aerial vehicles, missiles, munitions and adaptive aerostructures. He received his B.S. and Ph.D. degrees in Aerospace Engineering from KU in 1988 and 1993. He attended the University of Maryland, College Park as a US Army Rotorcraft Fellow where he received his MS in Aerospace Engineering in 1990. Dr. Barrett served for 12 years on the faculty of Auburn University, Alabama where he won every teaching award available for his position. He also served as a USAF Faculty Fellow, flight test engineer and a Visiting Professor for one year at The Technical University of Delft, Holland. His work on adaptive aerostructures has yielded many "firsts" including the first fixed- and rotary-wing aircraft to fly using adaptive materials for flight control. He has more than 100 publications and three patents on adaptive rotors, dragless wings and high performance convertible UAVs. In 1998 he was honored for his work in adaptive aerostructures when he claimed Discover Magazine's Discover Award for Aviation and Aerospace Technology. He has consulted for every major US Aerospace corporation and worked for all branches of the DoD, NASA and the NSF. He has taught short courses on Adaptive Aerostructures and Convertible UAV Design in the US, Sweden, Portugal, Germany, Holland, Singapore, India, Ireland, Scotland and England. He especially enjoys interacting with students and has advised and coached more than a dozen award winning AIAA student papers and design teams. He is currently the AIAA Chapter Advisor and maintains active memberships in the AMA, ASEE, ASME, Phi Beta Delta, SAE, SHPE, SPIE, Sigma Gamma Tau and Tau Beta Pi.

### **Richard Colgren, Associate Professor of Aerospace Engineering**

Dr. Richard Colgren, Associate Professor of Aerospace Engineering, comes to KU from the Lockheed Martin Aeronautics Company in Palmdale, California, where he was a Senior Staff Engineer. Including previous aircraft design and development research at Northrop, he has had 22 years of professional experience within the aerospace industry. He received his B.S. in Aeronautical and Astronautical Engineering from the University of Washington in 1982 and his M.S. in Electrical Engineering in 1987 from the University of Southern California. Dr. Colgren received his Doctorate in Electrical Engineering with an emphasis in systems at the University of Southern California in 1993 with a minor in Aerospace Engineering. He is an Associate Fellow of the American Institute of Aeronautics and Astronautics, among other society and national and international technical committee memberships. He has over 50 publications and holds two patents. He has been an Adjunct Professor at variety of universities including the University of Southern California and California State University, Fresno. His research focus is on intelligent vehicle systems and controls.

### **David R. Downing, Professor of Aerospace Engineering**

Dr. Downing was Chairman of the Department from August 1988 to December 1998. He teaches and conducts research in advanced flight control, display, and instrumentation systems. He received a B.S. in Aeronautical Engineering in 1962, and an M.S. in Instrumentation Engineering in 1963, both from the University of Michigan. He received his Sc.D. in Instrumentation Engineering in 1970 from the Massachusetts Institute of Technology. Dr. Downing has had professional experience at NASA's Electronic Research Center and Langley Research Center, where he served as project manager of Advanced Guidance, Control, and Display for General Aviation Aircraft. Dr. Downing has also been on the faculties of Boston University and Christopher Newport College. He received a NASA Group Achievement Award in 1979 and the School of Engineering Miller Award for Service in 1992. He is an Associate Fellow of AIAA and a member of IEEE, SAE, and ASEE.

### **Mark Ewing, Chairman and Associate Professor of Aerospace Engineering, Director Flight Research Laboratory**

Dr. Ewing joined the department in 1992 and has been Chairman of the Department since January 1999. His expertise is in the areas of engineering mechanics and the analysis, design and testing of lightweight structures. He received his B.S. in Engineering Mechanics from the U.S.A.F. Academy and in 1972, an M.S. in Mechanical Engineering and a Ph.D. in Engineering Mechanics from Ohio State University in 1978 and 1983 respectively. He served in the U.S. Air Force for 20 years, starting with engineering positions as a Turbine Engine Design Analyst and a Propulsion Staff Officer. He was an Instructor in Civil Engineering from 1978 to 1980 and an Associate Professor of Engineering Mechanics from 1983 to 1989 at the USAF Academy. Dr. Ewing closed his Air Force career as Chief of the Analysis and Optimization Branch, and Senior Research Engineer in the Structures Division, Flight Dynamics Directorate, Air Force Wright Laboratory. In 1994, Dr. Ewing was selected as the Outstanding KU Aerospace Engineering Educator. He also was presented with the 1994 Henry E. Gould award for the KU School of Engineering Outstanding Educator.

**Saeed Farokhi, Associate Dean of the Graduate School, Professor of Aerospace Engineering, and Department Graduate Advisor**

Dr. Farokhi joined the Department in 1984. He specializes in propulsion and fluid mechanics. He received a B.S. degree in Aeronautical and Astronautical Engineering in 1975 from the University of Illinois, and then received his M.S. and Ph.D. in Aeronautics and Astronautics from MIT in 1976 and 1981, respectively. His professional experience includes working four years as a Design and Development Engineer and Project Leader in the Gas Turbine Division of Brown, Boveri, and Co. in Baden, Switzerland. In 1989, Dr. Farokhi received both the Burlington Northern Foundation Faculty Achievement Award for his distinguished service to engineering research and the Miller Professional Development Award from the KU School of Engineering. He also received the 1990 and 1997 Henry E. Gould Award for Outstanding Teaching from KU, and was selected to receive the Outstanding Aerospace Educator Award in 1990, 1993, 1997 and 1999. Dr. Farokhi was appointed to John E. and Winifred E. Sharp Teaching Professorship in 1995. He has served as the Director of Flight Research Laboratory at KU from 1990 to 1995. Dr. Farokhi was named the Associate Dean of Graduate School in 2004. He has served as the National President of the Sigma Gamma Tau, The Honor Society of Aerospace Engineering, in 2000-2003. Dr. Farokhi is a Fellow of ASME, an Associate Fellow of AIAA and a member of SAE, ASEE, APS, Phi Beta Delta, and the American Academy of Mechanics.

**Richard Hale, Associate Professor of Aerospace Engineering**

Dr. Hale joined the department of Aerospace Engineering at the University of Kansas in 1998. His expertise is in the areas of engineering mechanics, experimental mechanics, and composite materials and structures. He received his B.S. in Aerospace Engineering from Iowa State University in 1988, his M.S. in Mechanical Engineering from Washington University in 1991, and his Ph.D. in Engineering Mechanics from Iowa State University in 1995. Dr. Hale was a Senior Project Engineer for the Boeing Company (formerly McDonnell Douglas Aerospace) from 1989 to 1998, where he worked on composite design and analysis processes, fiber placement, and structural concepts in advanced design. He was a member of Boeing's Parametric Composite Knowledge System team, which received the 1999 Technical Contribution Award from the St. Louis section of the AIAA. Dr. Hale holds three U.S. and one international patent for composite design processes, with further national and international patents in review. Dr. Hale was selected as the Outstanding Aerospace Engineering Educator for 1999-2000, 2001-2002 and 2003-2004, was a Bellows Scholar for the KU School of Engineering for 2000-2001, and received the Gould Award for Outstanding Education or Advising in Engineering in 2002, 2003 and 2005. In 2003 Dr. Hale also received the W.T. Kemper Fellowship for teaching excellence, as well as the KU School of Engineering Miller Professional Development Award for distinguished research in the engineering profession. Dr. Hale is a senior member of AIAA, and is a member of SAE, SEM, SAMPE, ASEE, Tau Beta Pi, Sigma Gamma Tau, Pi Mu Epsilon, and Phi Beta Theta.

### **Chuan-Tau Lan, J.L. Constant Distinguished Professor of Aerospace Engineering**

Dr. Lan joined the Department in 1968, and teaches and conducts research in theoretical and applied aerodynamics, flight dynamics and applied mathematics. He received his B.S. in 1958 at the National Taiwan University and his M.S. in 1963 at the University of Minnesota, both in Civil Engineering. In 1968 he received a Ph.D. in Aeronautics from New York University. Dr. Lan was selected as the Outstanding KU Aerospace Educator in 1991. He co-authored with Dr. Roskam a textbook on airplane performance, and is the author of a book entitled Applied Airfoil and Wing Theory. Dr. Lan is an Associate Fellow of AIAA and a member of Sigma Gamma Tau, and Tau Beta Pi.

### **Craig McLaughlin, Associate Professor of Aerospace Engineering**

Dr. McLaughlin joined the faculty of the Aerospace Engineering Department at the University of Kansas in 2007. Before coming to KU, he spent five years in the Department of Space Studies at the University of North Dakota. From 1994-2002 Dr. McLaughlin worked in the Space Vehicles Directorate of the U. S. Air Force Research Laboratory. There he served as principal investigator for formation flying for the TechSat 21 mission and as team lead for the Guidance, Navigation, and Control Team. Before that he provided mission planning design and support for the MightySat II technology demonstration satellite, which captured the first hyperspectral images taken from space. The MightySat II team won the AFRL Commander's Cup Award in 2002. Dr. McLaughlin received his M. S. and Ph. D. in Aerospace Engineering Sciences at the University of Colorado at Boulder in 1994 and 1998 respectively. He received a B. S. in Aeronautical Engineering from Wichita State University in 1992.

### **Ray Taghavi, Professor of Aerospace Engineering**

Dr. Taghavi joined the Department in 1991 with expertise in fluid mechanics and propulsion. He received his B.S. in Mathematics from Tehran University in 1965, his M.S. in Aerospace Engineering from Northrop University in 1978, and his Ph.D. in Aerospace Engineering from the University of Kansas in 1988. Dr. Taghavi has had professional experience at NASA's Lewis Research Center from 1986 to 1991, where he supported the NASA's High Speed Research (HSR) Program. His research activities included supersonic jet noise, excitation & control of shear layers, and mixing enhancement of swirling flows. Dr. Taghavi was selected to receive the Outstanding KU Aerospace Educator Award in 1995 and 2005. He was the recipient of the 1999 SAE Ralph R. Teetor National Educational Award and the 1999 Spahr Professorship Award from the KU School of Engineering, and was also selected as one of the 1999 Boeing Welliver Faculty Fellows. Dr. Taghavi is the recipient of the 2001 AIAA Abe M. Zarem National Educator Award. He is a Fellow of ASME, an Associate Fellow of AIAA, and a member of SAE, ASEE, Sigma Gamma Tau, and Tau Beta Pi.

## 1. 4 Application Requirements

### 1. 4.1 Application Materials Needed

In order for applications to be considered, the following materials must be submitted to the addresses provided in Section 1.4.4

#### Send to the Graduate School:

1. Graduate Application for Admission with fee

#### Send DIRECTLY to the department:

1. GRE score report
2. One official copy of transcripts from each post-secondary university attended
3. TOEFL or IELTS score report (International students only)
4. Statement of Financial Resources (International students only)
5. Three letters of recommendation
6. Statement of Purpose specifying Area of Interest
7. Curriculum Vitae (optional)

### 1.4.2 Admissions Deadlines

Our department deadlines for admission are March 1<sup>st</sup> for the Fall semester, December 1<sup>st</sup> for the Spring semester, and April 1<sup>st</sup> for the Summer semester. **For full consideration for fellowships, scholarships and research/teaching assistantships, applications should be received by January 1<sup>st</sup>.** Application materials should indicate the interest in financial assistance or research/teaching assistantships.

### 1.4.3 Document Specifications

#### Application Fees:

Domestic Students:	Paper \$55	Online \$45
International Students:	Paper \$60	Online \$55

#### Statement of Financial Resources:

As a part of the application process, all students must submit credible evidence of financial support for the first year of study. Financial documents must be less than 6 months old, indicating the type and amount of currency in US dollars. If the bank account is not in the applicant's name, please attach a statement signed by the account holder indicating the relationship to the student for whom the support will be provided.

Acceptable evidence includes:

- Bank statement from checking, savings, stock holdings and/or certificate of deposit
- Bank letter on letterhead indicating date account opened, average balance and current balance
- Scholarship or sponsorship letter verifying amount, source and dates of award

### Statement of Purpose:

It is important to state the area of interest, such as Aerodynamics, Fluid Mechanics, Flight Dynamics and Control, Propulsion, Structures, Materials, Aerospace Vehicle Design, Flight Testing, Uninhabited Aerial Vehicles, or Orbital Mechanics. It is very helpful also to indicate whether the primary interest is in aeronautics or in astronautics. This input will help the department match students with faculty advisors.

### **1.4.4 Contact Information**

The University of Kansas Graduate School  
Graduate Applications Processing Center  
1450 Jayhawk Blvd, Room 313  
Lawrence, Kansas 66045-7535  
785-864-6161  
[gradschool@ku.edu](mailto:gradschool@ku.edu)  
website: <http://www.ku.edu/graduate>

Graduate Advisor  
The University of Kansas  
Aerospace Engineering  
2120 Learned Hall  
1530 W. 15th Street  
Lawrence, Kansas, 66045  
[aerohawk@ku.edu](mailto:aerohawk@ku.edu)  
website: <http://www.engr.ku.edu/ae>

## **1.5 Admission Standards**

### **1.5.1 Minimum Requirements for Masters Applicants**

Students who wish to apply for admission to the MSAE or MEAE programs must have as a minimum: a BSAE degree from a university or college with a program equivalent to the KU-BSAE program. Students applying with either: a BS degree from an aerospace engineering program which is not equivalent to the KU BSAE program, or: a BS degree from a non-aerospace engineering program will have to make up certain undergraduate AE courses at the discretion of the department graduate advisor. Such make-up courses will not count toward the MSAE or MEAE degree.

### **1.5.2 Minimum Requirements for Doctoral Applicants**

Students applying for admission to the Ph.D. or D.E. programs must have as a minimum an M.S. or M.E. in Aerospace Engineering, unless they are admitted on a Fast Track basis with a bachelor degree in engineering. The department graduate advisor will evaluate the total academic preparation to determine if additional courses are required to prepare the student for graduate work in aerospace engineering. Any undergraduate courses which must be taken do not carry graduate credit.

Except for BSAE, MSAE or MEAE graduates from KU, all applicants must supply a recent Graduate Record Examination (GRE) and three letters of recommendation from individuals familiar with their academic record and performance. Applicants must have as a minimum a GPA of 3.5/4.0 for all courses taken during their M.S. or M.E. program.

### **1.5.3 GPA Requirements**

Applicants must have a minimum GPA of 3.0/4.0 for a regular admission status. In exceptional cases applicants with a GPA of between 2.75-2.99 may be granted probationary admission. In such instances the student must maintain a GPA of at least 3.0/4.0 during the first semester of graduate study at KU. Grades of D and F are not accepted. A student failing to maintain these standards will be dismissed from the graduate program. A probationary student who maintains these standards will automatically attain regular graduate student status at the end of first semester. On rare occasions and as supported by other strong evidence of achievement (e.g., significant industrial experience), a provisional admission status may be granted to students with a cumulative GPA below 2.75. After one semester of full-time graduate studies and maintaining a GPA of at least 3.0, a provisionally-admitted student has to file a petition to change his/her status to a graduate student with regular admission status.

Applicants from outside KU must submit Graduate Record Examination (GRE) scores and three letters of recommendation from individuals familiar with their academic performance.

### **1.5.4 Transfer Credit for Graduate Courses**

Up to six hours of approved graduate work may be transferred to KU from other universities. Students with a BS degree from KU may transfer up to eight hours of approved graduate work from other universities.

### **1.5.5 GRE Requirements**

Applicants must have a minimum of 50% on the Verbal and Analytical sections of the GRE and 85% on the Quantitative section. Applicants with lower scores, but otherwise exceptional record, will be considered for provisional admission.

### **1.5.6 Non-English Speaking Students**

Applicants for whom English is not the native language must submit an institutional copy of their TOEFL (Test of English as a Foreign Language) score achieved no more than two years prior to the semester of admission. The following standards will be applied (with the first score being the paper test and the second being the computer test):

- Applicants with total TOEFL scores of 570 for the paper-based exam (230 for computer-based or 88 for internet-based) or higher and with a minimum of 57 on all three parts of the TOEFL examination may be admitted to the graduate program as a regular student.
- Applicants with a TOEFL score between 550 (213 cbt or 79 ibt) and 569 (227 cbt or 90 ibt) may be admitted to the graduate program with provisional admission status.
- Applicants with TOEFL scores below 550 (213 cbt or 79 ibt) will be denied admission.

Once on the Lawrence campus, all students, regardless of their TOEFL scores, will be screened by the Applied English Center (AEC). If a student is judged by the AEC to have a written or a verbal deficiency, the student may be required to take not-for-degree AEC courses. This will limit the number of degree-counting courses, which a student can take. In such a case the student should expect to take a longer calendar time to complete the graduate program. All students who have not satisfied the AEC requirements by the end of the third semester on the Lawrence campus will be dismissed from the graduate program.

## **1.6 Financial Aid**

Where possible the department offers financial support to graduate students. Financial support may be offered in the following forms:

- Graduate Teaching Assistant (GTA). GTA positions include a stipend, full tuition waiver and other benefits.
- Graduate Research Assistant (GRA). GRA positions include a stipend plus eligibility for in-state tuition and other benefits.
- Fellowship

The department strives to provide approximately equal total compensation for GTA and GRA positions. Important note: acceptance into the graduate program does not guarantee financial aid.

To be considered eligible for GTA, GRA or Fellowship, a completed application for entry into the graduate program and a request for financial aid must be received before January 1. Awards will be announced by April 1. In unusual cases, an appointment may be available in the Spring semester.

GTA and Fellowship appointments are made by the department chairman following a review and recommendation by the faculty.

GRA appointments are made by individual faculty members who have funded research projects. Students interested in applying for a GRA appointment are advised to contact the faculty member(s) directly who work in the area of interest.

## 1. 7 Thesis, Dissertation and Project Report Publication Guidelines

The University of Kansas has adopted the electronic submission method for theses and dissertations, effective December 2005. To learn more about the theses and dissertation preparation and electronic submission, visit the Electronic Theses and Dissertations website at [www2.ku.edu/~etd/](http://www2.ku.edu/~etd/). In addition, the Aerospace Engineering Department requires a CD of the thesis or dissertation to be submitted to the AE-Office.

## 1. 8 Definition of a Full-time Graduate Student

The minimum enrollment required for a full-time graduate student is defined as follows:

Teaching or Research Appointment	Minimum Course Enrollment
50% (GTA or GRA)	6 semester hours
0% (GTA or GRA)	9 semester hours

Important note: An international student can only be appointed at the 50% level or less (except for summer) in accordance with the U.S. Immigration Laws.

## 1. 9 Course Numbering System

The course numbering system used by the Department of Aerospace Engineering is:

100 - 299	Courses for freshmen and sophomores
300 - 499	Courses for juniors and seniors
500 - 699	Courses primarily for juniors and seniors. These courses may be taken by graduate students with fewer than 30 hours of graduate credit.
700 - 799	Courses for graduate students with fewer than 30 hours of graduate credit. These courses may also be taken by undergraduates.
800 - 900	Courses for graduate students with more than 30 hours of graduate credit.

## 2. Master's Program

### 2.1 Outline of Typical Master's Program

A seven-step outline of a typical Master's program in Aerospace Engineering is as follows:

- Step 1: After earning the BSAE (or equivalent) the student applies for admission to the Master's program.
- Step 2: The student selects or (upon request) is assigned a major advisor based upon the student's area of interest. The major advisor assists the student in selecting courses for the first year of study and the preparation of an initial plan of study (Section 2.2) including the formation of an initial thesis or project committee.
- Step 3: After completing the first semester of study with a GPA of at least 3.0/4.0 the student prepares a final plan of study: see Section 2.2
- Step 4: The student completes the final plan of study, finishes the required course work with a GPA of at least 3.0/4.0 and defines an area of thesis or project research.
- Step 5: The student completes the MS or project research in accordance with original research plan of Step 4 and writes a thesis or project report. The thesis or project report must be approved by the thesis/project committee.
- Step 6: The student completes the 6-month internship requirement (MEAE only)
- Step 7: After approval by the thesis/project committee the student defends the thesis/project before the student's Masters Committee, other department faculty and students (at their option) and invited guests.

### 2.2 Plan of Study

A Plan of Study must be completed and approved no later than the end of the student's first semester in residence. The Plan of Study serves as a record of the student's intentions, an indicator of the likely time-to-degree, and as an official acknowledgement of the advisor's and committee member's approval of the student's study plans. The form can be accessed and changed by the student subsequent to initial approval, but any changes must be approved by the advisor and committee. Information included as part of the plan of study is:

- Names of the three members of the thesis/project committee. As a general rule these committee members will be drawn from the AE faculty but exceptions may be approved
- Proposed thesis/project title or, at least, the proposed area of thesis/project research
- Proposed sequence of courses

The online plan of study is located at <https://gradplan.engr.ku.edu/>. Plan of study worksheets are available to print on the Aerospace Engineering website.

Detailed course descriptions can be found in Appendix A.

## **2.3 Master of Science in Aerospace Engineering (MSAE)**

The Master of Science program in Aerospace Engineering (MSAE) has two options:

Thesis Option: requires a minimum of 30 semester hours of graduate work, including 6 hours in the satisfactory completion of a thesis.

Project Option: requires a minimum of 33 semester hours of graduate work. This option does not require a thesis but does include a project within with at least 3 hours of Special Problem/Project have been satisfactorily completed.

Both the thesis and the special problem/project must be orally defended before the student's Masters Committee, other department faculty, graduate and undergraduate students (at their option), and invited guests.

To earn the MSAE degree the student must:

- Complete the MSAE course requirements in accordance with an approved plan of study
- Prepare and defend a thesis or problem/project report approved by the student's Masters Committee

The student is expected to demonstrate a working knowledge of aerospace engineering as part of the thesis or project defense.

### **2.3.1 Minimum Course Requirements for MSAE**

The minimum course requirements for the MSAE are:

Thesis Option: At least 24 semester hours (not counting courses with grades of D or F) beyond the BSAE degree plus 6 hours of thesis

Project Option: At least 30 semester credit hours beyond the BSAE degree plus 3 semester credit hours of project.

If a student enters the MSAE program without an equivalent BSAE background the department graduate advisor may require the student to make up certain undergraduate courses in AE to achieve BSAE equivalence. Such make-up courses do not count toward the MSAE degree.

### **2.3.2 Thesis or Project Committee**

As part of the plan of study a student is required to form a Thesis or Project Committee with a minimum of three AE faculty members. Additional committee members may be selected by the student from either AE or other School of Engineering faculty members. The chairman of the Thesis or Project Committee must be an AE faculty member.

## **2.4 Master of Engineering in Aerospace Engineering (MEAE)**

The Master of Engineering program in Aerospace Engineering (MEAE) is a program which emphasizes systems design and management skills and procedures rather than the more analytical emphasis of the MSAE program. The MEAE program requires a total of 36 semester hours of graduate work, including a 6 hour requirement for an industrial internship.

An important requirement of the MEAE program is a minimum of six months of industrial internship in an industry or government organization. Because this internship is a degree requirement, and because neither the University nor the Department of Aerospace Engineering can guarantee internship employment, students must indicate in writing before they have completed their first semester how the internship requirement will be satisfied.

To earn the MEAE degree the student must:

1. complete the MEAE technical course requirements
2. complete the MEAE design, technology and management course requirements all according to an approved plan of study
3. prepare and defend a design project report approved by the student's ME Committee
4. complete a minimum of 6 months of industrial internship

### **2.4.1 Minimum course requirements for the MEAE**

The minimum course requirements for the MEAE are:

- At least 15 semester credit hours in technical courses beyond the BSAE degree
- At least 9 semester hours of design, technology and management courses (These may be selected from the E.M. courses in Table 2.1)
- At least 6 semester hours of design project
- At least 6 hours of industrial internship

A detailed description of acceptable courses can be found in Appendix A.

A letter stating how the student intends to satisfy the internship requirement must be attached to the plan of study.

If a student enters the MEAE program without an equivalent BSAE background the department graduate advisor may require the student to make up certain undergraduate courses in AE to achieve BSAE equivalence. Such make-up courses do not count toward the MEAE degree.

### **2.4.2 Project Committee**

As part of the plan of study a student is required to form a Project Committee with a minimum of two AE faculty members and one Engineering Management faculty member. Additional committee members may be selected by the student from either AE or other School of Engineering faculty members. The chairman of the Project Committee must be an AE faculty member.

## 3. Doctorate Program

### 3.1 Outline of Typical Doctorate Program

A seven-step outline of a typical Doctorate program is as follows:

- Step 1: After earning the MSAE or MEAE degree (or equivalent) the student applies for admission to the Doctorate program. A student judged to be capable of earning the degree is admitted to the program as a Doctoral aspirant. Exceptionally qualified students with a BSAE (or equivalent) degree and a GPA of at least 3.75 may be admitted as a doctoral aspirant.
- Step 2: The aspirant selects or (upon request) is assigned a major advisor based upon the aspirant's area of interest. The major advisor assists the aspirant in selecting courses for the first year of study and the preparation of an initial plan of study including the formation of an initial dissertation committee. Note well: The Doctoral aspirant must be classified as a full-time graduate student as defined in Section 1.8.
- Step 3: After completing the first year of study with a GPA of at least 3.5/4.0 (grades of D or F do not count toward the Doctorate degree) the aspirant requests the preparation of a qualifying examination: see Section 3.3.
- Step 4: After passing the Qualifying examination the aspirant forms a Dissertation or Project Committee and prepares a final plan of study: see Section 3.2.
- Step 5: The aspirant completes the final plan of study and satisfies the FLORS (Foreign Language or Research Skills) requirement: see Section 3.4.
- Step 6: The aspirant prepares for the comprehensive examination. An important component of this is a documented, original research plan which becomes the focus. This original plan must be approved by the aspirant's committee. After committee approval the aspirant defends the original research or project plan. Sections 3.6.3 and 3.7.3 describe the requirements for the comprehensive examination. After passing the comprehensive examination the aspirant becomes a doctoral candidate.
- Step 7: The candidate completes the doctoral research in accordance with the original research or project plan of Step 6 and writes a dissertation or project report. The dissertation or project must be approved by the candidate's committee. After approval by the candidate's committee the candidate defends the dissertation or project report: see Sections 3.6.4 and 3.7.4.

The residency requirement described in Section 3.5 can be satisfied during any of Steps 1-7. The doctoral requirements must be completed within eight years after being admitted to the doctorate program. In cases which require more than eight years the candidate's committee may grant an appeal for an extension of this period. An extension is typically granted only when the candidate takes an educational delay to pursue and engineering position outside the university.

The sequence of steps described here is typical. In special situations this sequence may be altered. However, any changes in the sequence must be approved by the candidate's committee and by the department graduate advisor.

## 3.2 Plan of Study

A Plan of Study must be completed and approved no later than the end of the student's first semester in residence. The Plan of Study serves as a record of the student's intentions, an indicator of the likely time-to-degree, and as an official acknowledgement of the advisor's and committee member's approval of the student's study plans. The form can be accessed and changed by the student subsequent to initial approval, but any changes must be approved by the advisor and committee. Information included as part of the plan of study is:

- Names of the five members of the dissertation/project committee. As a general rule these committee members will be drawn from the AE faculty but exceptions may be approved.
- Proposed dissertation/project title or, at least, the proposed area of dissertation/project research
- Proposed sequence of courses

The online plan of study is located at <https://gradplan.engr.ku.edu/>. Plan of study worksheets are available to print on the Aerospace Engineering website.

Detailed descriptions courses can be found in Appendix A.

## 3.3 Qualifying Examination

The purpose of the qualifying examination is to assess the aspirant's breadth of knowledge and to demonstrate the aspirant's ability to formulate mathematical representations of real physical situations in the broad field of aerospace engineering.

It is recommended that the qualifying examination be taken after two semesters of course work which is part of the plan of study discussed in Section 3.2.

The qualifying examination is a written examination which covers mathematics and three of the following six areas at the option of the aspirant:

- structures and materials
- aerodynamics
- dynamics and controls
- propulsion
- astronautics

The qualifying examination is normally conducted over a two-day period. On each day, a morning and afternoon session is devoted to one of the four areas selected by the aspirant.

The outcome of each of the four areas may be: pass, pass with remedy or fail. Pass with remedy usually requires the aspirant to take additional graduate course work in that area with a B grade as a minimum.

Note well: an aspirant is allowed two attempts to pass any part of the qualifying examination. Unsuccessful aspirants (after two attempts) are barred from further doctoral study in AE at KU.

### **3.4 FLORS (Foreign Language or Research Skills) Requirement**

Aspirants can satisfy the FLORS requirement by selecting one of three options as long as their committee chairman approves of that choice:

- Option 1: Aspirants must demonstrate proficiency in computer science and complete three hours of graduate course work in instrumentation or experimentation if their area of interest is primarily theoretical.
- Option 2: Aspirants must demonstrate proficiency in computer science and complete three hours of graduate course work in computational methodology if their area of interest is primarily experimental.
- Option 3: All aspirants may elect to substitute a demonstration of reading proficiency in a non-native language (other than English) for the demonstration of computer proficiency. Such a language must be one with a significant body of literature in the area of the aspirant's dissertation research. Examples of acceptable foreign languages in aerospace engineering are: German, French, Russian, Chinese, Japanese, Dutch and Spanish.

Note well: These requirements are in addition to the courses taken as part of the plan of study.

### **3.5 Residency and Internship Requirements**

Doctoral students are required to spend at least two semesters (this may include a summer semester) in residence study at The University of Kansas. During this period of residence the student must be a full time graduate student as defined in Section 1.8. An appointment for teaching or research is acceptable as long as that activity is directed toward the aspirant's or candidate's degree objectives.

In addition, the DEAE student must complete a 12 month industrial internship requirement: see Section 3.7. To obtain credit for this, the DEAE student must also enroll for a minimum of 12 semester credit hours of industrial internship.

### **3.6 Doctor of Philosophy in Aerospace Engineering (PhDAE)**

The Doctor of Philosophy program in Aerospace Engineering is a traditional program that requires students to successfully demonstrate their abilities in a broad spectrum of aerospace technology, mathematics and original research. To earn the Ph.D. degree students must:

1. Complete Ph.D. course requirements in accordance with an approved plan of study
2. Pass a qualifying examination
3. Complete a FLORS (Foreign Language or Research Skills) requirement
4. Satisfy the residency requirements
5. Pass a comprehensive examination
6. Prepare and defend a Ph.D. dissertation which must contain an original contribution to the field by the candidate.

#### **3.6.1 Minimum Course Requirements**

The minimum course requirements for the PhDAE are:

- 1) At least 60 semester credit hours beyond the BSAE degree (or equivalent). These 60 hours must be distributed as follows:
  - a) at least 15 semester credit hours of graduate mathematics beyond the BSAE degree
  - b) at least 15 semester credit hours of technical courses (above 600 level) must be distributed outside the area of specialization in the areas of:
    - i) structures and materials
    - ii) aerodynamics
    - iii) design
    - iv) dynamics and controls
    - v) Propulsion
- 2) at least 15 semester credit hours of technical courses (above 600 level) in the area of specialization
- 3) At least 15 semester credit hours of doctoral dissertation.

A maximum of 30 credit hours earned while completing the MSAE or MEAE (or equivalent) degree can be used to satisfy a portion of requirements 1 & 2, provided those credits are appropriate to the overall PhDAE program of the aspirant.

Unique situations can be accommodated with the combined approval of the AE department graduate advisor and the aspirant's major advisor.

Detailed descriptions of accepted courses can be found in Appendix A.

### **3.6.2 Dissertation Committee**

After successfully completing the qualifying examination the PhDAE aspirant forms the final dissertation committee. This committee consists of four AE faculty members plus at least one faculty member from outside the AE department. The outside member represents the Graduate School. The dissertation committee chairman is normally the aspirant's major advisor. The dissertation committee assists the aspirant during the remainder of the PhDAE program, particularly with the dissertation research. If the outside member of the dissertation committee is not a member of the graduate faculty an ad hoc appointment to the graduate faculty must be secured before such a person is allowed to serve as a member of the dissertation committee.

### **3.6.3 Comprehensive Examination**

The purpose of the comprehensive examination is to determine whether or not the aspirant has an acceptable proposal for research leading to a dissertation. This research and the ensuing dissertation must contain an original contribution of the aspirant to the field.

The comprehensive examination consists of two parts:

- Part 1: a written proposal outlining in reasonable detail the work or research plan to be done for the dissertation. This written proposal must contain a historical outline (with references) of similar work done in the field.
- Part 2: an oral examination during which the aspirant defends the proposed work or research plan. In addition the aspirant is expected to demonstrate proficiency in his/her area of specialization.

Note well: At least two weeks before the comprehensive examination is scheduled the aspirant must submit copies of the work or research plan to the dissertation committee for review.

The comprehensive examination will be conducted by the aspirant's dissertation committee. The examination must be public and reasonable questions from the public must be addressed by the aspirant. After the comprehensive examination, the candidate must continuously enroll in 6 hours of dissertation in regular semesters and 3 hours during the summer until the required 18 hours of dissertation is satisfied. After the 18 hours of dissertation, a candidate should continuously enroll at a minimum of one hour per semester including the semester of dissertation defense.

### **3.6.4 Dissertation and Public Defense**

Upon passing the comprehensive examination the aspirant becomes a candidate for the PhDAE degree. The candidate now completes the dissertation work or research and writes the dissertation. The dissertation must contain an original contribution made by the candidate to the field. In addition, a comprehensive review of the pertinent literature must be included. This dissertation must be approved by the candidate's dissertation committee.

Note well:

- a) The dissertation must be publicly defended in the presence of the candidate's dissertation committee. Public notice of this defense must be given at least two weeks before the defense. The dissertation defense must be public and reasonable questions from the public must be addressed by the candidate.
- b) At least five months must elapse between passing the comprehensive examination and conducting the dissertation defense.

### **3.7 Doctor of Engineering in Aerospace Engineering (DEAE) Program**

The Doctor of Engineering program in Aerospace Engineering (DEAE) is a unique program that emphasizes system design and management skills. The program also requires students to successfully demonstrate their abilities in a broad spectrum of aerospace technology, mathematics and original research. To earn the DE degree students must:

1. complete DE course requirements in accordance with an approved plan of study
2. pass a qualifying examination
3. complete a FLORS (Foreign Language or Research Skills) requirement
4. satisfy the residency requirements
5. pass a comprehensive examination
6. Prepare and defend a DE design/project report which must contain an original contribution to the field by the candidate.
7. complete a 12 month industrial internship requirement

An important requirement of the DEAE program is a minimum of twelve months of industrial internship in an industry or government organization. Because this internship is a degree requirement, and because neither the University nor the Department of Aerospace Engineering can guarantee internship employment, students must indicate in writing before they have completed their first semester how the internship requirement will be satisfied.

#### **3.7.1 Minimum Course Requirements**

The minimum course requirements for the DEAE are: at least 60 semester credit hours beyond the BSAE degree (or equivalent).

These 60 hours must be distributed as follows:

- 1) at least 15 semester credit hours of graduate mathematics beyond the BSAE degree
- 2) at least 15 semester credit hours (beyond 600 level) must be taken in engineering management courses
- 3) at least 15 semester credit hours of technical courses (beyond 600 level) must be distributed in the areas of:
  - a) structures and materials
  - b) aerodynamics
  - c) design
  - d) dynamics and controls
  - e) propulsion
- 4) at least 15 semester credit hours of DE project

In addition, the DEAE student must complete a 12-month industrial internship requirement. To obtain credit for this, the DEAE student must also enroll for a minimum of 12 semester credit hours of industrial internship.

A maximum of 30 credit hours earned while completing the MSAE or MEAE (or equivalent) degree can be used to satisfy a portion of the requirements 1) through 3), provided those credits are appropriate to the overall DEAE program of the aspirant. Unique situations can be accommodated with the combined approval of the AE department graduate advisor and the aspirant's major advisor.

Detailed descriptions of acceptable technical and engineering courses can be found in Appendix A.

### **3.7.2 Project Committee**

After successfully completing the qualifying examination the aspirant forms the final project committee. This committee consists of four AE faculty members, one faculty member from the area of engineering management plus at least one faculty member from outside the AE department. The project committee chairman is normally the aspirant's major advisor. The project committee assists the aspirant during the remainder of the DEAE program, particularly with the project work and associated research. If the outside members of the project committee is not a member of the graduate faculty an ad hoc appointment to the graduate faculty must be secured before being allowed to serve as a member of the project committee.

### **3.7.3 Project Research and Project Examination**

The purpose of the project research and comprehensive examination is to determine whether or not the aspirant has an acceptable proposal for research/work leading to a successful project. This research/work and the ensuing project report must contain an original contribution of the aspirant to the field.

The project research and comprehensive examination consists of two parts:

- Part 1: a written proposal outlining in reasonable detail the work or research plan to be done for the project. This written proposal must contain a historical outline (with references) of similar work done in the field.
- Part 2: an oral examination during which the aspirant defends the proposed work or research plan. The aspirant is also expected to demonstrate proficiency in his/her area of specialization.

Note well: At least two weeks before the comprehensive examination is scheduled the aspirant must submit copies of the work or research plan to the project committee for review. The comprehensive examination will be conducted by the aspirant's project committee. The examination must be public and reasonable questions from the public must be addressed by the aspirant.

### **3.7.4 Project Report and Public Defense**

Upon passing the comprehensive examination, the aspirant becomes a candidate for the DEAE degree. The candidate now completes the project work/research and writes the project report. In addition, a comprehensive review of the pertinent literature must be included. This project report must be approved by the candidate's project committee.

Note well:

- a) The dissertation must be publicly defended in the presence of the candidate's dissertation committee. Public notice of this defense must be given at least two weeks before the defense. The dissertation defense must be public and reasonable questions from the public must be addressed by the candidate.
- b) At least five months must elapse between passing the comprehensive examination and conducting the dissertation defense.

## 4. Department Facilities, Equipment and Other Resources

### 4.1 Introduction

The School of Engineering and the Department of Aerospace Engineering at the University of Kansas have extensive facilities that support our undergraduate and graduate education and research missions.

All faculty members are active in funded and unfunded research. If a student is interested in becoming involved in research he/she should contact the appropriate faculty member. Undergraduate students can receive academic credit for research performed by enrollment in AE 592 Special Projects in Aerospace Engineering.

### 4.2 Research Facilities

Each Student during his/her career in the department will have the opportunity to work with a broad range of experimental equipment as well as modern computer software packages. This equipment and the faculty coordinator are listed below.

#### 4.2.1 On-Campus Facilities



Picture 1: Closed Circuit Subsonic Wind Tunnel

#### Aerodynamics/Fluid Dynamics Laboratories

The Closed Circuit Subsonic Wind Tunnel, shown on the left, has a 36" by 51" test section and a maximum speed of 200 mph. This tunnel is equipped with a six-component strain-gauged balance and computerized data acquisition system. The Department's laser Doppler velocimeter and hot-wire anemometer can be used in this tunnel. Flow visualization techniques include a laser light sheet, smoke, helium bubbles, and surface oil streak-line methods. A computerized, two-axis traversing system is available for flow field mapping. The test section and operator's station is

located in Room 1180 of Learned Hall. Coordinator: S. Farokhi

The Open Circuit Subsonic Wind Tunnel has a 21" by 30" test section and a maximum speed of 120 mph. This tunnel is useful for fundamental fluid mechanics experiments due to its low turbulence factor. The Department's laser Doppler velocimeter, hot wire anemometer, and helium bubble system can be used in this tunnel. Coordinator: D. Downing

The Supersonic Wind Tunnel, pictured on the right, has a 2" by 3¼" test section with a Mach number range of 1.5 to 3.0. The tunnel is a blow-down type equipped with a Schlieren system and pressure measurements. This tunnel is located in Room 1180, Learned Hall. Coordinator: S. Farokhi



Picture 2: Supersonic Wind Tunnel

The Water Tunnel has a 60' long open channel, 29" wide and 34" deep. Water is pumped to the channel at a rate of 1500 gal/min. The maximum water speed is about 1 ft/sec. This facility is mainly used for flow visualization purposes by using dye injection around models. The water tunnel is located in Room 1161, Learned Hall and is shared with the Department of Civil Engineering. Coordinator: R. Taghavi

The Mal Harned Propulsion Laboratory consists of a test cell capable of testing gas turbine engines up to 8,000 pounds of thrust, as well as reciprocating engines. The control room is equipped with basic engine testing instrumentation. This facility is located in the Department's hangar at Lawrence Airport. Coordinator: R. Taghavi

#### Structural Dynamics and Acoustics Laboratory

The Structural Dynamics and Acoustics Laboratory consists of a modal test system, an acoustics data acquisition system, a structural control system, and a scanning laser vibrometer.

The Modal Test System is used to determine the vibratory "signature" of structures using vibration data from various sensors, including piezoceramic accelerometers. For example, the signature, or modal characteristics, of an aircraft component may be determined in order to properly design a control system or prevent aerodynamic flutter. The system is based on a PC with a 32-channel analog-to-digital board. Vibration excitation is provided by both an electrodynamic shaker and a modal hammer.

The Acoustical Data Acquisition System is used to measure sound in support of structural acoustics research. The system is based on a PC with a 32-channel analog-to-digital board.

The Structural Control System is used to provide positional and vibrational control of a flexible structure. Current research is focused on controlling flexible space structures. The system is based on a 486 PC with a 32-channel analog-to-digital board. The computer controls actuators, including a linear stepper motor, via a precision power amplifier.

#### Mechanical Testing Facilities

Mechanical Testing Facilities are shared with the Departments of Mechanical and Civil Engineering. These facilities provide testing capabilities for articles ranging from material coupons to large-scale structures. Available test equipment includes 222 kN and 89 kN MTS servo-hydraulic test machines, a 489 kN Instron servo-hydraulic test machine, 267 kN and 107kN Baldwin hydraulic test machines and instrumentation including extensometers, load cells, strain gages and digital data acquisition systems. Additional equipment for experimental stress analysis includes a reflection polariscope and a portable four beam Moiré interferometer.

#### Composites Materials Laboratory

The Composites Materials Laboratory is a shared facility with the Department of Mechanical Engineering. The composite lay-up facility is a 40 m<sup>2</sup> "clean" room with a 6 m<sup>2</sup> lay-up table and 1.3 m<sup>3</sup> of -30° C material cold storage. The composite tooling and processing laboratory encompasses 50 m<sup>2</sup>, and contains a radial diamond saw, 17.8 cm diamond blade precision sectioning saw, 22.9 cm abrasive cutter, two hydraulic specimen mounting presses, orbital and vibrating polishers and a microhardness tester.



Sample inspection and documentation is aided with a Nikon Epiphot inverted reflected light photomicroscope capable of magnification to 1000X, with Polaroid and 35mm film or digital video capture. Composite manufacturing equipment includes a filament winding machine and an electronically controlled filament plate winder. The composite curing facility encompasses 140 m<sup>2</sup> and includes an autoclave for curing thermoset and thermoplastic composite materials, 107 kN and 667 kN electrically heated water cooled platen presses, and electronically controlled ovens. The autoclave is rated to 2.4 MPa and 370° C and has a usable space of 30x30x91 cm. The small oven is rated to 370° C and has a usable space of 51x51x46 cm. The composite materials laboratory also houses an electronically controlled walk-in curing oven capable of 260° C, with a usable space of 1.5x1.8x3.0 m.

Textile weaving is enabled by a 122 cm Macomer twenty-harness computer driven dobby loom. Fiber placement capability is provided with four robotic arms. Equipment includes a five-axis ASEA IRB 6 industrial robot with a payload of 6.0 kg, a six-axis Intellidex 605 table mounted robot with a payload of 5.4 kg, and two seven-axis Intellidex 705 floor mounted robots with a payload of 5.4 kg each. The ASEA has a maximum reach of 1.2 m, with a base rotation of 340°, a shoulder rotation of 80°, an elbow rotation of 65°, wrist rotation of ±90°, and a tool spin of ±180°. The Intellidex machines have a reach of 0.7-1.5 m, a large shoulder and forearm rotation of ±135°, a small shoulder and upper arm rotation of ±115°, an outboard axis rotation of ±170°, and a tool spin axis rotation of a full 360°. Coordinator: R. Hale

#### Nondestructive Evaluation Laboratory

The nondestructive evaluation laboratory is a shared facility with the Department of Civil Engineering. Available equipment includes a SONIX CSF1000-3X digital 3-axis automated immersion ultrasonic scanning system (pictured at left) with capabilities for A-scan, B-scan and C-scan testing in through-transmission or pulse-echo mode. Current equipment provides a scanning envelope of 0.8x0.9x1.2 m. In addition, the laboratory houses a combination digital acoustic emission acquisition and analysis, and low frequency ultrasonic generation, acquisition and analysis system. Acoustic emission and ultrasonic inspection capabilities are enhanced by state of the art data acquisition software running on PC workstations. Finally, the laboratory has an ultrasonic flaw detector. These systems are used for laboratory and field-testing and inspection of materials and structures. Coordinators: R. Hale and G. Ramirez

The Department of Civil Engineering also provides access to the Engineering Microanalysis Laboratory, which equipped with a Philips 515 Scanning Electron Microscope, an ELMDAS Digital Image Acquisition System, and an EDAX PV-9900 Energy Dispersive Spectrometer with light element capability. Specimens are coated using a Technics Hummer X Sputter Coater. Coordinator: D. Darwin

#### Instrumentation Laboratory

The Instrumentation Laboratory is equipped with basic electronic and measurement instrumentation. The Department's laser Doppler velocimeter, hot wire anemometer, and flow visualization equipment is located in this laboratory. This facility is located in Room 1152 Learned Hall. Coordinator: Ray Taghavi

Design Laboratory



**Picture 3: 3-Axis Automated Immersion Ultrasonic Scanning System**

The Aerospace Vehicle Design Laboratory consists of a general work area equipped with PC and work station computer terminals and printers. Specialized design software includes AeroCAD, AAA, NASTRON, PATRAN, Satellite Tool Kit and Unique Plus. Coordinator: M. Ewing

### Computer Hardware and Software

Engineering also has workstations in the Flight Research Laboratory. Engineering students can use the University's VAX ALPHA V7.1 mainframe computer, and can also gain access to the supercomputer through Telnet connections. The students also have a wide range of modern software packages available to them, including: NASTRAN, PATRAN, PRO-E and ANSYS finite element codes and preprocessors; ASTROS and LAGRANGE finite element optimization software; Unigraphics, CATIA, AeroCAD and PRO-E CAD software; parabolized Navier-Stokes codes, unsteady 2D and 3D full Navier-Stokes codes, Panel methods codes, and steady 2D and 3D thin-layer Navier-Stokes codes; Fluent computational fluid dynamics software; PLOT-3D and other graphics codes; VORSTAB, prediction of stability derivatives for airplane configurations with vortex flow effect in subsonic and supersonic flow; nonlinear control system design code for high-alpha applications; combined aerodynamics-and-dynamics code for transonic store separation; transonics code for flutter prediction; MATLAB and Labview.

Additional facilities include a high-speed networking lab with a 2.4 Gb/s SONET connection; DSP and digital radio lab; integrated, diverse networking environment; and a leading-edge lightwave research lab. Complementing the hardware facilities are some of the best-in-class design and development tools, such as BONEs Designer® and Signal Processing Workstation (SPW). For development of new software, CORBA, C++, Java, and Lisp are available, among others, to ensure that industry-established solutions are used to smooth the technology transfer process. Resources available for data mining and knowledge capture include multiagent development tools (CORBA, C++, ACCS), information retrieval and web tools (KUIR Information Retrieval Library), data mining tools (SNOB, Cobweb, ID3, C4.5, statistical analysis packages), artificial intelligence development tools and languages (Lisp, CLOS, CLIPS, Prolog, GBB, OPS, MEM-1), commercial knowledge-based development languages (AML), and image processing and computer vision tools (KUIM Image Processing Library).

### Garrison Flight Research Center

The Garrison Flight Research Center was established in 2004 with the renovation of the existing 18,000 square foot university hangar. The Lawrence Municipal Airport (upgraded to 22,000 square feet) has a classroom, machine shop, electronics shop, offices, an AST 4000 fixed base simulator and hangar space for several aircraft. These provide resources for developing intelligent vehicle systems for the flight research of both piloted and uncrewed air vehicles. Additional shop and assembly space, along with a propulsion test cell, are available in an adjacent building.

### Flight Test Laboratory

The Flight Test Laboratory can support aerodynamic, performance, and stability and control flight testing. This laboratory, located in the Garrison Flight Research Center, operates the department's Cessna 172 Skyhawk and Cessna 182 RG. The Cessna 172 is used both for transportation and research, while the Cessna 182 is dedicated to flight research activities. The Cessna 182 is specifically configured to accommodate in-flight test instrumentation. There is also a one-third scale Piper Cub used for fixed wing UAV research. Two Raptor 50 have been obtained specifically for intelligent vehicle research. One has been extensively modified for this

work, having a three axis accelerometer, a three axis gyro, four string-pots to measure the pitch and roll collectives, the throttle, and the tail rotor, and a data logger to record both analog and digital sensor channels. A three axis magnetometer is being added. The second Raptor is being used for performance evaluations, and will eventually be used for cooperative flight experiments. A Yamaha RMAX is being used for rotary wing UAV research. It will be able to carry even heavier payloads than the Raptor 50s.

In addition to a programmable INS with three axis gyros and accelerometers, it will have a differential GPS and a three axis magnetometer, along with fully instrumented controls and flight test recorder and data link. These air vehicles are shown below.



**Picture 7: Yamaha R-Max**

window projection system and built-in weather and turbulence effects with a programmable control loader. Student designed vehicles may be entered in the flight characteristics module, such that developing vehicles may be "flown" and experienced by the design team.

In addition, KUAE has recently invested in an AST 4000 Fixed Base Simulator, produced by American Simulation Technology - Olathe, KS. This flight simulator is PC computer based, with programmable LCD Instrument Panels and programmable digital aircraft dynamic models. The "vehicle" can accommodate our experimental autopilot module, and offers an out the



**Picture 6: Raptor 50**

Aerospace Manufacturing Facilities

The Department of Aerospace Engineering maintains a research machine shop with two milling machines, a lathe, sheet metal break and shear equipment, band saws and drill presses. In addition, the School of Engineering maintains a fully equipped machine shop with multiple milling machines, surface grinders, vertical and horizontal band saws, drill presses, welding equipment, and a paint booth. New acquisitions include a Stratasys



**Picture 5: Cessna 172**

on modeling rapid prototyping center and a computer numerically controlled (CNC) mill with five axes of motion and 48" x 20" x 20" travel in translational axes.

Prodigy fused depositi



**Picture 4: Cessna 182**

The Adaptive Aerostructures Laboratory

(AAL) maintains unique capabilities supporting the design, fabrication and testing of aerospace structures with adaptive materials. Unlike conventional materials, adaptive materials change some property as a function of an applied control signal or stimulus. The AAL maintains a range of stocks of piezoelectric,

electrostrictive, shape-memory-alloy, magnetostrictive, magnetorheological and other adaptive materials and processing equipment. In addition to supporting work with adaptive materials, the AAL has generated many aerospace "firsts" in subscale uninhabited aerial vehicles, morphing aircraft, missiles and munitions. It is currently host to a unique ballistics laboratory where guided bullets and cannon shells are being designed and tested in the 40mm x 10m and 20mm x 5m gas guns. More than 50 subscale aircraft are housed in the 1200+ sq. ft facility as well as 9 grades of graphite-epoxy composites, 4 grades of Kevlar, composite cure oven, diamond saws and precision post processing machines. Through the years, more than 18 AIAA award winning students have graduated from the AAL, including the winners of the 2006 International Student Paper Competition.

#### 4.2.2 Off-Campus Facilities

In addition, a mutual agreement enabling shared utilization of research faculty and facilities, between the KU-FRL and the Institute for Aviation Research of Wichita State University, makes the following space and equipment at the Institute for Aviation Research available for use by researchers of the KU-FRL:

Wind tunnels

Water tunnel

Environmental chamber

Composite structures lab

Structural testing lab

CAD/CAM lab

Satellite integration facility

Flight simulator with a high performance graphics system

Scanning electron microscope

Transmission electron microscope

X-ray double crystal diffractometer

Laser velocimetry system

Programmable oven

Dynamic physical and ultrasonic testing machines

Autoclave (240 psi and 800 deg F)

Hydraulic press

Crash sled

Motion analyzer

Anthropomorphic dummies and laboratory management system for dynamic testing

High-resolution graphics terminals for computer-aided design, engineering, and manufacturing

An autoclave (400 psi and 1000 deg F) and other equipment for composite materials research

Dynamic shaker for environmental testing



Picture 8: AST 4000 Fixed Base Simulator

## Appendix A: Recommended Graduate Courses and Their Descriptions

All courses listed in this Appendix may be taken for credit toward one of the MSAE, MEAE, PhDAE or DEAE degree programs. Not all graduate courses are offered every semester or even every year. Students are encouraged to contact the appropriate department about the availability of any course. Other graduate courses may be considered at the discretion and direction of the thesis/dissertation advisor.

### A1. Aerospace Engineering Graduate Course Descriptions

**AE 701 Structural Design (3).** Design and internal construction of major structural components: wing, fuselage, empennage, landing gear, engine pylons. Layout of major structures and system interfaces, internal geometry, material alternates, manufacturing alternates and design constraints. Certification and proof of design requirements.

*Prerequisite: AE 421, AE 508, and AE 510. LEC*

**AE 704 Dynamics and Vibrations (3).** Problems in engineering dynamics and vibrations. Topics include applications of generalized forces and coordinates, Lagrange equations, and a study of the performance of single and multiple degrees of freedom in vibrational systems. (Same as CE 704.)

*Prerequisite: AE 508. LEC*

**AE 705 Structural Vibrations and Modal Testing (4).** Classical theory of structural vibrations. Single and multiple degrees of freedom free and forced vibration. Theory of modal summation. Measurement techniques for dynamic data. Methods of identifying modal parameters from measurement data. Numerous laboratory and computational projects.

*Prerequisite: AE 508. LEC*

**AE 707 Aerospace Structural Loads (3).** Steady state spanwise and chordwise airloads, windshears, gusts, landing gear loads, bird strike, traumatic loads, special commercial and military load requirements.

*Prerequisite: AE 507 and AE 545. LEC*

**AE 708 Aerospace Structures III (3).** Modern methods in aircraft structural analysis. Computer solutions of linear problems of elastic structures. Orthotropic panels, effects of buckling non-linearity, structural optimization.

*Prerequisite: AE 508. LEC*

**AE 709 Structural Composites (3).** Fiber materials, tapes, cloths, resin systems; general anisotropic theory, elastic constants, matrix formulation; computer analysis, strength, theory of failure; introduction to design with composites, preliminary design, optimization, processing variables, product design.

*Prerequisite: C&PE 121, AE 508 or CE761; and AE 510 or ME 600 or CE 710. LEC*

**AE 710 Advanced Structural Composites (3).** The course objectives are to provide each student with a more in-depth understanding of and practical hands-on experiences with available fiber and matrix materials, manufacturing methods, and the mechanical behavior of composite materials and structures. Modern software tools and manufacturing methods are addressed, to include optimization techniques and design for manufacturability. Classical plate theory, bending, buckling, and vibration of anisotropic plates is addressed. Damage tolerance and repairability, as well as nondestructive evaluation techniques are also covered. Skills learned in previous composite courses will be utilized to design, analyze, and fabricate structures of current industrial relevance.

*Prerequisite: AE 508 or similar, AE 709 or similar, or consent of instructor. LEC*

**AE 712 Techniques of Engineering Evaluation (3).** The formulation of problems arising in aerodynamics, heat transfer, stress analysis, thermodynamics, and vibrations. The expression of these problems in a form amenable to quantitative evaluation by dimensional reasoning, analog techniques, relaxation methods, and classical analysis. LEC

**AE 721 Aircraft Design Laboratory I (4).** The purpose of this course is to provide aerospace engineering students with an opportunity to gain more in-depth airplane design education through team design work. This team design work will involve detailed design efforts in such areas as: landing gear design, systems design, propulsion system integration, structures design, and aerodynamic design.

*Prerequisite: AE 507, AE 521, AE 545, AE 551, and AE 571. AE 521 may be taken concurrently. LAB*

**AE 722 Aircraft Design Laboratory II (4).** The purpose of this course is to provide aerospace engineering students with an opportunity to gain more in-depth airplane design education through team design work. This team design work will involve detailed design efforts in such areas as: landing gear design, systems design, propulsion system integration, structures design, and aerodynamic design.

*Prerequisite: AE 507, AE 521, AE 545, AE 551, and AE 571. AE 521 may be taken concurrently. LAB*

**AE 724 Propulsion System Design and Integration (3).** Theory and design of propulsion systems for both low and high speed aircraft and their integration into the overall configuration. Internal and external design and analysis of inlets and nozzles including their effect on the external aerodynamics of the aircraft. Engine/inlet compatibility and the problems of matching both steady state and dynamic characteristics to obtain peak, stable performance.

*Prerequisite: AE 521 and AE 572. LEC*

**AE 725 Numerical Optimization and Structural Design (3).** Classical theories of unconstrained and constrained optimization. Numerical techniques for unconstrained optimization, including the steepest descent, conjugate gradient and “Newton’s” methods. Numerical techniques for constrained optimization, including sequential approximate problem techniques as well as the method of feasible directions. Computer aided solutions to practical design problems in aerospace engineering. Final design project.

*Prerequisite: MATH 220 and MATH 290 or junior status. LEC*

**AE 730 Advanced Experimental Fluid Dynamics (3).** Theory, operation, and hands-on laboratory experiments on various flow measurement techniques including: multi-hole directional pitot probes, hot-wire anemometry, laser-Doppler velocimetry and particle image velocimetry. Flow visualization techniques including smoke injection, dye injection, helium bubbles, etc.

*Prerequisite: AE 430, AE 545, or consent of instructor. LEC*

**AE 731 Supersonic Aerodynamics Laboratory (1).** Supersonic wind tunnel and shock tube operations, techniques, and instrumentation. Flow study and model testing.

*Prerequisite: AE 545. LAB*

**AE 732 Introduction to Flight Test Engineering (3).** Course presents flight test principles, instrumentation, planning, and operation of aerospace vehicle flight testing. Course is structured with lectures, laboratories, and flight experiments. Student teams plan and execute a series of flight test experiments including: familiarization with flight test measurements, static system calibration, rate-of-climb performance, and determination of vehicle flight dynamics.

*Prerequisite: AE 445 and AE 550 or consent of instructor. LEC*

**AE 743 Compressible Aerodynamics (3).** Compressible flow with heat and friction; shock polars, 1-D unsteady gas dynamics, shock tube, conical flows, methods of characteristics, hypersonic flow theory.

*Prerequisite: AE 545. LEC*

**AE 745 Applied Wing and Airfoil Theory (3).** Applications of potential flow theory to aerodynamics of airfoil sections; wings and wing-body combinations. Introduction to high angle-of-attack and transonic aerodynamics.

*Prerequisite: AE 545. LEC*

**AE 746 Computational Fluid Dynamics (3).** Applications of numerical techniques and digital computers to solving fluid flow problems. Solutions involving incompressible and compressible flows, inviscid and viscous flows. Finite difference techniques for different types of partial differential equations governing the fluid flow.

*Prerequisite: AE 545. LEC*

**AE 748 Helicopter Aerodynamics (3).** Helicopter components and their functioning: rotor aerodynamics, performance, stability and control, aeroelastic effects and vibrations.

*Prerequisite: AE 551. LEC*

**AE 750 Applied Optimal Control (3).** Introduction to optimal control analysis and design tools useful for the design of Multi-Input/Multi-Output controllers. Linear Quadratic Regulator problem extended by including advanced command techniques and advanced controller structures. The techniques are illustrated with aerospace applications.

*Prerequisite: AE 551 or ME 682 or consent of instructor. LEC*

**AE 751 Advanced Airplane Dynamics (2).** Theory of elastic airplane stability and control using quasi-steady math models. Introduction to theory of nonlinear airplane stability and response behavior. Roll and pitch coupling phenomena. Lyapunov stability and approximate inverse Laplace transform methodology. Airplane response to atmospheric turbulence using power spectral density methods. Lagrangean dynamics.

*Prerequisite: AE 551. LEC*

**AE 753 Digital Flight Controls (3).** Introduction to the classical Zplane analysis and design tools useful for the design of control systems containing continuous dynamics and a digital computer. Mathematical modeling of the digital computer and design of digital compensators. Aerospace applications used to demonstrate the concepts.

*Prerequisite: AE 551 or ME 582 or consent of instructor. LEC*

**AE 754 Missile Dynamics (3).** Design of missile configurations. General equations of motion. Aerodynamics of missiles in subsonic through hypersonic flight regimes. Theory of missile trajectory. Linear and nonlinear theories of missile flight dynamics. Introduction to guidance and control. Launching problems and free flight dispersions.

*Prerequisite: AE 551. LEC*

**AE 755 Robust Control of Nonlinear System (3).** Basics and application of robust control, where the dynamic systems modeling is nonlinear. This course develops the fundamentals of robust control (uncertainty, disturbances, noise, singular values, sensitivity function, norms), the tools for robust control (small gain theory, Lyapunov theory, stability theory, loop shaping), basics of nonlinear systems (concepts of nonlinearities, phase-plane, nonlinear models, nonlinear elements, nonlinear behavior, nonlinear controls), rudiments of robust nonlinear control (nonlinear uncertain systems, describing functions, dynamic inversion), including applications of the covered theory and methods.

*Prerequisite: MATH 290 and AE 551. LEC*

**AE 760 Spacecraft Systems (3).** Fundamentals of spacecraft systems and subsystems. Spacecraft systems engineering, space environment; basic astrodynamics; and the following spacecraft subsystems; attitude determination and control; electrical power; thermal; propulsion; structures and mechanisms; command, telemetry, and data handling; and communications. Same as AE 560 with the addition of a research paper. Not available for students that have taken AE 560.

*Prerequisite: AE 507, EECS 319, MATH 124, and ME 312 or equivalents. LEC*

**AE 765 Orbital Mechanics (3).** Motion of space vehicles under the influence of gravitational forces. Two body trajectories, orbit determination, orbit transfer, universal variables, and mission planning using patched conics. Transfer orbits.

*Prerequisite: MATH 220, MATH 290, and CE 301 or equivalent. LEC*

**AE 766 Spacecraft Attitude Dynamics and Control (3).** Dynamics of rigid spacecraft, attitude control devices including momentum exchange, mass movement, gravity gradient and reactor rockets. Design of feedback control systems for linear and bang-bang control devices.

*Prerequisite: AE 551 or permission of instructor. LEC*

**AE 767 Spacecraft Environments (3).** Fundamentals of spacecraft environments. Description and analysis of the natural environment in which spacecraft operate post-launch. Includes optical, electromagnetic, corpuscular radiation, plasma and dust from low Earth orbit, through outer heliosphere.

*Prerequisite: PHSX 212 required, PHSX 313 or PHSX 351 recommended. LEC*

**AE 771 Rocket Propulsion (3).** Basic elements of rocket propulsion: systems, propellants, and performance.

*Prerequisite: AE 545 or equivalent. LEC*

**AE 772 Fluid Mechanics of Turbomachinery (3).** Fundamentals of two and three-dimensional flows in turbomachinery. Study of secondary flows and losses. Flow instabilities in axial flow compressors (stall and surge).

Aerodynamic design of a multistage axial flow compressor. Noise associated with a transonic axial flow compressor. Turbine blade cooling. Calculation of stresses and blade life estimation in axial flow turbines. Fundamentals of radial flow turbomachinery.

*Prerequisite: AE 572 or consent of instructor. LEC*

**AE 781 Introduction to Adaptive Aerostructures (3).** This course covers the basic material properties and modeling techniques for structures that are capable of changing some physical property in response to a command signal. The course will be useful for students from nearly every branch of engineering and includes a fabrication and testing practicum introducing basic post processing and integration techniques used with piezoelectric, shape memory alloy and magnetorheological materials. The course concludes with an overview of applications and examples of adaptive products.

*Prerequisites: ME 311 Mechanics of Materials or equivalent*

**AE 790 Special Problems in Aerospace Engineering (1-5).** Directed studies of advanced problems in aerospace engineering. Open only to graduate students with departmental approval. RSH

**AE 803 Aeroelasticity (3).** Introduction to self-excited vibrations, wing flutter, panel flutter, unsteady aerodynamics, launch vehicle structural vibrations.

*Prerequisite: AE 508, AE 545, AE 551, and AE 704. LEC*

**AE 821 Advanced Aircraft Design I (3).** Aerodynamic design optimization. Aircraft cost prediction methods: development, manufacturing, and operating. Minimization of operation costs and implications to configuration design. Design to minimize life-cycle costs. Design decision making on the basis of cost. LEC

**AE 822 Advanced Aircraft Design II (3).** Design of flight control systems, fuel systems, hydraulic systems, and electrical systems. Weapon system integration problems, design for low radar cross sections. The kinematics of landing gear retraction systems. LEC

**AE 840 Aerodynamics of Viscous Fluids (3).** Concepts of boundary layer equations of viscous fluids. Various transformations for compressible boundary-layer equations. Approximate and exact finite-difference solutions, including effects of suction and blowing. Transitions Concept of turbulent flow and solutions of turbulent boundary layer equations. Applications in aeronautics.

*Prerequisite: AE 545. LEC*

**AE 845 Transonic Aerodynamics (3).** Applications of potential flow, Euler and Navier-Stokes solvers to transonic and vortex-flow aerodynamics. Concept of rotated finite difference scheme. Convergence acceleration and multigrid techniques. Methods of flux vector splitting, upwind differencing, and approximate factorization. Turbulence modeling.

*Prerequisite: AE 746. LEC*

**AE 850 Advanced Control Seminar (2).** Extension of AE 750 covering digital optimal control, optimal estimation, and advanced control topics. Combination of lecture, seminar, and project format. Review of current journal articles. Development of analysis and design computer programs.

*Prerequisite: AE 750 and consent of instructor. LEC*

**AE 890 M.E. Internship (1-6).** One credit per month of engineering internship.

*Prerequisite: Admission to Master of Engineering in Aerospace Engineering program and approved internship. FLD*

**AE 892 Special Problems in Aerospace Engineering (1-8).** Directed studies of advanced problems in aerospace engineering. Open only to graduate students with consent of instructor. RSH

**AE 895 M.S. Thesis (1-10).** THE

**AE 896 M.E. Project (3-6).** A design problem or system study satisfying the project requirement for the Master of Engineering degree in Aerospace Engineering.

*Prerequisite: Admission to Master of Engineering in Aerospace Engineering program. THE*

**AE 941 Hypersonic Aerodynamics I (3).** The gasdynamics of aerospace vehicles operating in the speed range above Mach 5. Rarified and dissociated gas flows; magnetogasdynamic and heat transfer problems.

*Prerequisite: Consent of instructor. LEC*

**AE 990 DE Internship (1-12).** One credit per month of engineering internship.

*Prerequisite: Admission to DE program and approved internship. FLD*

**AE 996 Ph.D. Dissertation (1-15).** THE

**AE 997 D.E. Project (1-16).** A major design problem or system study satisfying the project requirements for the Doctor of Engineering in Aerospace Engineering degree.

*Prerequisite: Must be a Candidate for the Doctor of Engineering in Aerospace Engineering. THE*

## **A2. Recommended Mathematics Graduate Courses and Their Descriptions**

**MATH 542 Vector Analysis (2).** N Vector algebra; vector and scalar fields; line and surface integrals; theorems of Gauss, Green, and Stokes. Curvilinear coordinates. Applications. Introduction to tensor analysis. Not open to those with credit in MATH 143.

*Prerequisite: MATH 123. LEC*

**MATH 590 Linear Algebra (3).** N Vector spaces, linear transformations, and matrices. Canonical forms, Determinants. Hermitian, unitary and normal transformations. Not open to students with credit in MATH 792.

*Prerequisite: MATH 123 or equivalent. LEC*

**MATH 627 Probability (3).** N Introduction to mathematical probability; combinatorial analysis; the binomial, Poisson, and normal distributions; limit theorems; laws of large numbers.

*Prerequisite: MATH123 or equivalent. LEC*

**MATH 628 Mathematical Theory of Statistics (3).** N An introduction to sampling theory and statistical inference; special distributions; and other topics.

*Prerequisite: MATH 627. LEC*

**MATH 646 Complex Variable and Applications (3).** N Analytic functions of a complex variable, infinite series in the complex plane, theory of residues, conformal mapping and applications.

*Prerequisite: MATH 123 or MATH 124. LEC*

**MATH 647 Applied Partial Differential Equations (3).** N Boundary value problems; topics on partial differentiation; theory of characteristic curves; partial differential equations of mathematical physics.

*Prerequisite: MATH 320. LEC*

**MATH 648 Calculus of Variations and Integral Equations (3).** N Topics in the calculus of variations, integral equations, and applications.

*Prerequisite: MATH 320. LEC*

## **A3. Recommended Civil Engineering Graduate Courses and Their Descriptions**

**CE 704 Dynamics and Vibrations (3).** Problems in engineering dynamics and vibrations. Topics include applications of generalized forces and coordinates, Lagrange equations, and a study of the performance of single and multiple degree of freedom vibrational systems. (Same as AE 704.) LEC

**CE 710 Structural Mechanics (3).** Basic concepts in the analysis of stress and strain and the behavior of materials. Topics include elementary theory and problems in elasticity, theories of failure of materials including fracture mechanics and introduction to plasticity. LEC

**CE 721 Experimental Stress Analysis (3).** Introduction to experimental stress-analysis techniques. Theory and application of mechanical strain gages, electrical strain gages, photoelastic techniques, and brittle coatings. LEC

**CE 767 Introduction to Fracture Mechanics (3).** Theories and modes of structural failure as related to structural design. Application of fracture mechanics to failure analysis, fracture control plans, fatigue crack growth, and stress-corrosion crack growth.

*Prerequisite: CE 310 or CE 311 plus a structural or mechanical design course. LEC*

**CE 800 Theory of Elasticity (3).** The basic equations of the theory of elasticity; stress and strain transformation, strain-displacement, compatibility and stress-strain relations. Formulation of problems and exact solutions. Introduction to approximate solution methods based on energy methods and finite elements. LEC

**CE 861 Finite Element Methods for Solid Mechanics (3).** Stress analysis of 2-D and 3-D solids, plates, and shells by the finite element method. Element formulations and behavior with emphasis on the isoparametric concept. Computer modeling and interpretation of results. Introduction to material and geometric nonlinear analysis of solids.

*Prerequisite: CE 761 or equivalent. LEC*

**CE 869 Plates and Shells (3).** The analysis and design of plates and shells including thin and thick plates, membrane theory of shells and bending theories of shells. LEC

**CE 913 Advanced Fracture Mechanics (3).** Development of Griffith- Irwin crack theory and plane strain-stress intensity factors. Advanced analytical and experimental aspects of fracture and fatigue. Development of fracture control plans.

*Prerequisite: CE 767 or consent of instructor. LEC*

#### **A4. Recommended Mechanical Engineering Graduate Courses and their Descriptions**

**ME 612 Heat Transfer (3).** An applied study of conductive, convective, and radiative heat transfer mechanisms in solid and fluid systems. Engineering applications include solid conduction, free and forced convection in fluids, thermal radiation and heat exchangers, evaporators, and furnaces. Prerequisite: A course in differential equations and ME 312.

*Corequisite: ME 510. LEC*

**ME 627 Automotive Design (3).** Basic concepts of automotive design and manufacture. Primary focus of course on vehicle design and performance. Design is subdivided into vehicle components of frame, suspension, front and rear axle, steering power train, front and rear wheel drive, and braking. Integration of these ideas into a vehicle design project with analysis of its performance culminates the course.

*Prerequisite: ME 501, ME 510, and ME 412.*

*Corequisite: ME 520, ME 550, ME 612, and ME 628. LEC*

**ME 701 The Finite Element Method for Stress Analysis (3).** Introduction to the finite element method for solid mechanics. Finite element formulations for plane stress, plane strain, beams, spars, axisymmetric solids, shells, and 3D solids. Assembly and solutions of finite element equations, computations of stresses and strains and post processing of results for further use in the design process. Finite element modeling techniques and laboratory sessions for solving actual problems.

*Prerequisite: ME 508 and ME 528, or equivalent. LEC*

**ME 708 Microcomputer Applications in Mechanical Engineering (2-3).** Design and implementation of interfaces of microcomputers to mechanical equipment. Includes laboratory experiments presenting selected industrial applications. Emphasis on human factors, functional design parameters and microprocessor interfaces. Includes instruction concerning specifications of practical hardware configurations and writing of programs necessary to accomplish mechanical systems applications.

*Prerequisite: Permission of instructor. LEC*

**ME 731 Convective Heat and Momentum Transfer (3).** The formulation and solution of steady and unsteady convective heat, mass, and momentum transfer problems. Topics include boundary layers, duct flows, natural convection with and without phase change, development of analogies, transport properties, numerical methods.

*Prerequisite: ME 612 or equivalent. LEC*

**ME 761 Theory of the Finite Element Method (3).** Finite element method for solid mechanics, heat transfer, fluid mechanics, and dynamics. Modeling techniques, software implementation, and solution of problems.

*Prerequisite: ME 508 or equivalent. LEC*

**ME 770 Conductive Heat Transfer (3).** The formulation of steady- and unsteady-state conduction heat transfer problems and their solution by analytical and numerical methods.

*Prerequisite: ME 612 or equivalent. LEC*

**ME 774 Radiative Heat Transfer (3).** The formulation of steady and unsteady radiation heat transfer problems and their solution by analytical and numerical methods.

*Prerequisite: ME 612 or equivalent. LEC*

**ME 780 Kinematic Synthesis of Mechanisms (2-3).** A study of methods of synthesis of mechanisms from kinematic specifications.

*Prerequisite: ME 520. LEC*

## **A5. Recommended Electrical Engineering and Computer Science Graduate Courses and Their Descriptions**

**EECS 562 Introduction to Communication Systems (4).** A first course in communications, including lectures and integrated laboratory experiments. After a review of spectral analysis and signal transmission, analog and digital communications are studied. Topics include: sampling, pulse amplitude modulation, and pulse code modulation; analog and digital amplitude, frequency, and phase modulation; frequency and time division multiplexing; and noise performance of analog modulation techniques.

*Prerequisite: EECS 212 and EECS 360. LEC*

**EECS 644 Introduction to Digital Signal Processing (3).** Discrete time signal and systems theory, sampling theorem, z-transforms, digital filter design, discrete Fourier transform, FFT, and hardware considerations.

*Prerequisite: EECS 360. LEC*

## **A6. Recommended Engineering Management Graduate Courses and Their Descriptions (ME and DE only)**

**EMGT 608: Principles of Engineering Management (3).**

See instructor for content

**EMGT 800 Special Topics in Engineering Management (1-4).** Advanced or experimental work of a specialized nature representing unique or changing needs and resources in engineering management. RSH

**EMGT 802 Statistical Analysis and Prediction of Engineering Systems (3).** Applied statistical methods to engineering systems will be introduced in this course for analyzing engineering and management systems. Emphasis will be given to applied regression analysis, analysis of variance, analysis of time dependence by smoothing, Bayes method, time series analysis, auto-regressive moving averages and forecasting model.

*Prerequisite: Skills in probability, statistics, and computer application. LEC*

**EMGT 803 Technological Forecasting and Assessment (3).** This course focuses on the impact of technology on society. Techniques of technology forecasting such as Delphi, cross-impact analysis, trend projection, decision trees, and scenarios are discussed. Case studies of technology assessments are presented. Each student is asked to conduct preliminary technology assessment which is a systematic study of the effects on society which may occur when a technology is introduced or modified.

*Prerequisite: Elementary skills in statistics, computer programming, and linear algebra. LEC*

**EMGT 804 Business Development and Marketing of Professional Services (3).** Principles and theories of business development and marketing as applicable to professional engineering and architectural practices. LEC

**EMGT 805 Management of Innovation (3).** Management of technology and technological change through innovation, imitation, and obsolescence; planning, organizing, motivation, and control for innovation; organizational climate and its effects on innovative ideas and entrepreneurship; project/product decisions and R&D strategies in small and large companies; innovation in multinational corporations. LEC

**EMGT 806 Finance for Engineers (3).** A study of finance including financial planning and management in technological based organizations. Topics covered include financial statement analysis, present value of financial markets, capital budgeting, taxes, investment decisions, replacement decisions, cash flow budgets, and sources of capital. LEC

**EMGT 808 Quality Management (3).** The overwhelming challenge that faces the U.S. today is the need to regain its competitive position in the world marketplace. This course offers a broad view of Quality Management in that it focuses on the managerial aspects of quality, rather than just the technical. For example, students will learn the Malcolm Baldrige award criteria which focuses on leadership, data analysis, human resources, quality assurance, quality results, and customer satisfaction. In addition, a review of the theory and approaches of the major quality leaders such as Deming, Juran, and Crosby will be covered. Practical applications of TQM concepts in a technological environment will be stressed throughout the course. LEC

**EMGT 809 Personal Development for the Engineering Manager (4).** Includes the study of theories, tests for, and objectives of engineering and management ethics. Explores personal values. Measures personality profile and preferred communication style for each student. Includes management of stress, time, and career. Each student prepares career and personal development plans. Managerial writing and communication skills are developed through weekly projects including report and proposal preparation, internal correspondence concerning praise and reprimand, and organizational policy preparation. Interpersonal and nonverbal communication styles are studied. Relies heavily on instructor-assisted peer mediation of topics after introduction of constructive techniques of interpersonal communication. LEC

**EMGT 810 Applications of Quantitative Analysis in Decision Making (3).** This course emphasizes the use of general system theory, classical optimization and optimality conditions, model development, and theory and application of mathematical programming, to include: linear programming, dynamic programming, queuing models, integer and non-linear programming, and introduction to decision analysis.

*Prerequisite: Elementary skills in linear algebra, probability, calculus, and computer application. LEC*

**EMGT 811 Engineering Systems Simulation (3).** Methods of developing, implementing, and using computer simulations for management processes such as inventory control, waiting lines, project monitoring, and capital investment decisions are covered. Extensive use is made of simulation languages and interactive graphic-supported gaming and decision analysis. Engineering systems and chemical processes are studied under deterministic and stochastic conditions. Two hours lecture, three hours laboratory per week. LEC

**EMGT 812 Law and the Design Professional (3).** This course covers: legal doctrines relating to owners, design professionals, and contractors; sources of law, forms of association, and agency; contracts, including formation, rights and duties, interpretation, performance problems, disputes, and claims; standards of care and the management of construction claims; duties and obligations of the design professional, the owner, and the contractor; surety bonds and insurance.  
*Prerequisite: Admission to graduate study in engineering or architecture. LEC*

**EMGT 813 Design Project Management in Professional Practice (3).** Includes planning, organizing, staffing, directing, and controlling design projects. Treats those topics from viewpoints of profit, cost control, client satisfaction, and project team human relations. Also covers delegation, motivation, team building, performance reviews, conflict resolution, and group dynamics. Presents the project manager's job from an augmented model of the Blake-Mouton grid.  
*Prerequisite: Admission to graduate study in engineering or architecture. LEC*

**EMGT 814 Financial and Managerial Accounting for the Engineer (3).** The elements of the accounting cycle are defined so as to help the student understand the process from the balance sheet for the last period through the journal, ledger, income statement, trial balance and an adjusted balance for the current period. There is a heavy emphasis on the definition and significance of accounting terminology. The communication interfaces between engineering managers and the controller's office are examined as are recent developments in cost accounting.  
*Prerequisite: Admission to graduate study in architectural, construction, engineering or technology management, or permission of instructor. LEC*

**EMGT 821 Strategic Analysis of Technology Projects (3).** A study of the economic feasibility of competing engineering projects including the application of break-even analysis, decisions under uncertainty, decision trees, stochastic models, risk vs. return, and forecasting. A study of the financial figures of merit used to evaluate competing engineering projects including the DuPont rate of return method, the accounting rate of return, the operating return method, return on equity, earnings per share, margin on sales, selling price of stock, corporate credit rating, total sales, market share, market entry, and proforma year-end statements. A study of the strategic evaluation of a project including the proposed product or service, the organization, the environment, and the venture in general.  
*Prerequisite: Admission to the M.S. Engineering Management program or consent of instructor, EMGT 806, a course in applied statistics. LEC*

**EMGT 823 Management of Internal Engineering Projects (3).** The purpose of this course is to introduce the student to all aspects of managing a project within a company or organization. The entire project life cycle will be covered from inception to close-out, and many practical considerations will be discussed including material procurement, working with contractors and consultants, selecting software, and managing the project team. The course will focus on how to manage project scope, schedule budget, and resources using personal computer software. A semester project is required presenting an example of project management or investigating some aspect of project management in detail. LEC

**EMGT 824 Product Marketing for Engineering Managers (3).** Basic principles of marketing as applicable to engineering managers in the production- or operations-based enterprise. Includes a broad overview of the major components of marketing (competition, product, price, promotion, and distribution). Also details the integration of those components into the marketing plan. The students will develop a group marketing plan for an agreed-upon product.

*Prerequisite: Admission to a graduate program in engineering or Pittsburgh State's technology management program. LEC*

**EMGT 830 Case Studies in Engineering Management (2).** A capstone course for the program which provides an integration of the material presented in the other courses through the utilization of several engineering management case studies.

*Prerequisite: Completion of a minimum of 21 credit hours in the Engineering Management program. LEC*

**EMGT 835 Field Project (M.S.) (1-3).** A problem in engineering management, the satisfactory completion of which satisfies the project requirement for the degree of Master of Science in Engineering Management. THE

**EMGT 840 Systems Approach to Engineering (3).** This is a first course at the graduate level introducing the formal methods and processes in bringing complex systems into being and improving existing systems. Systems include both products and services. Emphasis is placed on: the definition of customer needs, the entire life cycle of systems, and introduction to formal specification methods, the value to cost ratio and the management of the systems engineering process. LEC

**EMGT 844 Managing Software Development Projects (3).** This course investigates the area of managing software development and presents the management process as a means of optimizing business considerations and project demands. Uncertainties in product/service specifications, technology risks, cost and delivery requirements impact the management functions. Cost and schedule estimation techniques are presented together with project planning, risk control and measurement technologies. The techniques presented in this course are directly applicable to management in other industry segments. Guest speakers are used to demonstrate applications in this course. LEC

**EMGT 850 Environmental Issues for Engineering Managers (3).** This course provides a survey of the environmental regulations, environmental problems, and environmental solutions that must be dealt with by engineering managers regardless of their function or industry. A historical perspective on the environment is presented followed by discussion of pollution generation (sources), transportation, fate, and effects. The quantity and quality of various types of pollutants emitted to various media and the risk posed by these pollutants is analyzed. The regulatory process is examined from the perspective of the legislator, the regulator, the regulated, the engineer, and the public. LEC

**EMGT 860 Special Problems in Engineering Management (1-4).** Graduate- level investigation requiring original, independent research on problems or subjects of immediate interest to a student or faculty member. Intended to develop a student's capability in coordinating two or more of the following: technology, finance, economics, applied mathematics, and managerial communication. EMGT 860 may be repeated for credit to a maximum of four hours in the degree program.

*Prerequisite: Approval of an outline of the proposed project by the instructor and the program director. RSH*

**EMGT 867 Advanced Operations Management (3).** This course provides the student with up-to-date information of the management of manufacturing operations. Emphasis is on quantitative methods for designing and analyzing manufacturing processes, simulation of manufacturing processes, and recent paradigms in manufacturing including just-in-time production, synchronous manufacturing, and agile manufacturing. A semester project is required covering some aspect of operations management in detail. LEC

## **Appendix B      Professionalism**

### **B.1. AIAA Guideline for Professional Conduct (Code of Ethics)**

#### **PRECEPT**

The AIAA member to uphold and advance the honor and dignity of the aerospace profession and in keeping with high standards of ethical conduct:

- I. Will be honest and impartial, and will serve with devotion his employer and the public;
- II. Will strive to increase the competence and prestige of the aerospace profession;
- III. Will use his knowledge and skill for the advancement of human welfare.

#### **RELATIONS WITH THE PUBLIC**

1.1 The AIAA member will have proper regard for the safety, health, and welfare of the public in the performance of his professional duties.

1.2 The member will endeavor to extend public knowledge and appreciation of aerospace science and its achievements.

1.3 The member will be dignified and modest in explaining his work and merit and will ever uphold the honor and dignity of his profession.

1.4 The member will express an opinion on a professional subject only when it is founded on adequate knowledge and honest conviction.

1.5 The member will preface any ex parte statement, criticisms, or arguments that he may issue by clearly indicating on whose behalf they are made.

#### **RELATIONS WITH EMPLOYERS AND CLIENTS**

2.1 The AIAA member will act in professional matters as a faithful agent or trustee for each employer or client.

2.2 The member will act fairly and justly toward vendors and contractors, and will not accept from vendors or contractors any commissions or allowances which represent a conflict of interest.

2.3 The member will inform his employer or client if he is financially interested in any vendor or contractor, or in any invention, machines, or apparatus, which is involved in a project or work of his employer or client. The member will not allow such interest to affect his decision regarding services which he may be called upon to perform.

2.4 The member will indicate to his employer or client the adverse consequences to be expected if his judgment is overruled.

2.5 The member will undertake only those professional assignments for which he is qualified. The member will engage or advise his employer or client to engage specialists and will cooperate with them whenever his employer's or client's interests are served best by such an arrangement.

2.6 The member will not disclose information concerning the business affairs or technical processes of any present or former employer or client without his consent.

2.7 The member will not accept compensation financial or otherwise from more than one party for the same service, or for other services pertaining to the same work, without the consent of all interested parties.

2.8 The member will report to his employer or client any matters within his area of expertise which the member believes represent a contravention of public law, regulation, health or safety.

## **RELATIONS WITH OTHER PROFESSIONALS**

3.1 The AIAA member will take care that credit for professional work is given to those to whom credit is properly due.

3.2 The member will provide a prospective employee with complete information on working conditions and his proposed status of employment, and after employment will keep him informed of any changes in them.

3.3 The member will uphold the principle of appropriate and adequate compensation for those engaged in professional work, including those in subordinate capacities.

3.4 The member will endeavor to provide opportunity for the professional development and advancement of those in his employ or under his supervision.

3.5 The member will not injure maliciously the professional reputation, prospects, or practice of another professional.

3.6 The member will cooperate in advancing the aerospace profession by interchanging information and experience with other professionals and students, and by contributing to public communication media, to the efforts of engineering and scientific societies and schools.

## **B.2 Ethical Conduct**

Ethical conduct is important in all aspects of life and it should be practiced, starting now, while you are still in school.

A very important aspect of ethical conduct is NEVER to engage in any form of cheating. Cheating would violate rule 3.1 in the Code of Ethics.

It is the policy of the Department of Aerospace Engineering to severely punish cheating in exams, quizzes, laboratory work and other assignments which are part of the AE curriculum. Students must be aware of the following consequences of cheating:

1. A graduate student caught cheating once will receive an F for that class regardless of when in the semester the cheating occurs.

2. A graduate student caught cheating twice will be expelled from the department and procedures for dismissal from the School of Engineering will be initiated against that student.

If a student has any questions whether a particular activity will be considered cheating, he or she should have this issue clarified by the instructor or professor before engaging in such an activity.

As a general rule, if there is such a question, it is safe to assume that the activity will be considered to be cheating.

## **B.3 Fair, Equitable and Competent Services**

All professionals are expected to provide fair, equitable and competent services to their employer, their client and/or to society as a whole. This section contains an elaboration of what this means.

### **Fair Services**

To render fair services to an employer or to a client a professional must always put forward the best effort regardless of race, gender or national origin. A professional must also see to it that he/she is fit to perform professional services.

As an example, coming to work with a hangover or without adequate rest, does not allow for the rendering of fair services.

### **Equitable Services**

To render equitable services a professional must not request significantly different compensation levels between various employers and/or clients.

### **Competent Services**

A professional can render competent services only if he or she is competent in the area where services are being rendered. Having a graduate degree in aerospace engineering does not necessarily mean that the individual is competent in all areas of aerospace engineering.

As an example, an individual with a PhD in Computational Aerodynamics is not necessarily competent in the area of landing gear design.

To remain competent in a given area and to extend competence into other areas a professional must invest time in lifelong learning. This can be done by attending courses, short courses and/or by individual reading of literature. A commitment to lifelong learning is an essential characteristic of a true professional. Table C2 contains a list of typical journals and magazines that should be read regularly by aerospace professionals.

Most professionals take out personal subscriptions to one or more of these publications. The department faculty members advise students to start building their own professional reference library now!

### **Services to Society**

True professionals freely give some of their time to work for charitable and/or general societal causes. This includes service to the profession (such as accepting a post as officer in a professional society), service to the community (serving on a church committee or city council) and service to the nation (such as joining a National Guard or serving on national committees).

#### **AIAA Publications**

*AIAA Journal*

*Journal of Aircraft*

*Journal of Spacecraft and Rockets*

*AIAA Student Journal*

*Journal of Propulsion and Power*

*Aerospace America*

*Journal of Guidance, Control and Dynamics*

#### **Other Publications**

- *Aviation Week and Space Technology (US weekly)*
- *Aircraft Engineering (British monthly)*
- *Flight International (British weekly)*
- *Business and Commercial Aviation (US monthly)*
- *Jane's All the World's Aircraft*

Plus: Recent books in the professional's area of interest

**Figure 1: Recommended Reference Literature**

## **B4 Advice from David L. Kohlman, Aerospace Engineer and Chairman of the Board, Kohlman Systems Research (KSR), Lawrence, Kansas.**

Embarking on your first full-time job in engineering is one of the most exciting challenges you will encounter during your career. And the first five years of your career may well be the most important. For how you plan and manage these early and critical years will shape your entire future and determine whether your career remains exciting and challenging for you, or becomes dull and routine.

There is a significant difference between the college campus and the industrial, professional environment. You will be required to make many adjustments and changes in your life. Don't forget the personal and professional habits which you adopt during these first five years will probably be with you for a lifetime. Therefore, it is important to be constantly aware of the quality of your performance and to frequently appraise yourself with respect to your goals as you build an initial reputation which will be difficult to change.

The following guidelines are suggested to help in formulating your own personal five-year plan and in assessing your development as a professional.

### **1. Have a Plan**

Don't drift through your career only reacting to random events and opportunities. Formulate specific goals and a timetable in terms of responsibility, position, salary, and professional skills. Keep the plan flexible, because you and your values will change considerably with time. But a specific plan will provide direction to your life and offer a means of evaluating the random opportunities which appear in everyone's career, usually when they are least expected.

### **2. Communicate**

Engineering students are traditionally weak in communication skills. Yet those skills are at least as important as your technical skills. Almost everything you do as an engineer must be communicated to other people. Proper spelling, grammar, sentence structure, and precise word usage are only the foundations of good communication. Organization, conciseness, clarity, and smoothness are also necessary. Anything less will impair your effectiveness and limit the probability that your ideas and innovations will be adopted. Your oral and written communications serve as advertisements for your professional skills. Don't be shortchanged by inadequate language skills.

### **3. Be Dependable**

Supervisors and management in every field of endeavor place a premium on the ability to get things done. Establish that reputation early. Whenever the boss assigns you a task, he wants to be able to stop worrying about it because he knows it will be done right and on time. If he can do this, you have made his job easier, insured you will get important assignments, and taken a big step toward your success as an engineer.

### **4. Go the Second Mile**

Decide early in your career that you will always try to do more than what is expected of you. That is the only way you can fulfill one of the basic laws of success: always be underpaid! If you are not worth more than you are getting paid, then you don't deserve a raise.

Try to anticipate the next assignment. Then you will be able to work more efficiently, with less supervision, and will experience the satisfaction of answering the boss' next request with "I've already done that and here are the results". Remember, someday you may be the one issuing assignments and making decisions.

## **5. Keep Learning**

Your college degree is only the beginning of a lifelong process of education. In the world of science and technology, there is a time-to-double available knowledge of about ten years (give or take a few). Unless your knowledge increases correspondingly, you will start becoming obsolete on graduation day.

Many employers have formal education programs for new engineers to teach company policy, procedures and practical skills. But most of your education must be self-initiated. A very important step is to join a professional or technical society appropriate to your field. This will expose you to a vast array of educational opportunities: magazines, journals, technical meetings, short courses, seminars and taped lectures. Take advantage of these valuable resources.

Eventually you may choose to return to graduate school to specialize or significantly improve your knowledge in some area. The important thing, however, is to continue learning throughout your career, one way or another. Set the pattern now, during your first five years, and you will never be obsolete.

## **6. Read**

There is more to life than engineering, and part of being a true professional is to be knowledgeable in fields beyond engineering. Set up a five year plan of reading which includes the following elements:

- A book a month from diverse areas such as history, economics, politics, sociology, psychology, business, fiction, etc.
- A good weekly news magazine such as Time, Newsweek, US News and World Report.
- A special news magazine in your field such as Aviation Week and Space Technology.
- A good metropolitan daily newspaper.

This is only a minimum. Include other magazines, books, papers, etc. which interest you and broaden your outlook on the world. You must be aware of what is going on in the world, well beyond your own borders, to become a successful professional with significant responsibilities.

Set aside a specific time each day to read. Only 30 minutes a day covers an amazing amount of reading in a year. Always carry a book or magazine with you to take advantage of all the times you have to wait for somebody or something. Finally, set a strict limit on TV watching and stick to it. Television is addictive and usually the biggest deterrent to reading.

## **7. Make friends**

A successful professional recognizes his co-workers are colleagues, not competitors. A pleasant, friendly personality will gain you many friends who will not only make your work environment enjoyable, but will teach you many valuable lessons as a result of their experiences, both successful and unsuccessful. Colleagues who are good friends are good for sounding out new ideas, evaluating results, troubleshooting problems, and listening to trial-run presentations. And it is colleagues with whom you openly and frequently communicate who are necessary to make Kohlman's Law work positively for you: "It's not who you know, but who knows what you know".

Above all, develop a positive attitude. Someone who complains, gripes, and is constantly finding fault poisons the atmosphere of an office and quickly becomes unpopular. If things are really that bad, change jobs.

## **8. Assess Your Situation**

To actively direct the course of your career, you must periodically assess where you are and where you are going in relation to your plans and goals. If you are not making adequate progress, it is time for a change in yourself, your situation, or your goals.

Don't be afraid to change companies when it becomes necessary or an outstanding opportunity occurs. But do be cautious about switching too quickly and too often. Except for very unusual circumstances, you owe an employer at least two or three years of service so he can realize a return on his investment in you. Also, an employer is unlikely to groom you for advancement or entrust you with major responsibilities if you have a record of job hopping every few years.

## **9. Enjoy Life**

If you can't enjoy life both on and off the job, something is seriously wrong. Find out what you enjoy most and shape your career and your leisure time accordingly. Develop a hobby, expand friendships, and broaden your outlook well beyond the world of engineering: become a whole person. Otherwise you may well find that a big salary, promotions, and responsibility are empty rewards.

Have a successful first five years and a successful career is almost assured. Enjoy!