

**ENGINEERING CRITERIA 2000**  
**Self-Study Report**  
**For Review of Engineering Programs**

1997-98 Edition

Submitted by

**Georgia Institute of Technology**  
**School of Aerospace Engineering**

August 1997

to the  
Engineering Accreditation Commission

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# PROGRAM SELF-STUDY for Aerospace Engineering

## Part I. Background

In this section, some basic information regarding the undergraduate program such as the degree title and mode of operation are given, followed by the program educational objectives.

The School was reviewed for accreditation by ABET in 1990. While full accreditation for a six year period was awarded, a number of minor deficiencies were cited. This section concludes with actions taken to date to correct these deficiencies.

### A. Degree Titles

Georgia Institute of Technology awards the following undergraduate degree in the field of aerospace engineering:

*Bachelor of Aerospace Engineering*

Undergraduate students who have completed the required number of work quarters through the Cooperative Division receive the degree with the following designation:

*Bachelor of Aerospace Engineering (Cooperative Plan)*

### B. Program Educational Objectives

The following educational objectives have been established, and published. The process used to establish these objectives is described in Part III.

1. *To provide the students with a comprehensive aerospace engineering education that includes in-depth instruction in aerodynamics, aircraft and spacecraft structures, flight mechanics, orbital mechanics, flight controls, propulsion and design of aerospace systems.*
2. *To prepare students for careers in AE and related multi-disciplinary fields by: emphasizing essential analysis and problem solving skills, exposing students to open-ended problems and design issues, fostering team work, promoting good communication skills and developing individual professionalism.*
3. *To provide students with adequate research and independent study opportunities that cultivate lifelong learning skills and nourish talents in creative engineering tasks such as research and development.*

### C. Program Modes

The Bachelor of Aerospace Engineering classes are offered during the day on campus, although evening classes are occasionally scheduled if a majority of students find them convenient. The cooperative plan follows closely the Institute guidelines for such programs, as discussed in the Institutional Status Report.

## D. Action to Correct Previous Deficiencies

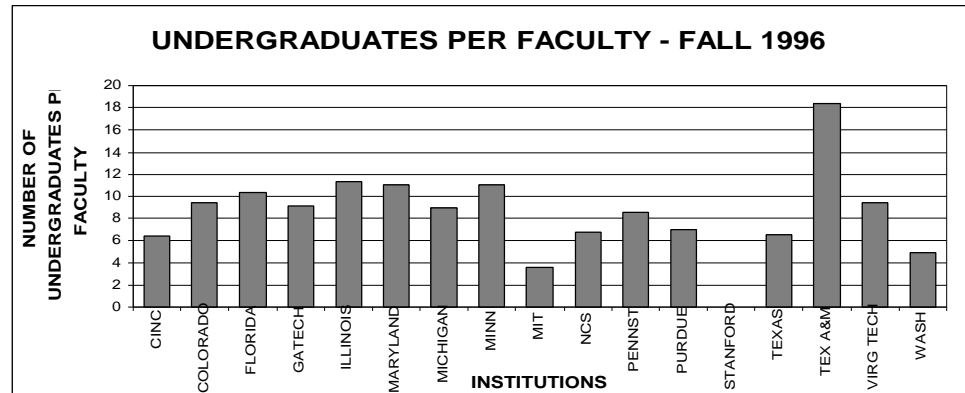
During the 1990 ABET evaluation, some deficiencies were cited. These deficiencies have been corrected, through curriculum revisions and facility improvements. The following specific actions have been taken, to address the deficiencies identified (shown in italics):

1. "The student-to-faculty ratio, about 19, is still too high, and some class sizes (e.g. AE 4001, AE 4103 and AE 4803) are too large for effective learning."

*This situation eased to some extent due to a decline in undergraduate enrollment during the early 1990s. Undergraduate students numbered 245 for the 1995-96 academic year and 243 for the 1996-1997 academic year. The total of academic faculty has remained around 28, making the current student-to-faculty ratio about 9.*

*Two adjunct faculty members and two joint faculty members have also been added to the faculty. These adjunct and joint faculty members regularly teach undergraduate courses.*

*The chart below compares the student-to-faculty ratio of the School with other institutions around the country:*



*The largest Aerospace Engineering class during academic years '94-'95 and '96-'97 had 42 students; average section sizes in all AE courses are given in Table II.*

2. "Although the minimum program criteria in the subject areas of materials and astronautics seem to be met, this is not apparent in the course catalog descriptions, and should be addressed to avoid confusion on the part of potential new students and faculty members."

*A course on aerospace materials titled MATE 3702, taught in the School of Materials Science and Engineering is now required in our undergraduate program. This course introduces the structural and thermal characteristics of aerospace materials. The AE faculty have also introduced four senior elective courses (AE 4770, AE 4791, AE 4792, AE 4793) which address composite material manufacturing, mechanical behavior of composites, and the elastic and plastic properties of composites.*

*Two new courses, the first titled orbital mechanics (AE 4501) and the second titled Spacecraft Attitude Dynamics (AE 4502) were developed and are regularly offered. One of these courses must now be taken as a requirement of the program.*

*The catalog has been updated, and explicitly lists the orbital mechanics (AE 4501) and Spacecraft Attitude Control course (AE 4502). It also lists the course on materials (MATE 3702) in the catalog as a required course*

3. "The curriculum includes a required course in technical writing, but there appears to be no instruction in oral communication beyond the freshman English courses. However, oral presentation during the laboratory and design courses are at least critiqued by the instructors."

*In the laboratory courses (AE 3010, AE 3111, AE 3510), typically taken during the junior year, the students are now required to design innovative experiments, make an oral presentation of their experiments and orally defend their decisions. Part of the grade in the course is based on the oral presentation.*

*In the senior capstone design course (AE 4351) team presentations are made at mid-term, and at the end of the course. To further motivate the students, a "Best Presentation Award" is made. The winning team presents their design to the entire undergraduate class.*

*An elective course on multimedia in engineering has also been developed and is routinely taught. In this course, students learn to integrate graphics, text, sound and analysis in presentation quality documents.*

4. "The laboratory facilities are just adequate for the program."

*A number of the laboratory facilities have been upgraded and new capabilities have been added since the last accreditation. The laboratories facilities can be divided into four groups; a short description of the upgrades for each follows. These facilities and the improvements are discussed in detail later, under the section titled "Resource Information."*

- a. Flight Mechanics and Controls Lab: New equipment has been installed in line with a shift in emphasis from computer simulations of control systems to hardware implementation (in order to address the weakness perceived at the time of the last visit). Also, four additional hardware oriented experiments are currently being set up with a focus on highlighting microprocessor based control; this is consistent with current and expected future trends in the Aerospace Industry. All the equipment needed for the new experiments have already been purchased.
- b. Structures Lab: In 1991, a major addition to this lab was a 22 kip Instron 8500 servohydraulic test machine (cost: \$75,000). This advanced testing system is shared with the Structures and Materials Research Lab, and it provides the new capability to incorporate fracture toughness and simple fatigue testing demonstrations and experiments in the undergraduate lab course. In addition, the Lab was upgraded in 1997 with the addition of a high performance PC data acquisition system and LabVIEW data acquisition software (cost: \$9,500). This is part of a joint effort with the Aerodynamics Lab to develop a comprehensive introduction to computer-aided data acquisition and control in the undergraduate laboratory program. In addition to PC systems in the two labs, an additional 2 PC systems were added to the AE Computing Applications Lab so that students could carry out pre- and post-processing work in connection with the lab courses (cost: \$5,000).
- c. Fluids, Aerodynamics and Propulsion Lab: In 1992, two major NSF grants were used to buy equipment for flow visualization (laser, optics, cameras, video recorders, computers and video editing equipment, cost: \$108,000). The flow visualization hardware is primarily used in undergraduate and graduate elective

courses on advanced diagnostics and flow control, undergraduate Special Problems projects, and sometimes in the required undergraduate lab. In addition, the lab was upgraded in 1997 with high performance data acquisition systems, LabVIEW data acquisition software, and compatible pressure transducers (cost: \$11,000). This is part of a joint effort with the Structures Lab described above.

- d. AE Computing Applications Lab: In 1993, the lab was upgraded with the addition of a special purpose server that could be used to store special purpose application software, course and lab accounts for all AE courses, and accounts for special instructional efforts. Students use the server course and lab accounts to access on-line course notes, submit homework assignments, and retrieve lab data and submit lab reports. The Lab was upgraded in 1997 with the addition of 4 new high-end Mac clones, 4 new Windows NT systems and 2 Windows 95 systems. These new systems are being used to support advanced computing applications (e.g., computational mechanics, slight simulation, multimedia creation) that are not within the capabilities of the baseline PC systems that are required of all entering freshmen starting September 1997. In addition, CAD, numerical computation and simulation, and WWW software were added.
5. "Current holdings in the aerospace engineering subject areas are adequate, but additional monograph and serial holdings would enhance the research and design capability of the program."

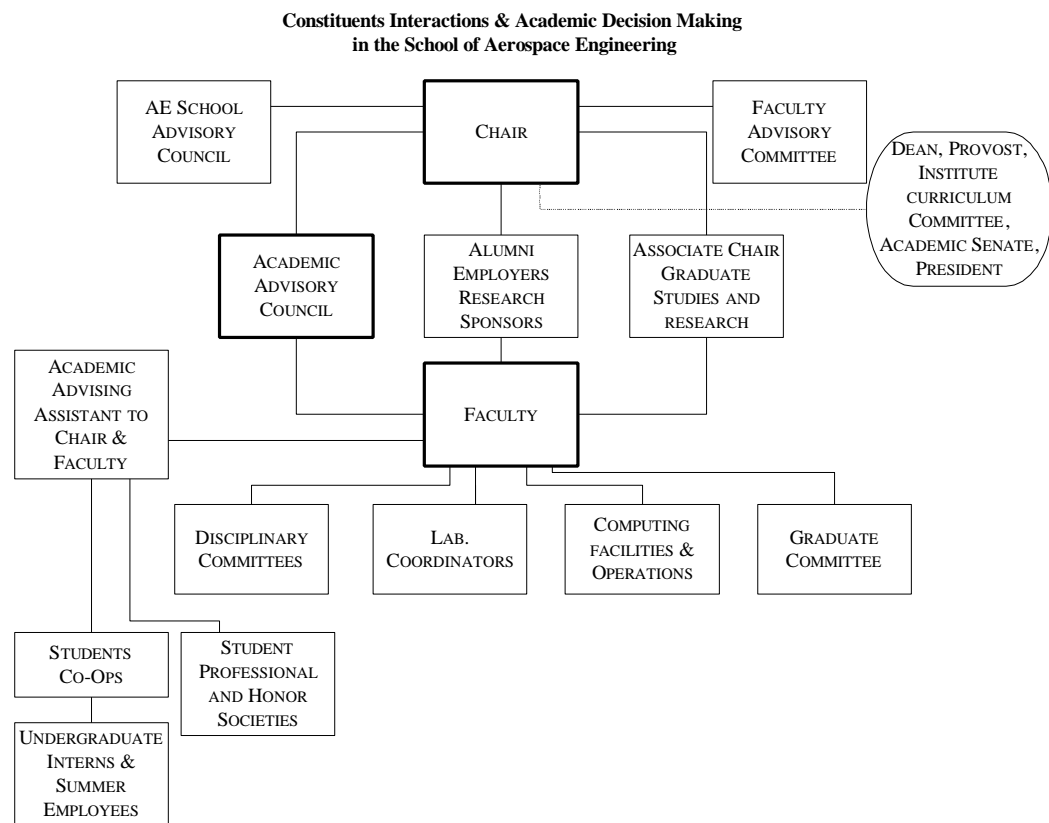
*The School of Aerospace Engineering library has been upgraded, and a student assistant is being employed to assist students in search processes. AIAA and AHS conference proceedings in all disciplinary areas are collected as either bound volumes or as CDs. These are available for both research and instructional purposes. Due to space limitations in the AE library, some of these proceedings are normally stored in the School's research laboratories, but are available to all AE students. These local resources complement the campus central library resources. The central library holds serials such as: AIAA Journal, Journal of Aircraft, J. of the American Helicopter Society, ASME Journals, NASA Contractor Reports, and AGARD conference proceedings. Many of the AIAA conference papers are also available in microfiche form.*

*Many recent NASA and government reports are accessible over the Internet. All the computers in the undergraduate computer laboratory and at the central library may be used to access these resources, and many student dormitories are currently being wired to access the Internet. Software for viewing these documents (e.g. Adobe Acrobat viewer, web browsers, Postscript viewers) and printing (e.g. network printers) are freely available within the School of Aerospace Engineering, and on computer clusters around the campus, and AE students are made aware of their availability in by the instructors.*

## Part II. Professional Component Information

This section describes the undergraduate aerospace engineering curriculum and how the instructional program will meet the educational objectives presented earlier. It also discusses how the curriculum meets or exceeds the program criteria specified by AIAA. In a sub-section titled Engineering Design Experience, the Capstone design courses are discussed in detail.

The undergraduate curriculum has been developed and refined over a period of time by our faculty members, many of whom have several years of academia, government and industry experience. Input from our constituents (e.g. students, alumni, employers of our students, research sponsors) and from the AE School Advisory Council has also been used to further refine the curriculum content over a course of several years. The figure below shows how the faculty and the constituents interact in the curriculum development process.



The following procedure is followed when a new course is developed, or an existing course is modified.

- a. *The course is taught several times as a special topics course by the instructor(s).*
- b. *The appropriate discipline committee submits the course outline and any additional supporting material (class notes, text book as needed) to the Academic Advisory Council, a body of faculty primarily composed of discipline committee Chairs. This council examines the course to ensure that it is consistent with the School educational objectives and expected outcomes.*

- c. *The course is brought to the faculty for discussion and approval by vote.*
- d. *The course outline and supporting data are forwarded by the Chair to the Dean, who ensures that the course material is consistent with the College educational objectives and mission.*
- e. *The course material is next sent to the Provost for approval that the course is consistent with the Institute educational objectives and mission.*
- f. *The Institute Curriculum Committee, a body of elected faculty representatives, recommends the course for inclusion in the program. Other units on campus have an opportunity to examine the course material, and make suggestions for improvement, and coordination among the units.*
- g. *The Academic Senate, made of elected representatives from all the units in the institute, makes the final recommendation to the President of the Institute that the course be approved for inclusion in the program.*

In this section, courses are at times referred to only by their course number for brevity. Outlines for all the undergraduate courses developed and taught by the School of AE faculty are given in Appendix A.

## **A. Curriculum Course Content**

The School of Aerospace Engineering offers a broad and well-rounded academic program in aerospace engineering. All the important disciplines of aerospace engineering - aerodynamics, structures and materials, dynamics, aeroelasticity, propulsion, flight mechanics and control, astronautics, and aerospace system design, are addressed through a combination of courses, electives, instructional laboratories, and capstone design experiences. The program also includes 31 quarter-hours of mathematics, 15 hours of physics, 10 hours of chemistry, and such fundamental engineering topics as material science, electronics, thermodynamics and engineering graphics. The program requires 9 hours of aerospace electives. Twelve hours of free electives are also required which may be used to broaden knowledge in either technical or non-technical fields. A significant level of design experience is provided through two capstone design courses (4 quarter hours each). The AE elective hours and free elective hours may also be used to pursue independent study and perform undergraduate research.

Table 1 (ABET Table 10) presented on the following 2 pages shows the course requirements of the basic curriculum, which meets or exceeds ABET requirements, as summarized below:

<b>Area</b>	<b>ABET Requirements (quarter-hours)</b>	<b>Present (quarter-hours)</b>
Math & Basic Science	48	64
Engineering Topics	72	90
Humanities & Social Sciences	24	36

Table 1. Course Requirements of Basic-Level Curriculum (ABET Table 10)

Year	Quarter	Course	Category and Credit Hours				
			Math/ Sci.	Engr. Topics		Hum/SS	Other
				Engr. Science	Engr. Design		
Freshman	1	Free Elecive					3
Freshman	1	Chemistry 1101- General Chemistry I	5				
Freshman	1	English 1001-Analysis of Literature and Language				3	
Freshman	1	Math 1507- Calculus I	5				
Freshman	2	Chemistry 1102- General Chemistry II	5				
Freshman	2	EGR 1170- Visual Communications & Engg. Design		3			
Freshman	2	English 1002-Analysis of Literature and Language				3	
Freshman	2	Math 1508- Calculus II	5				
Freshman	3	AE 2350- Introduction to Aerospace Engg.		3	(√)		
Freshman	3	Math 1509 - Calculus III	5				
Freshman	3	Physics 2121- Particle Dynamics	5				
Freshman	3	HPS 1040 or 1061- Health & Performance Systems					3
Sophomore	1	English 2101/2202/2301/2401 English Literature				3	
Sophomore	1	ESM 2201 - Statics		3			
Sophomore	1	History 1001/1002 - U. S. History				3	
Sophomore	1	Math 2507 - Calculus IV	5				
Sophomore	1	Physics 2122 - Electromagnetism	5				
Sophomore	2	ESM 3201 - Dynamics		3			
Sophomore	2	Math 2508 - Calculus V	3				
Sophomore	2	Physics 2123 - Optics & Modern Physics	5				
Sophomore	2	AE 2604- Computing in Aerospace Engg.		3	(√)		
Sophomore	2	POL 1251/3200 U. S. Government				3	
Sophomore	3	AE 2102- Introduction to Deformable Bodies		3	(√)		
Sophomore	3	Math 3308- Ordinary Differential Equations	5				
Sophomore	3	ME 3322- Thermodynamics		3			
Sophomore	3	Humaities/Social Sciences Elective				3	
Sophomore	3	Free Elective					3

Table 1 (cont'd). Course Requirements of Basic-Level Curriculum (ABET Table 10)

Year	Quarter	Course	Category and Credit Hours				
			Math/ Sci.	Engr. Topics		Hum/SS	Other
				Engr. Science	Engr. Design		
Junior	1	AE 3003 - Fundamentals of Aerodynamics		3	(√)		
Junior	1	AE 3105- Fundamentals of Stress Analysis		3	(√)		
Junior	1	AE 3111- Structures Lab.		3	(√)		
Junior	1	AE 3130- Vibrations & System Dynamics		4			
Junior	1	EE 3710- Intro. to electronic Systems		3			
Junior	1	Humanities/Social Sciences Electives				3	
Junior	2	AE 3005 - Viscous Fluid mechanics		3			
Junior	2	AE 3106- Structural Analysis by Virtual Work		3	(√)		
Junior	2	AE 3500- Aircraft Flight Mechanics		3			
Junior	2	EE 3741- Electronic Systems Lab.		3			
Junior	2	Math 4582- Advanced Engg. Mathematics	3				
Junior	3	AE 3004 - Compressible Flow	3		(√)		
Junior	3	AE 3010- Aerodynamics Lab	2				
Junior	3	AE 3501- Aircraft Flight Control	3				
Junior	3	English 3020- Technical Writing				3	
Junior	3	MATE 3702- Materials Engg. For Structures/Thermal Systems		3			
Junior	3	Humanities/Social Sciences				3	
Senior	1	AE 3510 - Flight Mechanics Lab.		2	(√)		
Senior	1	AE 4103- Analysis of Thin-walled Structures		3	(√)		
Senior	1	AE 4251- Jet Propulsion		4			
Senior	1	AE 4410 - Vehicle Performance		3	(√)		
Senior	1	Aerospace Elective		3			
Senior	1	Humanities/Social Sciences				3	
Senior	2	AE 4001 - High Speed Aerodynamics		3			
Senior	2	AE 4350- Aerospace Design Project I		4 (4)	(√)		
Senior	2	AE 4501/4502 Orbital Mech or Spacecraft FMC		3			
Senior	2	AE Electives		3			
Senior	2	Humaities/Social Sciences				3	
Senior	2	Free Electives					3
Senior	3	AE 4200 - Vibrations and Flutter		3			
Senior	3	AE 4351- Aerospace Design Project II		4 (4)	(√)		
Senior	3	AE Electives		3			
Senior	3	Humanities/Social Sciences				3	
Senior	3	Free Electives					3
Total Hours			64	90		36	15

## AIAA Program Criteria:

The program criteria specified by the American Institute of Aeronautics and Astronautics are as follows:

*"Aeronautical engineering graduates must demonstrate a knowledge of aerodynamics, aerospace materials, structures, propulsion, flight mechanics, and stability and control.*

*Astronautical engineering graduates must demonstrate a knowledge of orbital mechanics, space environment, attitude determination and control, telecommunications, space structures, and rocket propulsion.*

*Aerospace engineering graduates or graduates of other engineering programs combining aeronautical engineering and astronautical engineering must demonstrate knowledge covering one of the areas - aeronautical engineering or astronautical engineering as described above in addition must demonstrate knowledge of some topics from the area not emphasized. "*

Our present program should be viewed as an aerospace program, with emphasis on aeronautics. It emphasizes knowledge in aerodynamics (14 quarter hours), propulsion (7), structures (14), materials (3), dynamics and aeroelasticity (6) and flight mechanics, stability and control (12 hours). Students are also required to take a course (3 hours) either in orbital mechanics or spacecraft attitude control. In addition, many required courses in the areas of propulsion, structures, and introduction to aerospace engineering cover space-related topics and examples in spacecraft structures, rocket propulsion and the space environment. When these topics are considered, it is estimated that all AE students receive a minimum of 9 quarter hours of instruction in astronautics independent of electives.

Numerous electives are offered in aerospace areas. Students must schedule at least three courses from these electives and/or other special topics courses periodically offered, to satisfy the AE electives requirements. Electives are currently offered in the following areas:

*AE 4600 - Computational Fluid Dynamics*  
*AE 4360 - Fundamentals of Computer Aided Engineering and Design*  
*AE 4400 - Introduction to Propeller Theory*  
*AE 4551/2 - Instrumentation for Experimental Research I & II*  
*AE 4130 - Introduction to Computational Structural Analysis*  
*AE 4120 - Introduction to Composite Aerospace Structures*  
*AE 4010 - Advanced Diagnostics in Fluid Dynamics*  
*AE 4024 - Hypersonic Flow and Heat Transfer*  
*AE 4111 - Advanced Structures Laboratory*  
*AE 4261 - Introduction to Aerospace Combustion*  
*AE 4352 - Advanced design project*  
*AE 4352 - Design for Life-Cycle Cost*  
*AE 4360 - Fundamentals of Computer Aided Design*  
*AE 4760/1 - Engineering Acoustics and Noise Control I & II*  
*AE 4770 - Structural Integrity and Durability*  
*AE 4791 - Mechanical Behavior of Composites*  
*AE 4792 - Fundamentals of Fiber Reinforced Composites*  
*AE 4793 - Composite Materials and Processes*  
*AE 4794 - Laboratory in Composite Manufacturing and Testing*  
*AE 48XX- Avionics for Unmanned Aerial Vehicles*  
*AE 48XX- Multimedia in Engineering*  
*AE 8133 - Introduction to Space Vehicles (available to seniors with GPA>3.0)*

### Additional AIAA Criteria:

*"Graduates must demonstrate proficiency in the design process to include performing tradeoffs and achieving compromises necessary to meet stated design objectives covering a broad spectrum of the topics enumerated in (a)."*

Two required capstone design courses, AE 4350 (4 hours) and AE 4351 (4 hours) provide experiences in designing complex systems such as a complete aircraft. The philosophy behind these courses is described later under the section titled Engineering Design Experience. Students may also schedule additional elective courses in design:

*AE 4352 - Advanced design project (3 hours)*

*AE 4353 - Design for Life Cycle Cost (3 hours)*

Finally, three independent study courses, AE 4900 and AE 4901 and AE 4902 provide opportunities to pursue component and system design, under the guidance of design faculty.

### Relationship between the Educational Objectives and the Curriculum:

The ABET criterion 2 states that the engineering program *"must have in place a curriculum and process that ensures the achievement of the (educational) objectives."* The School of Aerospace Engineering educational objectives listed earlier state that the students will receive in-depth instruction in the areas of aerodynamics, aircraft and spacecraft structures, flight mechanics, orbital mechanics, flight controls, propulsion and design of aerospace systems. It is clear that the current program listed in Table 1 and presented in detail in Appendix A meets these objectives with over 90 hours out of a total of 205 quarter hours devoted to aerospace topics.

The AE educational objectives expect our program *"to prepare students for careers in AE and related multi-disciplinary fields by: emphasizing essential analysis and problem solving skills, exposing students to open-ended problems and design issues, fostering team work, promoting good communication skills and developing individual professionalism."* The capstone design projects, undergraduate labs, elective courses in design and laboratory courses are all designed to prepare students to pursue careers in AE and related multi-disciplinary fields.

Table 2 lists a summary of Course and Section Size. It may be noted that many classes are taught several times a year. In laboratory courses, several sections are usually offered. Each laboratory section is further divided into smaller groups of 4 or 5 students, to ensure each student has an opportunity to do hands-on experiments, and to collect/interpret data.

Table 2. Course and Section Size Summary (ABET Table 11)

Course No.	Title	No. of Sections Offered in Current Year	Avg. Section Enrollment *	Type of Class (1)			
				Lecture	Lab.	Recitation	Other (Specify) <sup>2</sup>
AE 2102	Intro. to Deformable Bodies	3	22	3	0		
AE 2350	Intro. to A.E.	3	35	3	0		
AE 2604	Computing in Aerospace Engineering	3	19	2	3		
AE 3003	Fundamentals of Aerodynamics	3	19	3	0		
AE 3004	Elements of Compressible Flow	3	21	3	0		
AE 3005	Viscous Fluid Mechanics	2	15	3	0		
AE 3010	Aerodynamic Laboratory	7	17	1	3		
AE 3105	Fundamentals of Stress Analysis	2	20	3	0		
AE 3106	Structural Analysis by Virtual Work	3	19	3	0		
AE 3111	Aerospace Structures Laboratory	4	20	variable			
AE 3130	Vibrations and System Dynamics	2	24	4	0		
AE 3500	Aircraft Flight Mechanics	3	18	3	0		
AE 3501	Aircraft Flight Control	1	26	3	0		
AE 3510	Flight Mechanics Laboratory	4	9	1	3		
AE 4001	High-speed Aerodynamics	2	21	3	0		
AE 4010	Advanced Diagnostics in Fluid Dynamics	1	14	variable			
AE 4103	Analysis of Thin-walled Structural Elements	2	25	3	0		
AE 4120	Intro. to Composite Aerospace Structures	1	19	3	0		
AE 4130	Intro. to Computational Structural Analysis	1	15	3	0		
AE 4200	Vibration and Flutter	2	23	3	0		
AE 4251	Jet Propulsion	2	18	4	0		
AE 4261	Introduction to Aerospace Combustion	1	13	3	0		
AE 4350	Aerospace Engineering Design Project I, II	2	34	variable			
AE 4351	Aerospace Engineering Design Project I, II	2	34				
AE 4352	Advanced Design Project	1	8				
AE 4353	Design for Life-cycle Cost	2	42	3	0		
AE 4360	Fund of Computer-aided Engr and Design	2	20	3	0		
AE 4400	Introduction to Propeller and Rotor Theory	2	16	3	0		
AE 4410	Vehicle Performance	2	24	3	0		
AE 4501	Orbital Mechanics	1	22				

AE 4502.	Spacecraft Attitude Dynamics	1	12	3	0		
AE 4770	Structural Integrity and Durability	1	8	3	0		
AE 4792	Fund. of Fiber-reinfor. Com I: Struc Mech	1	18	3	0		
AE 4793	Composite Materials and Processes	2	5	3	0		
AE 4803	System Simulation & Modeling	1	9	3	0		
AE 4813	Airfoil Design	1	13	3	0		
AE 4833	Crashworthy Design	1	21	3	0		

\* Summer enrollment figures are based on Phase I registration.

## **B. Engineering Design Experience**

The senior capstone design course sequence, AE 4350 (2-6-4) and AE 4351 (2-6-4), was developed to include all of the ABET criteria features as follows: development of student creativity, use of open-ended problems, develop and use of design methodology, formulation of design problem statements and specifications, consideration of alternative solutions, feasibility considerations, and detailed descriptions. The sequence also includes a variety of realistic constraints such as economic factors, safety, reliability, manufacturability, maintainability, aesthetics, ethics, and social impact.

The basic philosophy behind these courses is to teach design methods of increasing levels of sophistication and to apply this knowledge, throughout the two quarters, to a variety of design challenges of increasing complexity. This philosophy ensures a continuing high level of student interest. It also permits rapid infusion of the mass of pure and applied design knowledge necessary to achieve an overall grasp of the interdisciplinary and "compromising/optimizing" nature of the aerospace design process. Included in this process is insuring that design results conform to established engineering standards in the form of Military and Federal Aviation Requirements and Specifications.

A fundamental part of the capstone course also involves exposing students to the aerospace industry/government environment. This is accomplished in two ways. First, off-campus guest speakers are used; second, a mandatory field trip is made. The guest speakers are chosen from industry and government agencies with topics pertinent to the actual course content; the field trip ensures that each student has the opportunity to view, up close, aircraft and helicopters and to talk to users of the equipment, i.e., pilots and maintenance personnel.

In the first course, one vehicle is jointly developed to illustrate the design methods and technologies established more or less concurrently in class. In addition, each student completes homework and laboratory assignments designed to elaborate on the design techniques learned. Further, each student individually designs two separate air vehicles in response to written RFP's.

Life-cycle-cost is defined in this course and the methodology for its estimation is introduced and used. Equations based on a Rand Corporation model are used to establish acquisition and RDT&E costs for the current, jointly developed, air vehicle. Operational costs are discussed and the concept of accessibility and maintenance-man-hours per flight hour is introduced as a design-influenced parameter affecting these operational costs.

In the second course, individual design teams are formed (5-8 students on each team) and the students are introduced to the matrix-type organization often used in industry. The functions and responsibilities of each team member are discussed in detail and two special lectures are given. The first deals with the socio-economic impacts of the design process

including costs and employment, safety, energy consumption, and environmental contamination. The second addresses the questions, "How can I contribute to the aerospace industry and how do I get ahead?" and discusses in detail the ethics of participation in industry, how individuals progress, and the do's and don'ts in the workplace.

An RFP is issued, and a bidder's conference is held. Lectures are continued and homework assignments are set. The topics covered include re-sizing, re-matching to mission requirements, selection of the lift system, detailed weight estimation, performance estimation, engine-out sizing and design impact, major airloads on and experienced within structure (shear, torsion and bending moments), net loads on structure (inertia relief, distribution of life and fuel, underwing stores), material selection and distribution, production/manufacturing breaks, inboard profiles, horizontal and vertical tail sizing, stability and trim boundaries, influence of lift technology on tail design, introduction to V/STOL aircraft, an overview of low observables technology, and resulting technology drivers. The stability and control/handling qualities influence on the design process is discussed with the aid of Military Specification MIL-F-8785C. Frequency, damping and response parameters are compared at various points in the mission with the handling quality requirements. Design adjustments are made to ensure compliance. Propulsion integration is developed in terms of intake duct design, power accessory drive requirements, and methods of generating this power. Propulsion engine types are reviewed.

One final aspect of the Senior Design Project is the generation of the data for and the use of a flight simulator to permit the students to witness the first "flight" of their own aircraft. Each team participates in the "flight" which usually consists of a take-off, a circuit, and a landing. The input required includes stability and control derivatives, inertia properties, engine performances data, landing gear location and test speeds. A time history of the approach and landing, as acquired during the simulation, forms part of each team's final report. A critique of the handling qualities established during the "flight" is discussed with the team, and design changes, if any, are recommended.

Team presentations are made at mid-term (in isolation from each other and in the presence of an off-campus guest engineer), and a final presentation in front of the entire class is given at the end of the second quarter. A final written report is required, limited to 50 pages of response and 50 pages of back-up technical data. All final drawings are developed using commercial level CAD facilities. In the technology phase, the students are encouraged to write computer programs pertinent to the specific technology and its application. CAD application time accounts for about 10% of the work.

The final judgment is made on the competition by the faculty member teaching the design course and a trophy is awarded, and the winning team's name is displayed in the School's display case area. It is also customary for the winning team leaders to make a presentation at the military base visited at the start of the design year. A "Best Presentation" award is also made, judged by a board consisting of the Design Professor and two graduate students (occasionally an off-campus aerospace engineer as well). This presentation is repeated to the whole school on the next day, which is particularly important to freshmen and sophomores.

It is emphasized that the content of the aerospace engineering courses in the undergraduate curriculum is focused towards the capstone design courses, and the design instructor actively participates in the development of the course outlines. The goal is to insure that the fundamental elements of synthesis, analysis, construction, testing, and evaluation are included in the prerequisite courses so that students are fully prepared when they enter design activities. Classroom discussions are designed to relate the material at hand to the design experience yet to come. Design procedures are worked out and illustrated with component applications. Homework is assigned to develop computer experience in writing programs which enable parametric studies of specified systems. Methods for evaluating and validating specification compliance are applied to component designs provided by the instructor. A few examples are as follows:

<b>Course</b>	<b>Role in Supporting Design Courses</b>
AE 2350	Introduction to all aspects of aerospace engineering and design.
AE 3004	Design of supersonic wind tunnel
AE 3105	Design of beam structures to meet deflection requirements, beam structures to meet stress and material requirements, and columns with practical end conditions.
AE 3106	Deflection- and strength-based design of bar and beam structures for aeronautical and space structures.
AE 3501	Case studies in aircraft flight control design.
AE 4001	Method of characteristics for 2-D convergent-divergent nozzle design and analysis.
AE 4103	Design of torsion elements in structural systems and design of thin-walled, built-up structures for aerospace systems.
AE 4251	Performance prediction for futuristic engine design requiring choices of optimal design parameters for specified requirements.
AE 4410	Performance optimization and general purpose methods for determining a complete performance envelope for aircraft.
AE 4813	Airfoil design

In addition, three design elective courses are available: Computer-aided Design and Engineering (AE 4360), Advanced Design Project (AE 4352), and Design for Life-cycle Costs (AE 4353). These may be taken to satisfy the AE elective requirements. Some of these courses prepare the students to participate in national design competitions. For example, students enrolled in AE 4902, an independent study course, won the first place in the AIAA Air-breathing Engine Design Competition in 1995.

## Part III. Resource Information

This section describes the resources that are available to support a top quality program in aerospace engineering. They include faculty, facilities, and financial support from the Institute.

### A. Faculty

The strength of any School of Aerospace Engineering's academic and research program is its faculty. Our School currently enjoys the services of 28 full time faculty members, three joint faculty members, and several adjunct faculty members. The joint faculty members in the present context are defined as instructional and/or research faculty who hold a joint appointment in the School of AE and another instructional or research unit within Georgia Tech. Adjunct faculty members are research engineers from industry or the Georgia Tech Research Institute who teach courses part time within AE from time to time and have joint research interests with the school. All faculty, including adjunct appointments, must have Board of Regents approval.

Table 3 on the following pages summarizes the faculty workload for teaching, research and other functions compiled for the last term (Spring Quarter 1997) and the last full academic year (Fall 96-Spring 97).

Brief two-page curriculum vitae of the full time faculty members giving all the information requested by ABET are included in Appendix B. Some of the noteworthy credentials of our faculty are briefly listed.

- *Three of our faculty members ( Robert Loewy, Ben Zinn and Sathya Atluri) are members of the National Academy of Engineering.*
- *Four of our faculty members are AIAA Fellows or Honorary Fellows (Loewy, Calise, Hodges, Zinn)*
- *Our faculty members have won numerous national awards such as AIAA Aeroacoustics Award, AIAA L. Sperry Award, ASME Spirit of St. Louis Award, AIAA Combustion & Propellants Award, Curtis Award, State of Georgia Professor of the Year Award.*
- *Our faculty members serve on numerous AIAA, AHS and ASTM technical committees, on NRC committees, and advisory boards of NASA, FAA and DOD.*
- *Many of our faculty serve on Editorial Boards of reputed journals*
- *Our faculty have authored text books in the area of statics and dynamics (McGill), composites (Kardomateas, Talreja), and multimedia based text on engineering science and mechanics. They have also edited numerous books and monographs.*

**Table 3. Faculty Workload Summary (ABET Table 12)**

Faculty member (Name)	FT or PT	Classes Taught (Course No./Credit Hrs ) Curent Term	Total Activity Distribution				
			Teaching		Research		T
			Term	Year	Term	Year	
Armanios, E.	FT	AE 3111/2 (team), AE 2350/3, AE 3111/2, AE 4120/3, AE 4792/3	8	33	30	45	62
Bailey, S.	FT	AE 2102/3, ARCH 4313/3, AE 2102/3	50	25	0	0	50
Bauchau, O.	FT	AE 6104/3, AE 6103/3, AE 2604/3, AE 8143/3	25	33	25	31	50
Calise, A.	FT	AE 3500/3, AE 8103/3, AE 3501/3, AE 3510/2	0	31	50	39	50
Craig, J.	FT	AE 3105/3, AE 3106/3, AE 4360/3, AE 4360/3	25	33	5	10	70
Gramoll, K.	FT	AE 8505/3, ESM 2201/3, AE 4130/3, AE 4803/3, ESM 2201/3	50	42	20	20	30
Haddad, W.	FT	AE 2604/3, AE 3130/4, AE 3510/2, AE 8153/3	25	33	10	14	65
Hanagud, S.	FT	AE 4833/3; AE 6200/3, AE 6131/3, AE 6130/3	50	33	11	11	39
Hodges, D.	FT	AE 4200/3, ESM 3201/3, AE 6130/3	50	17	15	14	35
Jagoda, J.	FT	AE 3010/2, AE 3010/2, AE 6765/3	17	20	53	54	30
Jenkins, M.	FT	AE 4351/4, AE 4350/4, AE 4410/3	33	30	0	0	67
Kamat, M.	FT	AE 4103/3, ESM 3201/3, AE 3106/3, ESM 3201/3	50	33	0	0	50
Kardomateas, G.	FT	AE 3111/3 (team), AE 8123/3, AE 3111/2, AE 6100/3, AE 4103/3	33	33	5	12	62
Komerath, N.	FT	AE 3003/3, AE 4010/3, AE 6031/3, AE 6030/3	25	33	25	21	50
Loewy, R.	FT	AE 2350/3	25	8	0	3	75

Mavris, D.	FT	AE 4352/3, AE 4900/2, AE 6352/4, AE 4900/3, AE 4902/3, AE 6351/4, AE 4353/3	58	39	21	41	21
McGee, O.	FT	ON SABBATICAL	0	0	0	0	100
Menon, S.	FT	AE 6011/3, AE 3005/3, AE 6010/3, AE 6000/3	25	33	23	42	52
Olds, J.	FT	AE 6352/3, AE 6351/3, AE 6350/3, AE 8133/3	25	33	25	25	50
Prasad, J.V.R.	FT	AE 3500/3, AE 6503/3, AE 3130/4; AE 6511/3	25	36	9	26	66
Ruffin, S.	FT	AE 6801/3, AE 2604/3, AE 6800/3, AE 6020/3	25	33	30	33	45
Sankar, L.	FT	AE 4813/3, AE 6400/3, AE 6022/3, AE 6401/3	50	33	26	42	24
Schrage, D.	FT	AE 6352/3, AE 6351/3, AE 8113/3, AE 8113/3	25	33	10	21	65
Seitzman, J.	FT	AE 6767/3, AE 4251/4, AE 4261/3, AE 3010/2, AE 4251/4	25	44	8	14	67
Smith, C.V.	FT	AE 4410/3, AE 4501/3, AE 3003/3, AE 3105/3, AE 4502/3, AE 2350/3, AE 4200/3	50	58	0	0	50
Smith, M.	PT	AE 6023/3, AE 4001/3	25	17	N/A	N/A	N/A
Stevens, B.	PT	AE 3501/3, AE 6520/3	25	17	N/A	N/A	N/A
Talreja, R.	FT	ESM 2201/3, AE 7791/3, AE 4770/3, AE 2102/3	25	33	22	22	53
Yeung, P.K.	FT	AE 3005/3, AE 4001/3, AE 3003/3, AE 8103/3	25	33	9	8	66
Zinn, B.T.	FT	AE 3004/3, AE 6766/3, AE 3004/3	25	25	29	36	46

## **B. Facilities**

Instructional laboratory facilities are available for teaching required courses (AE 2604, AE 3010, AE 3111, AE 3510) as well as advanced elective courses. The undergraduate computing facility is also available for use by all students. A committee of faculty members designated as undergraduate laboratory coordinators periodically meet and implement upgrades to the laboratory facilities. A five year plan, in line with the School's long range plan, has been developed for each of these facilities. Here, the status, and the five year plan for each of these facilities are discussed.

### **Aerodynamics and Propulsion Laboratory Facilities**

The laboratory experience in Aerodynamics/Propulsion consists of a 2-credit-hour junior-level Core course (AE3010), and two 3-hour senior electives on Flow Diagnostics (AE4010) and Flow Control (AE48xx). AE3010 aims to introduce the student to various diagnostic techniques commonly used in Fluid Mechanics research, preliminary design, and testing. AE 4010 introduces modern techniques for sensing, visualization, signal processing and interpretation, and includes team projects. AE4813 covers theory on flow control techniques, requires students to survey recent work, and develop team experiments.

AE3010: Low-speed aerodynamics and 1-dimensional compressible flow are assumed prerequisites: these are covered in AE3003 and 3004 respectively. Viscous flow concepts are covered as needed in the lectures preceding each experiment. Each experiment is built around a series of related measurement techniques. In addition, the student learns to compare experimental results with the knowledge gained in the lecture courses. Six of the 8 experiments in AE3010 require results summarized into data reports, and the other two required full laboratory reports are required. The experiments are performed in teams of 3, but individual reports have to be done by each student. The reports include the student's answers to several questions which are set each quarter. The grading of the reports considers various aspects of technical reporting and laboratory practice. In addition, each student makes a 10-minute oral presentation to the class, describing the proposed solution to a hypothetical measurement problem assigned in the last 2 weeks of the quarter. This "proposal" is graded on creativity, thought and thoroughness. The audience is encouraged to ask questions. The data acquisition procedures are largely computerized and all laboratory reports must be produced using word processing and computer graphics. However, some aspects of the experiments are left to be done by human observation, careful alignment and adjustment, judgment and qualitative sketches.

AE4010: In the Senior Elective AE4010, lectures in flow measurement techniques and signal/image processing techniques are used to provide the student with a quick introduction to fundamental concepts, as well as the experience of drawing knowledge from diverse disciplines to solve problems. The laboratory gives students the experience of planning team projects and developing them, essentially from scratch, through to completion within the quarter. There are no Teaching Assistants or pre-tested experiments in this course: the team which develops each project presents their work to the others, and lets them participate, so that everyone becomes familiar with every project.

AE4813: The Flow Control Elective begins by surveying stability concepts used to achieve Flow Control, and then starts students out in teams of 3 to develop one experiment each. Students learn to search and survey papers relating to their interests, and summarize their findings in a presentation. In the latter part of the course, students exchange experiments so that everyone learns about all experiments. A final presentation of the experimental results forms part of the evaluation criteria.

Laboratories:

The facilities required to run AE3010 are located in Room 403/5 and 42" x 42" low speed wind tunnel in Room 106 of the main Aerospace Engineering building. The Combustion Laboratory is housed in Bldg. 102, a specially constructed building for combustion and propulsion research. A shock tube is set up parallel to the low turbulence tunnel in the same room. Supersonic flow experiments are carried out in a Mach 2 tunnel and an in-draft nozzle located in the Fluid Mechanics Research Laboratory across campus. In all 3 facilities, the undergraduate labs and courses are assigned top priority in scheduling. In addition, AE4010 and 4813 experiments are combined with research experiments in the 7' x 9' John J. Harper Low Speed Wind Tunnel in the Guggenheim Building and the facilities in Bldg. 102.

Presently, eight different sets of experiments are performed in AE 3010 during seven laboratory periods stretching over seven weeks. The titles of the laboratory experiments currently in place are:

1. *Force Measurements in a Subsonic Wind Tunnel.*
2. *Pressure Measurements in a Subsonic Wind Tunnel.*
3. *Flow Visualization.*
4. *Unsteady Velocity Measurements in a Subsonic Wind Tunnel Using a Hot-Wire Anemometer.*
5. *Velocity Measurements in a Subsonic Flow Using a Laser Doppler Velocimeter.*
6. *Measurements in Unsteady Combustion.*
7. *Transient Measurements in a Shock Tube.*
8. *Optical/Pressure Measurements in Supersonic Flow.*

The major items of equipment currently used in the undergraduate fluid mechanics laboratories are:

Item	Year Acquired	Approximate Cost
Low turbulence, low speed tunnel with lift balance	195x	Unknown
PC-based A/D system with a Scanivalve pressure switch and a Baratron electronic pressure sensor.	1987	\$ 28,500
Low speed wind tunnel with a 8"x8" transparent test section.	1987	\$ 2,000
Smoke tunnel with a variety of models.	Unknown	
Laser Doppler velocimeter (LDV) based upon a 15 mW, He-Ne laser with counter processor and 3-axis traverse.	1987	\$ 48,500
Hot wire anemometer data acquisition computer, oscilloscope.	1987	\$ 38,000
Rijke Tube type pulsating combustor with pressure transducers, thermocouple and photo-multiplier.	1987	\$ 30,000
Shock tube, instrumented with piezo-electric pressure transducers. This facility was refurbished.	Unknown	\$ 2,000
Mach 2, supersonic wind tunnel with a 2"x3" test section instrumented with pressure probes, Baratron, various models and a Schlieren system; donated by NASA.	Unknown	
In-draft nozzle attached to a large vacuum tank and instrumented with static and stagnation probes whose output is displayed on a manometer board.	Unknown	

In 1992, two major NSF grants were won under the Instrumentation & Laboratory Improvement Program and the Leadership in Laboratory Development Program. AE 3010 uses flow-imaging equipment listed below during some quarters, depending on the experience level of the teaching assistants and the interests of the instructors in the course. These advanced instruments are used primarily in AE4010, the flow control electives, graduate versions of these courses, and in undergraduate "Special Problems" individual projects. Equipment purchased under the NSF and associated institutional funding is listed below:

Item	Year	Cost
Argon laser : 5-watt	1993	\$38,000
FiberOptic System for LDV & laser sheet	1993	41,000
Miscellaneous optics	1993	5,200
Acousto-Optic modulator	1993	3,100
PULNIX NV700 Intensified camera system (2)	1993	7,300
HAMA Videocut 11 editing controller	1993	1,100
Sony V-101 video camera	1994	2,225
Video recorder/player	1993	1,100
RasterOps frame grabber system #2	1993	2,599
Macintosh Quadra computer system 900 #1	1992	6,970

These items of equipment meet and exceed the short-term and long-term goals which were set five years ago.

#### Aerodynamics/Propulsion Labs Goals and Objectives for Next Five Years

The goals for improving the undergraduate fluid mechanics laboratories over the next five years are three fold; to:

1. *renovate the 42" wind tunne,*
2. *refurbish the smoke tunnel to incorporate better lighting and flow-control facilities,*
3. *acquire a capability to use Pressure Sensitive Paints in aerodynamic measurements,*
4. *expand the planar velocimetry capabilities into a routine undergraduate experiment,*
5. *incorporate feedback control experiments into the aerodynamics laboratory, and*
6. *enable capture of short-time-scale events. in the combustion and supersonic flow experiments.*

#### Plan for Reaching Goals and Objectives

The following is a list of major equipment to be acquired over the next five year period. Experience with the NSF project and elective courses has proven that integration of research and undergraduate instruction has paid off handsomely for both: this experience will be used more aggressively in the AE3010 lab course as well. Software systems are being purchased with commonality in mind, so that the systems can be kept linked to the state of the art, and maintained as computers and instruments change. Research capabilities and image data bases will be exploited for the benefit of AE3010 lab course assignments and experiments.

Period	Item	Approximate Cost
<b>1st Year</b>	Renovate 42" wind tunnel	\$ 25,000
	Acquire high-speed digital data acquisition systems	\$ 25,000
	Acquire small wind tunnel with feedback control	\$ 5,000
<b>2nd Year</b>	Refurbish smoke tunnel for unsteady flow imaging and control	\$ 5,000

	Acquire fan calibration /measurement facility	\$ 5,000
	Incorporate video into supersonic tunnel experiments	\$ 3,000
<b>3rd Year</b>	Purchase High -Resolution camera and lighting system for Pressure-Sensitive Paint experiment	\$ 50,000
<b>4th &amp; 5th Years</b>	Incorporate 6-d.o.f. balance into undergraduate lab	\$ 10,000

### Flight Mechanics and Controls Laboratory Facilities

The primary goal of the undergraduate flight mechanics and control laboratory course (AE 3510) is to provide hands on experience for students on various aspects of dynamics and control. More specifically, this course is structured to give juniors in Aerospace Engineering a clear understanding of flight vehicle dynamics, stability and control, with emphasis on control system design. The experiments are designed to highlight the interdisciplinary aspects of advanced technology control relative to other sub-disciplines in aerospace engineering such as aerodynamics, structures, aeroelasticity and design. Also, emphasis is given to digital control as it replaces analog control, highlighting current and future trends in the aerospace industry.

#### Current Status:

The laboratory course is AE 3510 and the associated laboratory facilities are configured primarily to serve this course, in the Flight Mechanics and Control laboratory, located on the second floor of the Aerospace Engineering building. The laboratory currently occupies roughly 1200 sq. ft. of floor space. The following is a list of major equipment in the lab:

<u>Item</u>	<u>Year Acquired</u>	<u>Approximate Cost</u>
Two Tektronix oscilloscopes	1988	\$4,000
Four X-Y-t plotters	1988	6,400
Four multimeters	1988	880
Two CA04 Direct Digital controller sets	1988	2,800
Data translation A/D and D/A board	1988	1,100
Two LJE CA03 analog DC servo systems	1989	3,110
Two LJE CA04 digital DC servo systems	1989	3,300
Two Tektronix oscilloscopes	1989	2,900
One DC motor	1989	1,650
One tachometer	1989	940
One KEPCO power amplifier	1989	2,660
Four DEGEM Systems analog computers	1989	8,000
Three Signal generators	1989	2,550
Two accelerometers	1989	1,990
Four Gateway G6200 computers	1997	11,900
Model 205 torsional disk experimental set	1997	6,190
Four MX 31 motion control boards	1997	10,360
Two M31DB02 control expansion boards	1997	1,490
3 DOF helicopter experimental set	1997	9,880
Gyro experimental set	1997	4,180
Self erecting inverted pendulum experiment	1997	4,845
PA-0103 power supply unit	1997	1,140

The laboratory course currently consists of the following experiments:

1. *Modeling and analog control of a typical flight control system actuator.*
2. *Simulation of aircraft longitudinal and lateral dynamics.*

3. *Aircraft longitudinal stability/command augmentation system design.*
4. *Aircraft lateral stability/command augmentation system design.*
5. *Digital control of a typical flight control system actuator.*
6. *Spacecraft on/off control system.*
7. *Modeling of a flexible beam.*

A major strength of this laboratory course is its integrated treatment of simulation, modeling and control. Experiments involving simulation and modeling aspects have been designed to specifically enhance the knowledge gained in the theory/applications courses, AE 3130 and AE 3500. Similarly, the experiments involving analog and digital control have been designed to strengthen the students' understanding gained in AE 3501 regarding various aspects of feedback. The only weakness in the current laboratory course is the limited number of experiments involving the use of aerospace vehicle hardware. We plan to incorporate more aerospace vehicle hardware into these laboratory experiments, to remove this aspect of the course.

### Goals for the next five years

The overall goal for the next five years is to incorporate additional interdisciplinary aspects into the existing experiments; active control of a flexible robot arm is one such example. Existing experiments will be carefully updated to demonstrate the importance of various aspects of control/structure interaction, active flow control, propulsion control and flight path control. In the next two years, we intend to include more hardware related experiments dealing with aerospace vehicle dynamics and control. During the third through fifth years, modifications to existing experiments and/or development of new experiments will be carried out to include nonlinear control aspects. The long term goal is to carefully tailor all such experiments to illustrate the interface of flight mechanics and control with other aerospace disciplines.

### Plan for Reaching Goals and Objectives

Four new experiments that make use of off-the-shelf experimental sets, viz., 3 DOF helicopter experimental set, torsional disk experimental set, gyro experimental set and the self erecting experimental set, are currently being set up. All the equipment required for these new experiments have been purchased, and they will be designed and conducted to emphasize microprocessor-based control aspects. It is planned to develop a small wind tunnel-based aircraft model with pitching and plunging degrees-of-freedom, to illustrate various aspects of static and dynamic stability and response in atmospheric flight. The following is a list of major equipment to be acquired over the next five year period:

Item	Approximate Cost
<b>1st Year</b>	
Wind Tunnel-based aircraft model experiment	\$25,000
Routine maintenance of existing equipment	5,000
<b>2nd Year</b>	
Modification of existing experiments to incorporate interdisciplinary aspects - Four microprocessor controller boards and miscellaneous items	15,000
<b>3rd Through 5th Year</b>	
Modification of existing experiments and/or development of new experiments to illustrate nonlinear control aspects (roughly \$10,000 per year)	\$30,000
<b>Annual Maintenance Cost</b>	
Routine maintenance of existing equipment (roughly \$5,000 per year)	\$15,000

## Computing Applications Laboratory Plan

The Aerospace Engineering undergraduate curriculum has been designed to make extensive use of personal computers, with strong emphasis on the use of these systems for engineering problem-solving and not merely for abstract "programming" exercises. This use extends from the classroom to the project labs, and it includes the laboratories where experiments can be computer-controlled and data can be acquired directly into the computer. Students are expected to routinely simulate and analyze engineering systems, acquire and process experimental data, design and synthesize aerospace systems, and present problem solutions in peer review settings using both personal computers and workstations, as appropriate to the task at hand. Laboratory and project reports are required to be computer-prepared (either printed or submitted electronically), and presentations using contemporary audio/visual equipment are encouraged.

The introductory course in computer applications (AE2604) focuses almost entirely on the basic problem-solving tools that will be used throughout the undergraduate program of study. At present it is almost entirely based on the facilities available in the AE Computing Applications Laboratory, but in the coming years, extensive use will be made of student-owned computers. To varying degrees, each of the core courses in the AE undergraduate program currently makes use of the laboratory for computational analysis, simulation, visualization, data processing, etc., using both commercial software and custom prepared software. The AE elective courses which offer the opportunity to explore other advanced topics also make use of this laboratory.

The undergraduate instructional laboratories associated with the other major tracks in Aerospace Engineering all include computational facilities built around personal computers. Generally, these systems are designed and configured to run specialized software associated with the particular lab, and they are available on only a limited basis for general use. The AE Computing Applications Laboratory, on the other hand, is available to all students in Aerospace Engineering for at least 78 hours per week, and it provides the broadest collection of software and peripherals.

### Current Status

The AE Computing Applications Laboratory is supported by the technical staff in the School of Aerospace Engineering. The laboratory is currently operated from 8 AM until 11 PM, on Monday-Thursday, from 8 AM until 5 PM on Friday, and from 1 PM until 11 PM on Sunday. It is operated in an unattended mode during business hours and is under the supervision of student assistants during the evening hours.

Operations of the AE Computing Applications Laboratory were initiated in the mid-80's with a dozen PC/AT class personal computers. It was upgraded in 1990 with 32 Macintosh IIci systems, an AppleShare file server, an optical scanner, and three laser printers. These systems were further upgraded in Spring 1997 with the addition of 4 high-end Macintosh systems, 4 high-end Windows NT systems and 2 mid-range Windows NT systems. The present complement of hardware is listed below:

<b>Quan.</b>	<b>System</b>	<b>Display</b>	<b>Memory</b>	<b>Disk</b>	<b>Acquired</b>
4	PowerCenter Pro 210, CD	17" 24 bit	32 Mb	2 Gb	1997
4	Gateway G6-266, CD	17", 24 bit	64 Mb	6 Gb	1997
2	Gateway G5-166, CD	17", 24 bit	32 Mb	3.8 Gb	1997
1	Mac AWS95 Server	console	32 Mb	2 Gb	1993
8	Mac IIci, CD	14", 24 bit	20 Mb	380 Mb	1990
22	Mac IIci	14", 8 bit	16 Mb	240 Mb	1990
2	LaserWriter IINTx				1990
1	LaserWriter Plus				1987

The laboratory maintains a suite of software that is appropriate to the educational and research objectives of the School. The core includes word processors, spreadsheets, equation solvers, math systems, graphics systems and network access software. In addition, a smaller number of special purpose software systems are maintained. The table below lists the key programs.

Quan.	Items	Use
6	Microsoft Office 97 Pro	Office Productivity
4	Microsoft Office 4.2.1	Office Productivity
4	Microsoft FrontPage	Web Page Development
30	Microsoft Word	Word Processing
30	Microsoft Excel	Spreadsheet
30	Microsoft PowerPoint	Presentation Graphics
40	MatLab (lab license)	Analysis And Simulation
40	Simulink (lab license)	Simulation
30	TK Solver	Equation solving
30	MacDraw II	General graphics
2	ClarisDraw	General graphics
2	Visio Pro	General graphics
2	Visio Technical	General graphics
2	Code Warrior	C, C++ programming
4	DEC Visual Fortran	Fortran programming

In addition, the lab includes specialized software for supporting classes in computational structural analysis, aerodynamics visualization, and multimedia creation and presentation. Key programs in these areas include the following:

Quan.	Items	Use
8	COSMOS/M	Finite element analysis
8	Director 4	Multimedia authoring
8	Photoshop	Multimedia development
8	Strata Studio Pro	Multimedia development
8	Working Model	Multimedia simulation
8	QuickTime utilities	Movie development

Finally, the lab also includes a number of useful but less generally used software packages that include the following:

Quan.	Items	Use
10	DeskPaint/Draw	Paint graphics
1	Retrospect	Disk backup utility
5	Claris CAD	Drafting
1	Mini-CAD	Drafting
5	Mathematica	Symbolic & numeric analysis
2	Extend	Simulation
1	PageMaker	Document prep.
1	Illustrator	Tech. Illustration
5	MathType	Math formulas
2	Textures.LaTex	Technical Pub

The initial acquisition cost of the present hardware in the AE Computing Applications Laboratory is approximately \$289,000. The replacement cost of the hardware today is about \$120,000 and for the software, approximately \$26,000. Ten systems are new and the balance of the equipment is 7 years old, although it has been well-maintained and frequently upgraded with additional memory, more disk space, and the latest versions of most software. On the other hand, the older CPU's are quite slow for contemporary software, and the older Motorola 68030 CPU's in the Mac IICI's soon will no longer be supported for new releases of much of the useful software.

The laboratory is located in Room 318 and occupies approximately 700 sq. ft. of space. Each of the Macintosh systems and the printers is connected to the building ethernet local area network, which in turn is connected to the campus network and the Internet. As a result, users of these systems have full access to all the academic computing resources on the campus, including all student accounts on central systems, campus mail systems, and gateways to national networks. The optical scanner is connected to one of the Mac's, and many of the Mac's also include a separate CDROM unit. A unix-based Apple AWS95 Workgroup server is used to provide file sharing support for the lab. The server (called Jupiter) contains student accounts for each of the AE undergraduate courses that use these facilities. It contains a large volume of multimedia software developed by the AE Multimedia Laboratory. It also contains some of the applications software not also stored locally on each of the systems. The server supports a limited type of license management, it manages several printer queues, and it provides the latest Apple software for academic support. Most of these services will be moved to a new and much larger Windows NT Server during Summer 1997.

The AE Computing Applications Lab is also equipped with an LCD/overhead projector and audio system that can be used to project screen images for general laboratory instruction. The Sharp LCD panel provides 640x480 pixel resolution at 16 bits of color depth and can be continuously operated without degradation using a 4000 lumen Dukane overhead projector.

The Laboratory is heavily utilized by the students and is a major asset to our academic program, allowing our School to utilize computing effectively at all levels of the undergraduate program.

The primary weakness of the laboratory is in the general area of operation and maintenance. Because it is operated unattended during business hours and with direct staff supervision during all non-business hours or else it is locked, the cost for student lab assistants, routine maintenance, and normal software upgrade and acquisition is a significant and continuing expense.

### Goals and Objectives for Next 5 Years

Undergraduate computing will undergo a radical transformation in the next few years as we move into the era of required student computer ownership (starting in 1997-98). Each undergraduate student, starting with freshmen entering in September 1997, will be required to provide a basic personal computer and will be required to provide or purchase at Georgia Tech a standard base set of software. This personal computer system is expected to provide the student with most of the basic computational capabilities in support of the undergraduate program of study (sometimes referred to as productivity enhancement functionality). The systems are not expected to provide higher end capabilities that might be encountered in upper division courses and labs (e.g., computational analysis and modeling).

The implications for the present AE Computing Applications Laboratory are quite significant, since most of the present capabilities in this lab will be directly replaced by student computers. However, these student computers are not expected to be capable of handling the growing need for computational analysis, simulation and modeling in the upper division courses. Students will encounter significantly more demanding upper division applications for their computers just as these then 2 year old systems will be falling well behind the performance of comparably priced new systems. As a result, we believe there will continue to be a need for departmental computing laboratories, but the needs will be quite different than before. Future needs will move more towards higher end computational problem-solving, using high performance multi-processor personal computers and workstations to solve such problems as those involving FEM and CFD or controls simulations. Visualization and CAD software will increasingly demand use of 17 and 20 inch or larger monitors. And at the same time there is growing evidence that the present campus computing labs are providing more than basic

computing functionality; in fact, they may be providing very effective environments for project teamwork, group lab sessions, and other “social” aspects of the student learning process.

As a result of these considerations, the 5 year plan for the AE Computing Applications Laboratory is going to be quite different that it was for the past period. Yet the basic long-term goal will continue to be to provide computing systems that are appropriate to the educational program in Aerospace Engineering. The rapid advances in computing technology make this a continual problem, but the general lack of sufficient numbers of personal computers throughout the School for the use of individual staff members means that the replaced systems will continue to find some kind of productive use.

The short-term goals are the following:

1. *Replace the present Mac IICI systems with personal computers capable of handling the most demanding upper division coursework. This will involve replacing the present 32 systems with approximately 16 systems and associated peripheral equipment over a period of 3 years. These systems will be on the order of 300 MHz 604e Mac systems or 250 MHz Pentium II systems with 48 Mb of memory, 4 Gb of disk and 17 or 20 inch monitors. The systems will be upgraded on a 3 year cycle, so the goal will be to replace 5 systems per year while maintaining a complement of 15 or so systems at all times. As noted above, we have already started this process in 1997 with the addition of 10 new systems.*
2. *Add additional server capacity to support the undergraduate program. The present 2 Gb server must be upgraded by a factor of 2x in capacity and performance each year. As noted above, we are in the process of moving to a much larger Windows NT server.*
3. *Provide upgraded software including additional Matlab toolboxes, data acquisition, and analysis software for the basic software complement described above.*
4. *Continue to carry out student, staff and faculty training on the use of software and hardware in the laboratory. The laboratory setting is very important for this purpose.*

### Plan for Reaching Goals and Objectives

A plan for achieving the goal and objectives described previously is outlined below. From a funding viewpoint, the plan involves a deliberate effort to secure a balance between internal funding and timely grants and donations from external sponsors. Equipment/software acquisitions are summarized in the following table.

Period	Item	Approximate Cost
<b>1st Year</b>		
	Personal computer system upgrades (5)	\$ 22,500
	Additional software	4,000
	Server upgrade	3,000
<b>2nd Year</b>		
	Personal computer system upgrades (5)	\$ 22,500
	Unix workstations (2)	\$ 36,000
	Unix software	\$ 5,000
	Server upgrade	\$ 4,500
	Screen projection system in lab	\$ 5,500
	Software upgrades	\$ 3,500
<b>3rd Year</b>		
	Personal computer system upgrades (5)	\$ 22,500
	Unix workstations (1)	\$ 18,000
	Network upgrades	\$ 12,000
	Engineering analysis software	\$ 8,000
	Software upgrades	\$ 3,500

<b>4th year</b>	Personal computer system upgrades (5)	\$ 22,500
	Unix workstations (1)	\$ 18,000
	Software upgrades	\$ 3,500
<b>5th Year</b>	Personal computer system upgrades (5)	\$ 22,500
	Unix workstations (1)	\$ 18,000
	Software upgrades	\$ 6,000

### Aerospace Structures Laboratory

The aerospace structures laboratory provides hands-on experience for every AE undergraduate in structural testing and experimental data collection and analysis. The structures laboratory is taught in two courses, AE 3111 (required) and AE 4111 (elective). The required AE 3111 course is offered each quarter of the academic year. The class is limited to 30 students each quarter and is offered in three, 3-hour laboratory sections each week, with a separate hour of lecture. The elective course, AE 4111 - Advanced Structures Projects Laboratory, is designed to offer those students who are concentrating their studies on structures advanced experimental testing and analysis experience. The elective course is limited to 10 students per section, with three hours of laboratory and one hour of lecture.

These laboratory courses are formulated each quarter by selecting 5 or 6 experiments from the list below. This list changes as new experiments are designed and developed. Training is provided to allow each student to install strain gages in at least one of these experiments. Tests are conducted, data collected, and formal written reports prepared for each experiment. Where applicable, experimental findings are compared with predictions from design theory. Analysis of the data and the data visualization are carried out using spreadsheets and Matlab scripts, while reports are prepared using word processors. The use of CAD for drawings is encouraged but not required, since preparatory CAD courses are not a prerequisite for these laboratory courses. The subjects covered by the experimental projects currently available are:

- *measurement and uncertainty analysis*
- *transducer calibration*
- *strain gage applications/wheatstone bridge*
- *Young's modulus*
- *rosette strain gage use*
- *stress and strain transformation*
- *transducer design*
- *composite beam behavior*
- *sandwich beam behavior*
- *symmetric beam bending*
- *asymmetric beam bending*
- *column buckling, Southwell plots*
- *Wagner beam behavior*
- *space truss behavior*
- *plate with a hole in uniform tension*
- *lateral instability of a deep beam*
- *flat plate bending*
- *torsional rigidity*

### Current Status

In addition to AE 3111, is carefully planned to enhance what is learned in the following courses:

*AE 2102 - Introduction to Deformable Bodies*  
*AE 3105 - Fundamentals of Stress Analysis*  
*AE 3106 - Structural Analysis by Virtual Work*  
*AE 4103 - Analysis of Thin-Walled Structural Elements*  
*AE 4120 - Introduction to Composite Aerospace Structures*  
*AE 4130 - Introduction to Computational Structural Analysis*  
*AE 4770 - Structural Integrity and Durability*

Dedicated space for the structures instructional laboratory is located in Room 301, Montgomery Knight building. In addition, space is shared with the Structures and Materials Lab in Room 106, and the Composites Manufacturing laboratory, Room 217.

A member of the faculty teaches the laboratory course 2 quarters per year. In addition to this professor, two Graduate Teaching Assistants are assigned to assist students in each laboratory section. One 30-year old Instron screw-jack testing machine is available in Room 301 for structural testing, and a second Instron 8500 series servohydraulic test machine is available in the Structures and Materials Lab. Thus, both static testing with controlled screw-jack displacements and full dynamic testing under either load, displacement or strain control can be experienced. The laboratory is also equipped with a new computerized data acquisition system, and emphasis is placed on the use of this system by the students to automate data collection from the experiments whenever possible. This is part of a joint effort with the Aerodynamics Laboratory (AE3010) to develop and implement a unified treatment of computerized data acquisition and control in tests using advanced instrumentation.

The facilities of the Structures Lab have been upgraded over the past 6 years, starting with the addition of a very powerful Instron 8500 servohydraulic test system in the Structures & Materials Lab. This system was acquired primarily to support the instructional laboratories, and it is shared with the graduate research program. It is located downstairs in the main structures laboratory where it is convenient to the hydraulic power supply systems. More recently, the Laboratory has been further upgraded with the addition of a new PC-based data acquisition and control system. This has been done in a joint effort with the Aerodynamics Laboratory (AE3010) to develop a comprehensive approach to computer-based instrumentation and data acquisition. Over the next several years, extensive courseware and lab projects will be developed to provide advanced instruction in the design and deployment of computer-based instrumentation for structural measurement. This effort is also being linked closely to the introductory course in problem-solving with computers (AE 2604). The most recent Laboratory upgrade has involved replacement equipment for older worn and damaged equipment. In addition, several transducers were acquired in order to allow fracture toughness testing and additional composite materials testing.

Major equipment items currently in the structures laboratory are as follows:

Item	Year Acquired	Approximate Cost
Pentium PC Data Acquisition System with National Instruments Boards & LabVIEW and LabWINDOWS Software	1997	\$12,500
Extensometer & Crack Opening Displacement Gages	1997	2,000
Strain Measurement Systems	1997	2,000
Cantilever Beam Bending Test Kits	1997	2,000
Replacement Displacement Gages	1997	2,000
Air Line Separator	1997	500
Replenish Strain	1997	200
Instron 8500 22 kip Servohydraulic Testing Machine (shared with the Structures & Materials Lab)	1997	1,500
Cantilever beam tester apparatus	1988	\$ 1,000
Beam bending test apparatus(3 &4-point)	1988	\$ 2,200
Strain indicators and power supplies;	1988	\$ 1,700

Switch/balance boxes	1988	\$ 950
Multimeters and decade resistors	1988	\$ 700
Micrometer slide tables	1988	\$ 600
Extensimeters	1988	\$ 1,350
Micrometer; electronic calipers	1988	\$ 1,500
Strain gage kits	1988	\$ 1,500
Electronic scales	1988	\$ 800
Slide projector and library	1988	\$ 1,600
Furniture, cabinets, etc.	1988	\$ 3,000
Strain gage tester & welder	1987	\$ 900
Electronic scales	1985	\$ 400
Micrometer	1980	\$ 100
Strain indicators with switch & balance boxes	1974	\$ 500
Dial gages; magnetic clamps	1974	\$ 1,500
Multimeter; beam tester	1970	\$ 400
Photoelastic equipment	1968	\$ 6,000
Strain indicator/balance box	1968	\$ 400
Multimeters & slide table	1968	\$ 300
Instron 20 kip screw jack testing machine with oven	1967	\$10,000

A major strength of the structures laboratory program is the fact that there are several professors on the faculty with experimental structures backgrounds who have taught the structures laboratory courses in various forms for the past twenty years. During this period, over 20 different experiments have been designed and developed which provide participatory training in structural testing for each student. These experiments provide verification of design theory taught in several courses in the structures curriculum. Each quarter, certain basic experiments are conducted, along with 2 or 3 others selected from the list. The experiments are also designed to develop certain skills, such as:

- *use of precision calipers and micrometers*
- *selection and installation of strain gages and strain gage rosettes*
- *calibration of deflectometers and load cells*
- *use of strain gage indicators, wheatstone bridges, and associated circuitry*
- *operation of the Instron mechanical testing machine*
- *testing using the Instron 8500 servohydraulic test machine*
- *data acquisition and control using a PC and LabVIEW*

Laboratory contact time for each student is maximized by offering three 3-hour laboratory sections each week. In addition, 2 GTA's are assigned to assist in the laboratory. In this manner the structures laboratory courses provide a full three hours of laboratory experience with a student/instructor ratio of about 4/1.

The main weaknesses of the structures laboratory courses are:

- *More experiments are needed which involve such new aerospace materials as graphite-epoxy composites and matrix metals.*
- *The old Instron screw-jack machine is heavily utilized, but it should be upgraded with a modern control system to make it safer for student use and more adaptable to use with the existing computer data acquisition and control system.*
- *Greater use should be made of the Instron 8500 servohydraulic testing machine to demonstrate the state-of-the-art of cyclic testing of aerospace structures.*
- *More training is needed in the use of computerized data acquisition and control equipment in experimental testing.*

- *More dedicated undergraduate laboratory space is needed to expand the number of the laboratory work stations from 4 to 6 and to provide space for additional computer data acquisition systems and additional lab PC's.*

### Structures Labs Goals and Objectives for Next Five Years

An immediate goal is to upgrade the present 30 year old Instron T-series screw-jack mechanical testing machine, so as to refurbish the loading system and add programmable load and displacement testing capabilities. A subsequent goal then is to design and develop new experiments using this machine and the Instron 8500 servohydraulic machine which can be conducted by the students. These experiments will be planned to introduce the students to state-of-the-art computerized loading, data acquisition and analysis of structural elements subjected to cyclic loading. During this time period, additional experiments will be added to evaluate material properties and to verify design theory for the new aerospace materials.

The long-term objective of this plan is to expand the number of student work stations within each laboratory section from four to six. This will allow assigning only two students per station within each of the three laboratory sections, thus, providing more individual instruction. During the same period, one additional small screw-jack testing machine should be purchased. This will double the time currently available to provide hands-on static load testing experience for each student.

### Plan for Meeting Goals and Objectives

The following is a list of major equipment to be up-graded and acquired over the next five years.

<b>Period</b>	<b>Item</b>	<b>Approximate Cost</b>
<b>1st Year</b>	Refurbish Instron screw-jack test machine and add programmable loading capability.	\$ 35,000
	Develop new instructional material and experiments addressing computer data acquisition and control	1,500
	Acquire misc. laboratory equipment	2,000
<b>2nd Year</b>	Add more PC data acquisition systems	7,500
	Design and develop dynamic loading experiments using hydraulic and screw-jack test machines; design and develop experiments with newer aerospace materials - graphite epoxy and metal matrix composites.	5,000
	Acquire misc. laboratory equipment	2,000
<b>3rd Year</b>	Renovate and furnish 800 square feet of dedicated laboratory floor space	10,000
	Acquire misc. laboratory equipment	2,000
<b>4th Year</b>	Purchase new 10,000 pound screw-jack testing machine	68,000
	Acquire laboratory apparatus and instrumentation for two additional work stations	4,000
	Acquire misc. laboratory equipment	2,000
<b>5th Year</b>	Upgrade PC data acquisition systems	12,000
	Acquire misc. laboratory equipment	2,000

## Classroom Facilities

The Aerospace Engineering undergraduate curriculum involves a balanced combination of classroom and laboratory instruction. Classroom instruction in Aerospace Engineering is continually being revised, updated and improved to reflect the latest developments in the field and to incorporate the best and most appropriate instructional technology. To support these efforts, all of the classrooms in the School of Aerospace Engineering are also being continuously improved with the addition of new but proven A/V technology appropriate to our program of undergraduate instruction.

### Current Status

The renovation of the Guggenheim Building was completed in 1995, and it provided a complete renovation of three of the four primary classrooms used for instruction in Aerospace Engineering. Of these, the Design Lab in Room 442 received the most attention, because it was conceived as the centerpiece of our capstone design courses and the primary forum for seminars and other School-wide meetings. The other 2 classrooms in the Guggenheim Building (Rooms 244 and 246) now provide high quality instructional settings for typical undergraduate classes. The fourth classroom is in the A. French Building located across the campus about a block away.

### Design Lab

The Design Lab (Room 442) is located on the top floor of the Guggenheim Building in the complex of lab, library and office space that supports the undergraduate design courses and that houses the primary research computing facilities for the School. The Design Lab is designed as a large tiered classroom seating 100 in free standing chairs at continuous desk rows and providing excellent visibility and acoustics throughout. The room is equipped with a double-wide triple-track whiteboard, a cabinet style lectern and a multilevel lighting system (controlled from the lectern). The room design includes provision for future computer networking to each seat and it includes a grid of power outlets above the ceiling for A/V equipment and a future wireless communications system.

With a \$30k grant from the Provost, supplemented with \$10k of School funds, the Design Lab was outfitted in 1996 with a state-of-the-art A/V system for enhanced classroom instruction. The system is based on a dual screen projection system with ceiling mounted projectors illuminating two 12 ft. wide drop-down screens mounted above the whiteboards. The system is capable of independently presenting images on both systems from a Mac or a Windows 95 PC, from a VHS VCR, from a Video Presenter (visualizer), from an auxiliary PC or Mac, and from an auxiliary video source. Audio from any of these sources can be played through a high performance audio system. All of the equipment is housed in the lectern which also includes a built-in monitor that can also display any of the various sources. The A/V system is controlled from a small LCD touchpad control unit that can be moved about on the top of the lectern at the convenience of the speaker. The table below, summarizes the existing A/V equipment.

**Design Lab A/V Equipment Specifications**

<b>Item</b>	<b>Description</b>
Projectors	Dual Sharp XG-1100E LCD projectors (500 ANSI Lumens); 640x480 pixels.
Computers	Macintosh 7600/120 with 16 Mb memory, 1 Gb disk, CD; also includes a 100 MHz Pentium co-processor board with 16 Mb memory running Windows 95.
VCR	Panasonic VHS VCR with S-VHS playback capability
Visualizer	Sony Video Visualizer used to generate video display of overhead slides, A size paper copy, textbook pages, or small 3D objects.
Audio	Sony STR-305 75 Watt per channel stereo amplifier driving JBL Control 1 speakers
Aux Input Panel	Lectern mounted panel for connection of auxiliary computers (Mac or PC) or auxiliary video sources (composite or RGB). A scan converter will sync various computer display formats

Control System	Axcnt 1000 control system with matrix switching unit and LCD touch screen control panel
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The Mac/PC computer system located in the lectern can be readily employed to drive either or both projection systems, with the instructor being able to view selected computer or video signals on the lectern monitor. The computers can be used in a variety of ways ranging from simple still image presentations (“slide shows”) or operational demonstrations to “live” simulations or more sophisticated multimedia presentations. Since the computers are fully networked, any source from within the Georgia Tech campus or the worldwide Internet can be employed. Faculty can routinely prepare classroom materials on their office or home systems and upload them to the Design Lab computers for presentation at the next class meeting. Or the instructor can, from the lectern, log on to his/her office or lab computer and download instructional or demonstration software, etc. on-line during the class.

During the Summer Quarter 1997, the Georgia Tech campus instructional video network will be extended into the Design Lab. This will allow reception and presentation of any video channel or channels as needed. In addition, it will be possible to originate video material from this classroom.

This superb A/V facility was designed by a local commercial firm in collaboration with faculty from the School. It is one of only a few such installations on the campus at the present time and has been in service since September 1996. It has been used extensively to support upper division and graduate instruction throughout the past academic year and has been used to great advantage for research seminars, industry speakers and special lectures. All faculty who have used the room have expressed enthusiastic support for the facility. All of the equipment is presently under a full maintenance contract to insure that the greatest use possible is made of this room.

#### Guggenheim Classrooms 244 and 246

These two classrooms are mirror-image facilities located on the second floor of the Guggenheim Building, and they serve as general purpose classrooms seating 50 persons each. The rooms are arranged like the Design Lab with free-standing seats at continuous rows of desks. As with the Design Lab, these classrooms were configured in the renovation process to be able to support a variety of future technologies including network cabling to each seat as well as ceiling mounted A/V and wireless communications equipment. Multilevel room lighting is controlled from the lectern and a full-width whiteboard, a single pull-down screen and an overhead projector are provided for routine classroom lectures and A/V presentations.

Both of these classrooms are being equipped during the Summer Quarter 1997 with full A/V systems that will provide equivalent capabilities to those in the Design Lab, as described above. Due to the smaller size of these classrooms, only a single ceiling mounted projector will be provided, but all other functionality will be provided. The systems will include the equipment shown in the table below.

**A/V Equipment Specifications for Classrooms 244 and 246**

Item	Description
Projector	Sharp XG-1200E LCD projector (500 ANSI Lumens); 600x800 pixels (SVGA).
Computer	Choice of Macintosh 1400c laptop with 16 Mb memory, 750 Mb disk, CD; or a 133 MHz Pentium laptop with 16 Mb memory, 1 Gb disk, CD running Windows 95.
VCR	Panasonic VHS VCR
Visualizer	Optional: the unit from the Design Lab can be connected through the Aux Input Panel if necessary.
Audio	Sony STR-405 75 Watt per channel stereo amplifier driving JBL Control 1 speakers

Aux Input Panel	Lectern mounted panel for connection of auxiliary computers (Mac or PC) or auxiliary video sources (composite or RGB). A scan converter will sync various computer display formats
Control System	Axcent 1000 control system push-button control panel

Current plans are to employ the A/V systems in these classrooms in a similar manner to those used in the Design Lab. The lack of a permanent built-in computer system, and its replacement with the instructor's choice of either a Mac or PC laptop computer, are expected to provide better flexibility, but at a slight loss of convenience and a somewhat greater demand on the support staff. Each classroom is equipped with network connections that will be accessible using laptop computers.

The total cost of the new A/V facilities in these two classrooms is \$31,200. It is anticipated that the availability of this new equipment will eliminate the frustration of many faculty members who have not yet been able to make use of the Design Lab facilities.

#### A. French Classroom 101

Classroom 101 in the A. French Building seats 40 students in a configuration similar to that in Classrooms 244 and 246, as described above. However, the Classroom 101 facilities are over 10 years old and are beginning to show their age along with more obvious wear and tear. The room is equipped with a double-wide whiteboard and an overhead projector. A network port is also available for use with any computing equipment that is brought into the room. The Engineering Computing Support Department in the College of Engineering is housed in this building and can, on request, provide special computer equipment such as a laptop with LCD panel for use with the overhead projector or a small Unix workstation.

#### Conference Room 317, Montgomery Knight Building

Room 317 serves as the primary conference room for the School of Aerospace Engineering and the site for faculty meetings and many irregularly scheduled seminars, thesis presentations and other talks. It is a relatively large room that seats over 30 at a large conference table with seating for an additional 30 around the perimeter of the room. The room is wood paneled and attractively furnished for more formal occasions. At present the room is equipped with only an automatic drop-down screen over a single chalkboard. Either an overhead or 35mm projector can be used, although the process involves locating this equipment directly on the conference table.

During Summer 1997 this room will be outfitted with a new A/V system based on a ceiling mounted projector identical to those being installed in the Guggenheim Building classrooms (see above). Similar A/V source equipment will also be installed. The objective will be to provide capabilities equivalent to those now available in the Design Lab but for a single projector only. The new system will be located in a free-standing lectern connected by an umbilical cable to a wall receptacle and then to the room mounted equipment. The speaker will have access to all of the equipment and full system controls at the lectern. Computer generated presentations will be provided by means of a portable laptop computer (either Mac or PC will be available) that can be conveniently mounted on the lectern. In addition, all of the conference table chairs in Room 317 will be replaced and the perimeter furniture will be upgraded or replaced as part of a general refurbishment of this key facility. Total cost of the renovation and A/V system for Room 317 is \$21,200.

#### Goals and Objectives for Next 5 Years

Classroom instruction will continue to undergo rapid evolution in the coming years as computing and multimedia technologies make their presence felt much more strongly. We are fortunate to have been able to completely renovate 3 of the 4 primary classrooms and to equip them with contemporary A/V systems. The goals and objectives for the next 5 years will be to

sustain this commitment to providing well-proven state-of-the-art instructional equipment in the classrooms.

The basic five-year goals are the following; to:

1. Upgrade the computers and computer software in each room, as necessary, to be able to handle the latest multimedia materials, on-line simulations, etc.
2. Add DVD capabilities if and when this technology surpasses VCR's and conventional CD's.
3. Install local network connections to support student laptop computers if and when they become widely used and/or required.
4. Stimulate the exchange among the faculty of their developing experience and knowledge in the use of software and computing systems in the classroom.

**Plan for Reaching Goals and Objectives**

A plan for achieving the goal and objectives described previously is outlined below. As with the Computing Applications Laboratory equipment plan, achieving funding for this plan involves a deliberate effort to balance internal funding and timely grants from outside the department. These acquisitions are summarized in the following table.

Period	Item	Approximate Cost
<b>1st Year</b>		
	A/V systems maintenance contracts	\$ 1,800
	Additional software	\$ 1,000
	Projector lamps, consumables	\$ 600
<b>2nd Year</b>		
	A/V systems maintenance contracts	\$ 1,900
	Additional software	\$ 2,000
	Projector lamps, consumables	\$ 600
<b>3rd Year</b>		
	A/V systems maintenance contracts	\$ 2,000
	Computer system upgrades (2)	\$ 5,000
	Projector lamps, consumables	\$ 600
<b>4th Year</b>		
	A/V systems maintenance contracts	\$ 2,100
	Local network installation	\$ 15,000
	Projector lamps, consumables	\$ 600
	Software upgrades	\$ 1,500
<b>5th Year</b>		
	A/V systems maintenance contracts	\$ 2,200
	Projector lamps, consumables	\$ 600
	Computer system upgrades (2)	\$ 5,000
	Software upgrades	\$ 1,000

**C. Institutional Support and Financial Resources**

Support for the undergraduate instructional program comes from three sources: (i) State support through the office of the Dean of Engineering, (ii) Support received from the Georgia Tech Foundation in response to curriculum/lab/faculty development proposals, and (iii) Grants from government agencies (e.g. NSF) and industry.

In Table 4, expenditures of the Aerospace Engineering program are given for the past three fiscal years beginning on July 1, 1994. The projected expenditures for the fiscal year beginning July 1, 1997 are also given.

**Table 4. Support Expenditures for Aerospace Engineering (ABET Table 5)**

Expenditure Category	FY95	FY96	FY97	FY98
Operations (1) (not including staff)	\$178,654	\$210,676	\$262,203	\$217,238
Travel (2)	\$22,720	\$13,392	\$25,504	\$39,000
Equipment (3)				
(a) Institutional Funds	\$15,110	\$83,148	\$316,069	\$72,000
(b) (b) Grants and Gifts (4)		\$303,946	\$11,574	\$6,000
Graduate Teaching Assistants	\$318,552	\$273,358	\$173,687	\$196,000
Part-time Assistance (5) (other than teaching)	\$13,899	\$3,002	\$31,561	\$30,000

Notes:

1. Categories of general operating expenses.
2. Institutionally sponsored, excluding special program grants.
3. Major equipment, excluding equipment primarily used for research.
4. Including special non-recurring equipment purchase programs.
5. Not including graduate teaching and research assistnat or permanent part-time personnel.

ABET Criterion 7 states,

*"Institutional support, financial resources, and constructive leadership must be adequate to assure the quality and continuity of the engineering program. Resources must be sufficient to attract, retain, and provide for the continued professional development of a well-qualified faculty. Resources also must be sufficient to acquire, maintain, and operate facilities and equipment appropriate for the engineering program. In addition, support personnel and institutional services must be adequate to meet program needs."*

It is believed that this criterion is met and substantially exceeded in the program of the School of Aerospace Engineering for the following reasons:

1. *The Institute funding level has been steady for the past several years, with a modest cost of living increase, after fluctuations in the number of faculty (retirement, new hires, etc.) are accounted for. Institute support is currently about \$4M per fiscal year (approximately \$140k per faculty member).*
2. *Merit-based increases in salary have averaged around 6 percent for the past two years and a similar raise budget has been authorized for the year ahead. This has been beneficial in retaining highly qualified faculty and staff.*
3. *The Institute and the School of Aerospace Engineering have been very successful in offering competitive starting salaries to new faculty and staff.*
4. *The administrative/academic staff have been sufficient in number, averaging one administrative assistant for four faculty members. The academic office is staffed by two of these administrative assistants. The School's finance affairs are handled by three staff members supervised by a highly qualified financial manager. The School has its own*

instrumentation lab and workshop to address research and instructional needs, staffed by three engineers. Two engineers are in charge of maintaining academic and instructional computing facilities. Mailing, fax, printing and supplies are handled by another staff member. The physical plant is maintained by the Institute from a separate source of funding.

5. As discussed earlier, instructional laboratories are continually up-graded and kept in good condition. A significant portion of the funding for laboratory improvements comes from the Institute either as part of the School's operating budget, or from a Georgia Tech Foundation grants. For example, the Georgia Tech Foundation provided funding for improvements to the Computing labs this year, which permitted purchase of 8 Power PC computers. Funding was also made available for upgrades to structures and fluids laboratories. The Institute has provided funding for the installation of a high speed network within the Montgomery Knight Building during the summer of 1997. The Institute has also rewired all the dormitories so that students have internet access from anywhere on campus. Significant cost sharing to support curricula development and instructional grants received from external sources is also provided by the Institute. For example, significant cost sharing was provided by the Institute and the Georgia Tech Foundation for the Guggenheim building renovation, the NSF-funded SUCCEED program integrating design practices into engineering, and for an NSF supported initiative to upgrade the computing infrastructure in the Guggenheim building.
  
6. The AE faculty have been diligent and have shown creative leadership in securing external funding for laboratory improvements. For example, a grant from NSF (PI: Narayanan Komerath) was used to upgrade the fluid mechanics lab facilities. The multimedia laboratory has been upgraded through grants from NSF (PI: Prof. Kurt Gramoll) and publishers of multi-media texts. The senior capstone design lab, and two class rooms in the Guggenheim building were upgraded in part from an endowment from the Class of 1939. Under an NSF grant (PI: Menon and Craig), the high speed Internet network and research and instruction computing infrastructure were upgraded in the Guggenheim building.

The recent renovation of the Guggenheim Building illustrates how institute support, endowments, and sponsored research may be used to renovate, upgrade and maintain the School of AE facilities.

Georgia Tech State Funds (President's Office) Bd. of Regents	\$ 23,964
Major repair and Rehabilitation Funds	1,319,000
AE Class of 1939 Endowment	142,253
Georgia Tech Class Room Renovation Funds	142,800
National Science Foundation Infrastructure Upgrade Grant	615,000
<b>Total</b>	<b>\$ 2,243,017</b>

In summary, financial support provided by the Institute is sufficient to maintain a high quality instruction program in aerospace engineering.

## Part IV. Processes Information

### A. Educational Objectives

The Educational objectives of the Aerospace Engineering Program are:

1. *To provide our students with a comprehensive aerospace engineering education that includes in-depth instruction in aerodynamics, aircraft and spacecraft structures, flight mechanics, orbital mechanics, flight controls, propulsion and design of aerospace systems.*
2. *To prepare students for careers in AE and related multi-disciplinary fields by: emphasizing essential analysis and problem solving skills, exposing students to open-ended problems and design issues, fostering team work, promoting good communication skills and developing individual professionalism.*
3. *To provide students with adequate research and independent study opportunities that cultivate lifelong learning skills and nourish talents in creative engineering tasks such as research and development.*

#### Constituents:

The constituents of our educational program are: students, faculty, employers of our students - including industry, other universities and government laboratories - and aerospace professional societies. These groups are directly affected by the education given the graduating engineers through our program. At the same time, these groups directly influence the educational program, the curriculum content, and the acceptance of our students in the market place and in the society.

#### Process for the Establishment of Educational Objectives:

Our educational objectives were established in consultation with our constituents. The following process was followed.

1. *A committee of faculty members called the Academic Advisory Council drafted the first version of the Educational Objectives. This committee had representatives from all disciplines within Aerospace Engineering.*
2. *This draft version was circulated to the academic faculty by e-mail. Numerous, constructive suggestions and corrections followed. A typical e-mail correspondence between the faculty on this matter is shown in Appendix C.*
3. *The School of Aerospace Engineering branch of the Sigma Gamma Tau AE honorary society, and the AE School Students Advisory Committee (AESSAC) were consulted on the content of the educational objectives. Appendix C also contains the response from these two bodies of highly gifted students.*
4. *The AIAA and AHS professional societies were consulted. In general, the chairman or the vice-chairman of a committee in charge of educational affairs was contacted. A written response critiquing our educational objectives has been received from Mr. Jack Landgrebe of United Technologies, representing AHS. Appendix C also contains this response.*

5. *Several representatives from government labs and aerospace industries were also invited to critique the educational objectives. Responses have been received from a number of industries and individuals, and these are included in Appendix C.*
  - *Bart Osborne, Vice President, Advanced Concepts, Lockheed-Martin Aeronautical Systems Company*
  - *Perry Bankston, Jet Propulsion Lab*
  - *R. M. Thomas, Chief Engineer (Structures), Boeing Commercial Airplane Group*
  - *Warren Young, Chief of Research, Bell Helicopter Textron*
  - *Leland Nicolai, Lockheed Martin (Skunkworks)*
  - *William Walls, (Retired VP), Boeing Helicopters*

*These representatives agreed with the educational objectives as stated above, and made several useful suggestions for improving the content of the curriculum.*

## **B. Program Outcomes**

The expected outcomes of the undergraduate program have been established by the faculty as follows:

1. *The graduates of the undergraduate program in aerospace engineering will have an understanding of physics, chemistry and mathematics, and how they pertain to solving real world problems.*
2. *They will have a firm understanding of engineering science fundamentals that enables the graduates to examine real world problems for the underlying physical principles, and decide on appropriate methods of solution.*
3. *They will have the ability to analyze and design aerospace structural elements such as trusses, beams and thin walled structures.*
4. *They will have the ability to analyze and design airfoils and wings, accounting for viscous and compressibility effects.*
5. *They will have the ability to analyze and design air-breathing and rocket propulsion systems.*
6. *They will have the ability to analyze the flight dynamics of aircraft and spacecraft, and design flight control systems.*
7. *They will have the ability to work in teams and design complex systems such as aircraft and spacecraft, from a preliminary design perspective.*
8. *They will have good oral, written and graphical communication skills.*
9. *They will be well trained in the role of the engineer in society, and have an awareness of ethical, environmental and quality concerns in the engineering profession.*
10. *They will be trained to be life-long learners, pursuing and interested in independent study, research and development.*

### **Connection between the Educational Objectives and Program Outcomes:**

The first six items in the list of Program Outcomes list the skills the graduates will be expected to have in the areas of science, mathematics, fluid mechanics, propulsion, structures, and flight mechanics and controls. These are directly linked to the first educational objective,

*"To provide the students with a comprehensive aerospace engineering education that includes in-depth instruction in aerodynamics, aircraft and spacecraft structures, flight mechanics, orbital mechanics, flight controls, propulsion and design of aerospace systems."*

The seventh item on the Program Outcomes list deals with the ability of our graduates to work in teams and design complex systems. Our program emphasizes training the students in integrating technologies and systems from a variety of disciplines. This program outcome is linked to our second educational objective,

*"To prepare students for careers in AE and related multi-disciplinary fields by: emphasizing essential analysis and problem solving skills, exposing students to open-ended problems and design issues, fostering team work, promoting good communication skills and developing individual professionalism."*

The last three items on the list of Program Outcomes deal with how our graduates will interact with the technical community, and with the society. To be a fruitful member of society, the engineer must have good oral and written communication skills. He/she must also be aware of and sensitive to ethical, environmental and quality of life concerns. Finally, the engineer is expected to be on the cutting edge of the rapidly evolving field of aerospace engineering. The successful engineer continues to learn, to perform research and improve products throughout his/her career. These expected outcomes link well with the second educational objective above, as well as the third objective,

*"To provide students with adequate research and independent study opportunities that cultivate lifelong learning skills and nourish talents in creative engineering tasks such as research and development."*

### **Material that will be Available During Visit to Demonstrate Achievement of the Program Outcomes:**

During the accreditation visit, the following information will be available to demonstrate that the educational program is achieving the desired outcomes.

1. *Samples of students' work from examinations and home work will be available in the fields of aerodynamics, structures, flight mechanics and control and propulsion. These samples will demonstrate that the students are learning the fundamentals of these disciplines, and have the mathematics, physics, computing and chemistry background needed to excel in these disciplines.*
2. *Capstone Design Project reports will be available, which demonstrate that the students have the ability to work in teams, tackle open-ended design of a complex system such as an aircraft, and communicate well in writing.*
3. *Elective Design Project reports will also be available that show that the students can apply their design experience to a new problem such as the design of an autonomous rotorcraft or an air-breathing engine.*
4. *Representative samples of lab reports, and term papers from AE courses will be available that show that the students have the ability to communicate well in routine circumstances. The lab reports will also demonstrate the students' ability to independently design and conduct experiments, and interpret the resulting data.*
5. *Project reports emphasizing component design (e.g. airfoils, nozzles, control systems) will be available for examination.*

6. *Reports from independent studies and undergraduate research projects will be available for examination. For example, a group of our undergraduate students have designed and demonstrated in full-scale flight tests a technique for manufacturing in space (zero-g), using acoustic streaming to move and line up powdered materials. These and other interesting projects will be presented to the visitor.*

## C. Assessment

ABET Criterion 3 states....

*"Each program must have an assessment process with documented results. Evidence must be given that the results are applied to the further development and improvement of the program. The assessment process must demonstrate that the outcomes important to the mission of the institution and the objectives of the program, including those listed above, are being measured. Evidence that may be used includes, but is not limited to the following: student portfolios, including design projects; nationally-normed subject content examinations; alumni surveys that document professional accomplishments and career development activities; employer surveys; and placement data of graduates."*

Because of the short time period between the publication of the ABET Criteria 2000, and the current self-study, it was not possible to design and implement new assessment processes that exclusively evaluate whether the program expected outcomes are being achieved. However, the School and the College have, over a long period of time, participated in self-assessment studies aimed at continuously improving the quality of education in our School, and periodically seek and receive input from our constituents. The following assessment processes are already in place.

1. Employer/Alumni Questionnaire: The School of Aerospace Engineering, in conjunction with the College of Engineering, recently conducted a survey of aerospace employers, and AE alumni. The Alumni questionnaire is included in Appendix D. The employer surveys request supervisors to evaluate Georgia Tech graduates on their academic background and their performance on the job. Benchmark comparisons with graduates of other universities are also requested. The alumni surveys address the question whether the education received in the aerospace program adequately prepared the graduates for their current positions. The alumni are also asked to rate the service they received as students from the schools and campus organizations (library, computer clusters, student services, etc.).

At this writing, the responses have not been returned in sufficient quantities to process the data. These responses will be available for review during the site visit.

2. Audit Records of Courses Taken and Grades Received: The School keeps academic records of all the students enrolled in the program. Each student is assigned a personal advisor who assists the student in the scheduling of classes, and serves as a mentor. The advisor can also electronically access the records over the web, using a secure, password protected process.

The academic records are used by the advisor, who meets with the student at least once a quarter, and often many times more, to evaluate the following:

- (i) Deficiencies, e.g. 'D' grades in basic courses are quickly identified. The student is advised to repeat the course in a timely fashion. In such an event, the advisor also redesigns the program of study so that the student can complete the course work with minimum disruption.

(ii) The advisor is able to ensure that the pre-requisites are satisfied, and that the work load (e.g. number of course hours) is balanced.

(iii) Gifted students are also quickly identified, and directed towards advanced electives, independent research opportunities (AE 4900-4901-4902), and are also nominated by the advisor for campus-wide internships, scholarships and awards and industry internships.

(iv) Co-op students are advised for two quarters ahead.

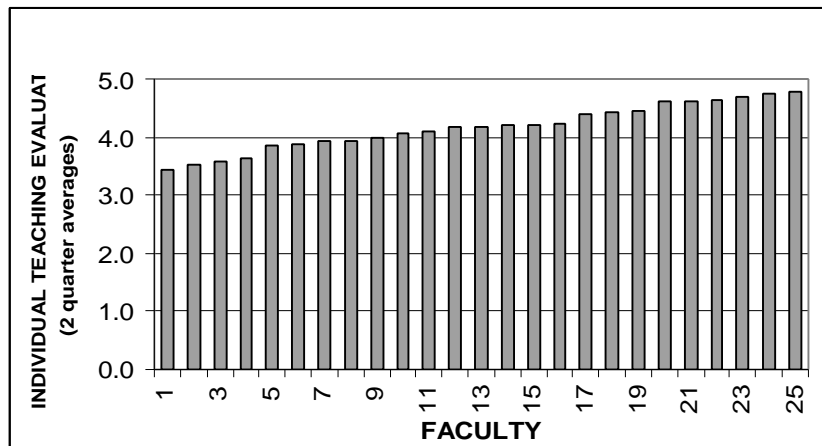
Audit records and transcripts can be examined using SQL queries. It is possible, for example, to track a group of students as they progress through the program, and assess the effects of scheduling choices (e.g. AE 2350, Introduction to Aerospace Engineering taken during Freshman year vs. Sophomore year; Honors Calculus vs. Regular Calculus) on the subsequent academic performance of the student. The electronic databases of transcripts became available only in Winter 1997. As a consequence, these queries have not been implemented at this time, but will be used as a valuable tool in the future.

Data indicating how the audit records of grades and courses taken are used to advise the students will be available during the site visit.

3. Evaluation of Teaching Effectiveness: The School, with the assistance of a campus organization called Center for Enhancement of Teaching and Learning (CETL) conducts a student survey of all courses taught by AE faculty. A sample survey may be found on Appendix D. The surveys are tabulated by CETL and made available to the faculty member teaching the course, and the Chair of the School, within a few weeks following the survey. This survey includes a section where students' can comment on their likes/dislikes about the course, and suggestions for improving the course presentation.

This data is made available in statistical form and as anonymous comments to the faculty member involved, but is further evaluated only by the Chair of the School, as part of an annual faculty performance review. Teachers are often counseled to attend workshops on enhancement of teaching skills, offered the CETL. Many young faculty members benefit from attending these courses, regardless of their evaluation in the student survey.

Typical teaching evaluations by the students of the AE faculty for the Spring 1996 and fall 1996 quarters are shown below. It is seen that more than half of the AE faculty received a score of 4.0 or above (out of a maximum of 5.0), and that the minimum was 3.4 (out of 5.0).

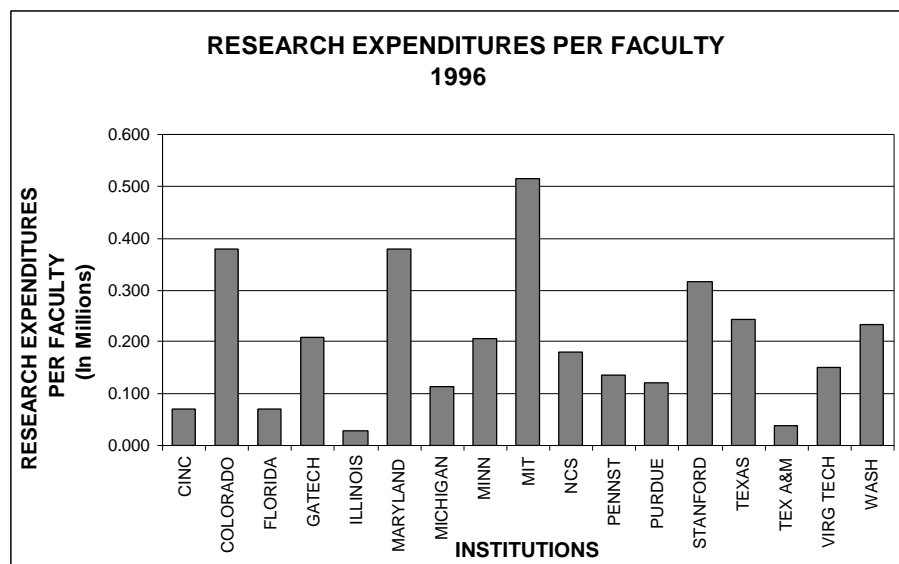
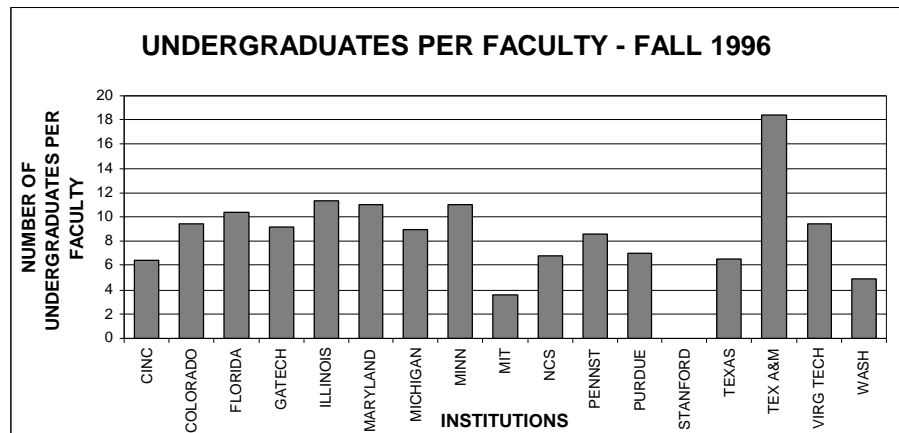
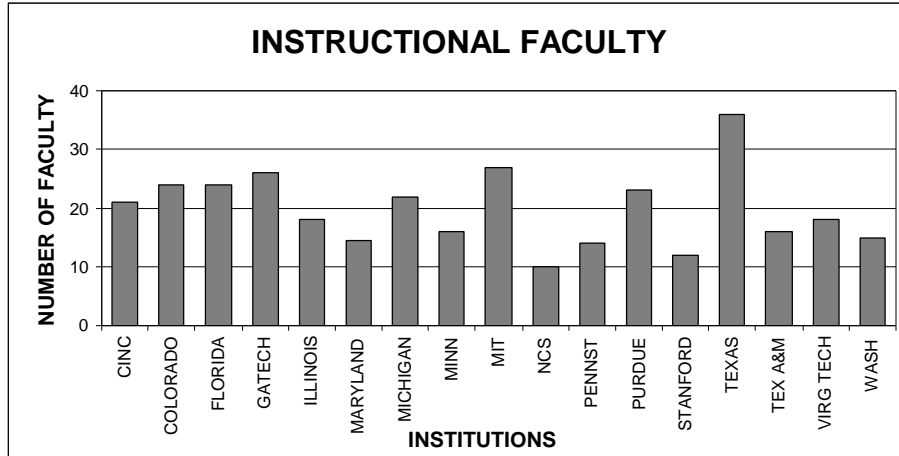


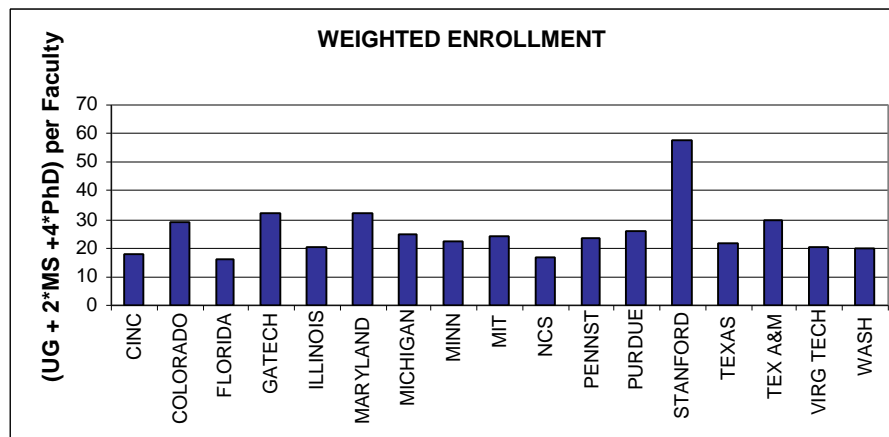
4. Feedback from AE External Advisory Council: The School of Aerospace Engineering is advised by an External Advisory Council. The members of this council come from academia, industry and government. It is presently chaired by Dr. Dan Hartley of Sandia National Laboratories (dhartl@sandia.gov ; Phone: 505-845-9588). This council provides valuable advice and recommendations on issues such as such as undergraduate curriculum content, conversion from the present quarter to a semester system, establishment of educational objectives, expected outcomes, etc. These suggestions and recommendations have been very valuable to the School, and are very seriously considered by faculty and academic administration.

As an example of the role that this council plays in assessing the program, and as an illustration of the mechanism that exists for improving our program based on the Council input, the Minutes of the AESAC conducted on May 2, 1997 are included in Appendix D. It is seen that the council receives input and provides feedback on topics such as astronautics courses, distance learning, undergraduate advisement, multi-media based education etc., to name a few.

5. Feedback from the AE Student Advisory Council: The advice of this council is solicited on all important matters that affect the students' career at Georgia Tech. For example, during the past year, the opinion of this council was sought, and followed on the following topics:
  - i. Aerospace Engineering Educational Objectives
  - ii. Effectiveness of the Advisement Process
  - iii. Semester Curriculum Content
6. Benchmarking against Nationally Ranked and Public Universities: The School of Aerospace Engineering collects, and participates in national benchmark surveys. Our school has established the following list of benchmark institutions. These were chosen to represent a mix of nationally ranked institutions, and state supported universities:
  - i. Cal Tech
  - ii. University of Cincinnati
  - iii. University of Colorado at Boulder
  - iv. University of Florida
  - v. University of Illinois at Urbana-Champaign
  - vi. University of Maryland
  - vii. University of Michigan
  - viii. University of Minnesota
  - ix. MIT
  - x. North Carolina State University
  - xi. Penn State University
  - xii. Purdue
  - xiii. University of Southern California
  - xiv. Stanford University
  - xv. University of Texas at Austin
  - xvi. Texas A&M University
  - xvii. VPI
  - xviii. University of Washington

Data is collected on number of faculty, undergraduate and graduate enrollment, undergraduates-to-faculty ratio, Bachelors' /Masters'/ Ph.D. degrees awarded per faculty, research expenditures per faculty, etc. Representative charts from collected data are shown below.





This data is used to improve the educational program both at the graduate and undergraduate level as follows:

1. *Weakness in an area - e.g. low undergraduate or graduate enrollment, high student to faculty ratio - is identified and corrective action taken.*
2. *This data is used to balance the dual role of the as educators and researchers. The School's mission is to excel in undergraduate education, as well as graduate studies/research. Data such as faculty per capita sponsored funding, and the weighted number of students advised by the faculty member are used as we strive for a balance in these two important activities.*

### Other Metrics:

The following additional metrics are used to assess the educational program.

1. *External reviews and National Rankings are collected and analyzed.*
2. *Data on number and amounts of endowments, fellowships and scholarships available to support students' education are collected and analyzed.*
3. *ABET Accreditation reviews and reports are maintained.*
4. *A record of the number of teaching awards given to the AE faculty is kept.*
5. *Data on the number of students who pursue graduate studies are kept.*
6. *Student employment status following graduation is collected, and a data base is maintained.*
7. *Industry recruiters are interviewed, as their schedules permit, to receive their opinions of the strengths and weaknesses of our graduates, and their suggestions for improving our curriculum.*

Analysis is done by the Chair of the school in collaboration with a Faculty Committee (e.g. the Academic Advisory Council, Faculty Honors-Awards Committee, Graduate Committee), as the data is collected. The data is used by the School to assess the success of the undergraduate program and of our graduates.

When one or more of these metrics indicate a decline in the quality of a particular program, corrective actions are immediately taken. As an example, it was observed that a sufficient number of graduates do not receive NSF graduate fellowships. The reasons were examined. It was found that such fellowships are based at least in part on the student's interest in graduate research and his/her track record in undergraduate research. The School and the faculty increased their effort in enrolling students in independent study and undergraduate research programs (e.g. AE 4900, 4901 and 4902). The Institute initiated an undergraduate research internship program, where rising seniors receive scholarships to pursue undergraduate research.

## New Assessment Processes:

Over the next several years, the existing survey instruments, and assessment processes will be modified so that they specifically assess the program outcomes. We plan to implement the following assessment processes in the near future.

Exit Surveys: In the past, the School has collected input from graduating students through oral interviews at the time the degree petition is reviewed, and during the quarterly advisement process. During the next year, the following formal process will be implemented:

1. *Graduating seniors will fill out an exit survey. Three modes of collecting this data are being considered: over the web, administration of survey forms through AESSAC, and interviews of the students by their faculty advisors. One of these three modes will be selected and implemented. The resulting data will be on file in the academic office, and available for an analysis by academic administration and to interested faculty.*
2. *The Academic Advisory Council, a faculty committee made of representatives from the discipline committees will evaluate the collected data on a quarterly basis. The minutes of the Council will be distributed to the academic faculty through e-mail. The Council will periodically bring recommendations for improving the program to the faculty for vote.*
3. *Graduates who have participated in the survey, and are interested in any actions taken will be notified on an annual basis.*

Portfolios: The faculty of the School of Aerospace Engineering periodically collect samples of student work for two purposes: for examination by ABET visitors, and for electronic archiving of documents in the central library. These archival documents are available to students and faculty alike. In general, this collection will not exclusively contain a single student's complete work, and is not a true portfolio.

During the next two years, this process will be revised for outcome assessment purposes as follows:

1. *Portfolios of several students (typically 10 per class, from an entering class of 75 freshmen) will be collected. These students will be notified, be able to periodically review the contents of their portfolios, and may request their work to be removed from this collection. It will include their projects, term papers, computer programs, capstone design, independent study reports and their class work from math and science courses.*
2. *As part of the curriculum revision activities, the faculty will examine the portfolios to determine if the students are learning the skills spelled out in the expected outcomes, and to determine if these are the right set of skills required in the market place. Appropriate changes will be made to the assignments and course content based on this evaluation.*



## Part V. Accreditation Summary

In this section, we examine ABET criteria one by one, and discuss how the present program meets these criteria. Since much of the data and discussions related to the facilities, faculty, curriculum and the processes have been presented in detail in the previous four sections, this section only summarizes how the criteria are satisfied.

### A. Students

Criterion 1 states

*“The quality and performance of the students and graduates is an important consideration in the evaluation of an engineering program. The institution must evaluate, advise, and monitor students to determine its success in meeting program objectives.”*

The program has in place several processes for advisement, and outcomes assessment. The processes in place for outcomes assessment (e.g. alumni/employer survey, exit survey of students, benchmarking of the program against national institutions) were described previously. Here we discuss the processes in place for advisement, and mentoring/monitoring the students.

The School of Aerospace Engineering at Georgia Tech has a tradition of providing academic advising to every one of the students, undergraduate and graduate alike. The School has always required that our students speak with a faculty advisor each quarter before scheduling the following quarter's courses; registration is “frozen” until advisors “sign-off” has been obtained.

In the fall quarter of 1996, the advisement process was further improved when each student was assigned to a permanent advisor. This change was primarily in response to student opinion expressed through surveys in the School of Aerospace Engineering and the College of Engineering. The students like the idea of having one advisor for their entire time as undergraduates in aerospace engineering.

In implementing the new system, every full-time faculty member was given the responsibility of advising and mentoring a group of students until the students graduated. The number of students per faculty member varies with other responsibilities, and provisions exist for changing advisors if requested and updating the advisee lists as new students enter the School and old students leave.

Because all faculty members are now involved in academic advising, training sessions were provided for those faculty who were new to advising. Appendix E contains copies of the following material presented to each advisor. Many of this information is also available to the students and the faculty over the web at the site :  
<http://www.ae.gatech.edu/undergraduate> .

- *Notes for AE Undergraduate Academic Advisors*
- *Catalog differences since 1992*
- *Tentative scheduling of AE required courses*
- *Tentative scheduling of AE elective courses*
- *List of AE electives*
- *Sample credit sheets, with illustration of use*
- *Sample credit sheet flow charts, with notes and illustration of use*
- *Copy of a Georgia Tech transcript*
- *Example of notice to students concerning academic advisement*

- *Memoranda covering issues of potential interest to advisors*
- *Sample forms which advisors are sure to see*
- *Course listing form used for academic advisement*

It may have been noted that there are both credit sheets, which simply list the curriculum quarter by quarter, and credit sheet flow charts. Each advisor is free to use the method of his choice to record student progress, and, indeed, some advisors have devised their own procedures.

Academic advisement for the following quarter is conducted over a three-day period specified by the Institute. Of course, students are free to see their advisors at other times of mutual convenience. The only requirement is that advising should be completed by the end of the official advisement period so that each student is ready to begin course registration.

The procedure for academic advisement is typically as follows. The advisor and the student contact each other by e-mail to set up an appointment for advisement. The student first stops at the AE Academic Office and picks up his academic records which are maintained in that office. The student then completes as much of the course listing form as is possible and reports to the advisor. The advisor will probably record the preceding quarter grades and then, if necessary, help the student complete the schedule form, with due regard to the student's needs and the availability of courses. At the end of the advising session, the advisor signs the schedule form which is then returned to the Academic Office.

Students might also see their advisors at other times during the quarter. For example, the form for dropping a course requires advisor signature so that the advisor does have the opportunity to attempt to dissuade a student from a particularly ill-advised drop. Also, the student is strongly encouraged to see his advisor about almost any problem that arises in his life at Georgia Tech, and for counseling on graduate studies, career choices, etc.

Student feedback on this new advisement process has been collected, although to date this has been largely anecdotal. The Aerospace Engineering School Academic Council, an external body of advisors from Academia, Industries and Government met with the students on May 2, 1997, and discussed with the students their impressions of the advisement process. A very positive feedback was received.

A formal process with the intent of further improving the academic advisement procedure is also being implemented. A questionnaire for evaluating the updated Academic Advisement process has been prepared, and will be distributed to students, beginning in fall 1997. Data from the survey will be used by the faculty member in charge of advisement (Prof. Virgil Smith) and the School Chair to discern weaknesses and allow for continuously improving advisement.

## **B. Program Educational Objectives**

The requirements for Program Educational Objectives are specified in Criterion 2, which states that:

*“Each engineering program for which an institution seeks accreditation or re-accreditation must have in place*

- a. detailed published educational objectives that are consistent with the mission of the institution and these criteria*
- b. a process based on the needs of the program's various constituencies in which the objectives are determined and periodically evaluated*
- c. a curriculum and process that ensures the achievement of these objectives*
- d. a system of ongoing evaluation that demonstrates achievement of these objectives and uses the results to improve the effectiveness of the program.”*

The AE undergraduate program has met this criterion. It has an established list of educational objectives. These objectives were established by formal consultation with our constituents, i.e. faculty, students, industries/employers, and professional societies. The curriculum adequately addresses the disciplinary topics cited in the objectives. The curriculum stresses design of complex aerospace systems, as established in the objectives. The curriculum also provides independent study opportunities, and is designed to cultivate in the student a desire for life-long learning. Thus, the curriculum is in harmony with the established educational objectives.

A process of ongoing evaluation is present. The faculty, in consultation with our constituents, and through substantial participation in AIAA, AHS and ASEE and other forums, monitor emerging and new aerospace technologies and offer electives and independent study opportunities in these areas. Areas of importance to the industry, e.g. CAD, manufacturing, and integrated product and process development (IPPD) are also addressed in the curriculum as electives, and as graduate specialty areas. The objectives themselves are viewed as long term goals, and will change only gradually from year to year.

### **C. Professional Component**

ABET Criteria state:

*Criterion 3:*

*“Engineering programs must demonstrate that their graduates have*

- a. an ability to apply knowledge of mathematics, science, and engineering*
- b. an ability to design and conduct experiments, as well as to analyze and interpret data*
- c. an ability to design a system, component, or process to meet desired needs*
- d. an ability to function on multi-disciplinary teams*
- e. an ability to identify, formulate, and solve engineering problems*
- f. an understanding of professional and ethical responsibility*
- g. an ability to communicate effectively*
- h. the broad education necessary to understand the impact of engineering solutions in a global and societal context*
- i. a recognition of the need for, and an ability to engage in life-long learning*
- j. a knowledge of contemporary issues*
- k. an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.”*

*Criterion 4. Professional Component*

*“The Professional Component requirements specify subject areas appropriate to engineering but do not prescribe specific courses. The engineering faculty must assure that the program curriculum devotes adequate attention and time to each component, consistent with the objectives of the program and institution. Students must be prepared for engineering practice through the curriculum culminating in a major design experience based on the knowledge and skills acquired in earlier coursework and incorporating engineering standards and realistic constraints that include most of the following considerations: economic; environmental; sustainability; manufacturability; ethical; health and safety; social; and political. The professional component must include*

- a. one year of a combination of college level mathematics and basic sciences (some with experimental experience. appropriate to the discipline*

- b. *one and one-half years of engineering topics, to include engineering sciences and engineering design appropriate to the student's field of study*
- c. *a general education component that complements the technical content of the curriculum and is consistent with the program and institution objectives."*

The present program meets and exceeds these criteria in the following specific ways:

1. *The graduates receive in-depth instruction in mathematics, physics and chemistry. They apply this knowledge in their upper division, and in capstone design courses.*
2. *The laboratory courses are designed to encourage independent design of experiments and interpretation of data. Students receive training in interpretation of data, analysis and visualization of results, and in defending the conclusions of the experiments through oral and written presentations.*
3. *The capstone design courses and the electives on component design offer ample opportunities for the students to design complex systems, work in teams, and perform trade-off studies.*
4. *The capstone design courses train the students to work in multidisciplinary teams.*
5. *In the discipline-specific courses, and in CAD courses, many examples and applications are covered, and these teach the student not only to analyze, but also to design components, and to solve engineering problems.*
6. *Professional and ethical responsibility is emphasized from the very first course titled "Introduction to Aerospace Engineering" to the capstone design courses, using examples of accepted professional and ethical behavior, and stressing the responsibility of the engineer to society.*
7. *The laboratory courses, the capstone design courses, and professional society activities encourage development of oral and written communication skills. Many courses also require literature surveys and term papers. Formal instruction in technical writing and computer graphics is given.*
8. *While in-depth instruction in AE topics is required, the curriculum has provision for breadth and does not neglect any of the important disciplines underlying engineering practice. Courses on engineering science, graphics, mechanics, thermodynamics, electrical engineering and material science all broaden the student's perception of engineering, and train the student to tackle engineering problems in a global and societal context.*
9. *Life-long learning is emphasized through electives, independent study opportunities, covering historical aspects emphasizing continuous change, and numerous internships and fellowships.*
10. *Knowledge of contemporary issues is encouraged by offering seminars in aerospace and engineering fields, through field trips to industries, and by strongly encouraging participation in professional society activities.*
11. *The students get ample opportunity to use state of the art computers and operating systems, modern measurement tools and modern analysis tools such as CAD systems, simulators and computational analysis and simulation software, and visualization tools.*

The professional component exceeds the AIAA Criteria and ABET Criterion 4. The credit hours of math and science courses (64 quarter hours) exceed the requirement of 48 quarter hours. The engineering topics require 90 hours of instruction, which exceed ABET requirement of 72 hours. The general educational component (36 hours of humanities and social sciences) and the free electives (15 hours) are consistent with the program and the institution objectives.

#### **D. Program Outcomes and Assessment**

ABET criterion 3 states

*"Each program must have an assessment process with documented results. Evidence must be given that the results are applied to the further development and improvement*

*of the program. The assessment process must demonstrate that the outcomes important to the mission of the institution and the objectives of the program, including those listed above, are being measured. Evidence that may be used includes, but is not limited to the following: student portfolios, including design projects; nationally-normed subject content examinations; alumni surveys that document professional accomplishments and career development activities; employer surveys; and placement data of graduates.*

*The institution must have and enforce policies for the acceptance of transfer students and for the validation of credit courses taken elsewhere. The institution must also have and enforce procedures to assure that all students meet all program requirements.”*

The Program Expected Outcomes have been established in consultation with the faculty. The assessment involves collecting data and feedback from benchmark institutions, from the student advisory council, from the School’s external advisory council, from the student courses/grades data base, placement data and from employer/alumni questionnaires. This data is periodically examined by the Chair of the School, in consultation with faculty, to make adjustments to the program. Several examples of how this data is used to change the programs and policy were cited in the previous section dealing with assessment.

The Institute has established, publicized policies for the acceptance of transfer students and for the validation of courses taken elsewhere. These are given in the Institute Self-Study document. Student degree petitions are reviewed by the faculty advisor, by the Assistant to the Chair of the School (Prof. Virgil Smith), and ultimately by the Registrar's office, to ensure that all School and Institute requirements are satisfied.

## **E. Faculty**

ABET criterion 5 states

*“The faculty is the heart of any educational program. The faculty must be of sufficient number; and must have the competencies to cover all of the curricular areas of the program. There must be sufficient faculty to accommodate adequate levels of student-faculty interaction, student advising and counseling, university service activities, professional development, and interactions with industrial and professional practitioners, as well as employers of students.*

*The faculty must have sufficient qualifications and must ensure the proper guidance of the program and its evaluation and development. The overall competence of the faculty may be judged by such factors as education, diversity of backgrounds, engineering experience, teaching experience, ability to communicate, enthusiasm for developing more effective programs, level of scholarship, participation in professional societies, and registration as Professional Engineers”*

The AE faculty are sufficient in number (28 full time), with a low student to faculty ratio. (9 students/faculty). Each student is advised by a single faculty advisor, from freshman year through senior year. The faculty have substantial interactions with industry and government and professional societies through their consulting and research, and are able thereby to better assist the students in their professional development.

As described in Appendix B, the AE faculty are well qualified and are leaders in their chosen disciplines who come from a diversity of backgrounds. They are nationally recognized as Fellows, members of National Academy of Engineers, as editors of journals and as authors of text books. All the disciplines (fluids, structures, dynamics and aeroelasticity, propulsion, flight mechanics and control, and design) are adequately represented by the faculty.

## **F. Facilities**

Criterion 6 states

*"Classrooms, laboratories, and associated equipment must be adequate to accomplish the program objectives and provide an atmosphere conducive to learning. Appropriate facilities must be available to foster faculty-student interaction and to create a climate that encourages professional development and professional activities. Programs must provide opportunities for students to learn the use of modern engineering tools. Computing and information infrastructures must be in place to support the scholarly activities of the students and faculty and the educational objectives of the institution."*

As discussed in the section on resources, the fluids, propulsion, structures, controls and computing laboratories, and the class rooms are adequate in size, configuration and equipment to provide instruction to students in small groups, and to encourage design of experiments. The design lab facilities in the newly renovated Guggenheim Building are state of the art. Computing facilities within the school and the campus facilities (Cray Y/MP EL, IBM SP-2, SGI Origin 2000, CAD and workstation clusters) are all linked by a high speed network, and are accessible to the student from anywhere on campus. These facilities connect the student to outside databases and encourage scholarly activities of the students and the faculty alike.

## **G. Institutional Support and Financial Resources**

Criterion 7 states

*"Institutional support, financial resources, and constructive leadership must be adequate to assure the quality and continuity of the engineering program. Resources must be sufficient to attract, retain, and provide for the continued professional development of a well-qualified faculty. Resources also must be sufficient to acquire, maintain, and operate facilities and equipment appropriate for the engineering program. In addition, support personnel and institutional services must be adequate to meet program needs."*

As stated in the section on resources, the School receives approximately \$4M annually in institutional funds (\$140k per faculty). This is augmented by research activities which, including new equipment purchases, exceed \$5M per year. The administrative assistants (one each for four faculty), research engineers in charge of maintaining the computer infrastructure, the instrumentation lab and workshop technicians, and the business office staff are adequate in number to carry out all the operations of the educational program. Additional funding in the form of endowments, instructional research grants, and allocations from the Board of Regents have been available in the past for capital expenditures. It is anticipated that this manner of funding will continue.

## **H. Program Criteria**

AIAA Program criteria state:

*1. Faculty*

*Faculty teaching upper division courses must demonstrate an understanding of current professional practice in the aerospace industry to develop and deliver an educational program that is consistent with appropriate program objectives. It must further demonstrate that those faculty associated primarily with the aerospace or similarly named program have sufficient curricular and administrative authority to define, revise, implement, and achieve appropriate program objectives.*

*2. Curriculum*

(a) *Engineering Topics*

*Aeronautical engineering graduates must demonstrate a knowledge of aerodynamics, aerospace materials, structures, propulsion, flight mechanics, and stability and control.*

*Astronautical engineering graduates must demonstrate a knowledge of orbital mechanics, space environment, attitude determination and control, telecommunications, space structures, and rocket propulsion.*

*Aerospace engineering graduates or graduates of other engineering programs combining aeronautical engineering and astronautical engineering must demonstrate knowledge covering one of the areas - aeronautical engineering or astronautical engineering as described above in addition must demonstrate knowledge of some topics from the area not emphasized.*

(b) *Engineering Design*

*Graduates must demonstrate proficiency in the design process to include performing tradeoffs and achieving compromises necessary to meet stated design objectives covering a broad spectrum of the topics enumerated in (a)."*

The current program meets these program criteria as follows:

- 1. The AE faculty are sufficient in number to carry out the program. As demonstrated in the curriculum vitae (Appendix B) the faculty have an understanding of current professional practices in aerospace industry. A faculty committee known as the Academic Advisory Council has been given sufficient curricular and administrative authority to define, revise, implement, and achieve the undergraduate program objectives.*
- 2. The curriculum provides in-depth coverage of all discipline topics including aerodynamics, propulsion, flight mechanics and control, structures, dynamics, aeroelasticity and design. Topics in astronautics are covered in required courses. The students are also required to take a course on orbital mechanics, or spacecraft attitude dynamics.*
- 3. A two course sequence on design of complex systems is required in the program. Students undertake a major design project, and learn tradeoffs needed to meet the design objectives. They also learn to work as multidisciplinary teams. They learn to effectively use graphics, and to produce project reports and oral presentations to communicate the results of their design efforts. Additional courses on design for life-cycle cost, a graduate course sequence on spacecraft design which may be taken by undergraduate students with a good GPA, and numerous self-study courses give students still further opportunities to learn and implement industry design practices.*