Keeping Students Engaged: An Overview of Three Introductory Courses in Aerospace Engineering

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Abstract

The traditional approach of teaching major-specific courses beginning in the first or second semester sophomore year has many drawbacks that could lead to stifling student's enthusiasm and interest in his/her field of study and very often to the loss of many talented students to other programs. To alleviate this problem and to keep students engaged and interested in their chosen discipline, the Department of Aerospace Engineering at Mississippi State University began a major overhaul of its undergraduate curriculum in fall 1994 which, among many changes, led to the creation of three freshman/sophomore "Intro-to-ASE" courses. While providing an overview of the curriculum and activities conducted in each course, this paper discusses students' and instructor's assessments of effectiveness of these courses and highlights apparent successes and remaining challenges.

I. Introduction and Background

Although many factors influence a student's selection of a particular major in college, experience seems to indicate that most entering freshmen have very limited knowledge or a skewed understanding of what their chosen disciplines entail. Without the guidance offered by introductory courses, engineering students run the risk of either staying one or two years in a major they will eventually dislike or quickly losing interest in their field of study as a result of taking all the seemingly unrelated math and physics courses.

To help their entering freshmen learn more about engineering in general and its various disciplines in particular, some schools offer a common freshman experience through the use of first-year introduction to engineering program[1] while others have taken steps to offer introductory courses in their respective disciplines.[2,3]

Similar to some of the other aerospace engineering programs in the country before it[4], the Department of Aerospace Engineering (ASE) at Mississippi State University (MSU) recognized the need for restructuring its curriculum in part to modernize its undergraduate program and increase enrollment which had begun to decline rapidly since 1990 following nearly a decade of steady growth as indicated in Fig. 1. This decline in enrollment was in most part a reflection of career opportunities available to ASE graduates and was not necessarily unique to MSU. In fact, Mississippi State University is on par with the national average[*] in the percentage of entering freshmen choosing ASE as a major (1.8% compared to national average[5] of 1.6%), the percentage of engineering BS degrees awarded to ASE majors (2.25% compared to the national average[6] of 2.2%), and has exceeded the national average in recent years in the fraction of ASE BS degrees awarded to women (25% compared to national average[7] of 20%).

[*] We used 2000-2001 data as the data available for previous years lumped the aerospace and mechanical engineering programs together.

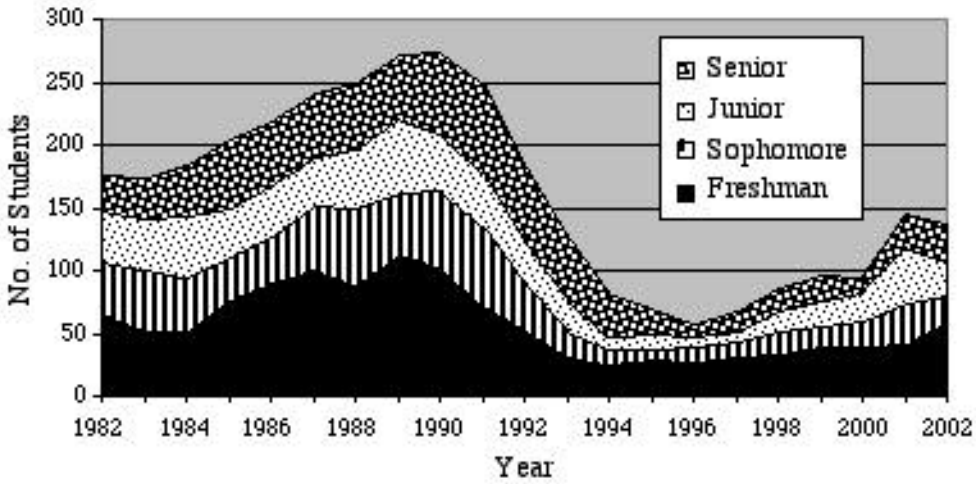

Fig. 1 ASE enrollment trend at MSU during the period from fall 1982 to fall 2002

Following a leadership transition in the department in 1991 and a successful ABET accreditation visit in 1993, a committee consisting of the department head and a select group of ASE faculty members was formed to develop a plan to address such issues as curriculum modernization, computer application in teaching and learning, ABET 2000 criterion 3 goals (Table 1), and most importantly, attraction and retention of students. Three subcommittees were formed with each given the task of revising courses in one of three major curriculum areas: flight mechanics, aerodynamics, and structures. A separate subcommittee was formed to develop the curriculum for the three new "Intro-to-ASE" courses.

Table 1. ABET 2000 Criterion 3 - Program Outcomes and Assessment

(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.

A new curriculum map was developed in 1994, ASE departmental goals and objectives were approved in 1997, and proposals for new or revised courses were submitted to the University Courses and Curricula Committee for approval in 1998. In 1997, the college of engineering at MSU voted to have the 1999 ABET accreditation be conducted under ABET 2000 criteria and in fall 1999 instituted the policy requiring each entering freshman to own a personal computer. In the same semester, the ASE department began to offer the first freshman-level introductory

course (e.g., ASE 1013) on an experimental basis and gradually transitioned to the new curriculum with the entering freshman class in fall 2000. The old and new curricula are listed in Table 2 below. As a result of the curriculum revision, the total credit hours required for BS degree in ASE was also reduced from 139 to 134 hours.

Table 2. Comparison of the old and new ASE curricula

Year	Old curriculum		New curriculum	
	Fall semester[a]	Spring semester	Fall semester	Spring semester
Freshman				
	Chemistry (3)	Speech (3)	**ASE 1013** (3)	**ASE 1023** (3)
	Chemistry lab (1)	Physics I (3)	Chemistry (3)	Physics I (3)
	Calculus I (3)	Calculus II (3)	Chemistry lab (1)	Calculus II (3)
	Graphics[b] (3)	Social science (3)	Calculus I (3)	Social science (3)
	English comp I (3)	English comp II (3)	English comp I (3)	English comp II (3)
	Humanities (3)	Humanities (3)	Humanities (3)	Humanities (3)
Sophomore				
	FORTRAN[b] (1)	Flight mech. I[b] (3)	**ASE 2013** (3)	Speech (3)
	Statics (3)	Dynamics (3)	Statics (3)	Dynamics (3)
	Linear algebra[b] (3)	Diff. equations I (3)	Calculus III (3)	Diff. equations I (3)
	Calculus III (3)	Calculus IV (3)	Physics II & lab (3)	Calculus IV (3)
	Physics II & lab (3)	Physics III & lab (3)	Social science (3)	Physics III & lab (3)
	Social science (3)	Tech writing (3)	Fine arts (3)	Mech. of materials (3)
	Fine arts (3)			
Junior				
	Gas dynamics (3)	Flight mech. II (3)	Aero-thermo (3)	ASE lab I (3)
	EE systems (3)	Structures I (3)	Structures I (3)	Static stability (3)
	Mech. of materials (3)	Inc. aerodynamics (3)	EE systems (3)	Structures II (3)
	Fluid mechanics (3)	Electronics (3)	Fluid mechanics (3)	Inc. aerodynamics (3)
	Vibrations (3)	Electronics lab (1)	Tech writing (3)	Vibrations (3)
	Diff. equations II[b] (3)	Heat transfer (3)	Free elective (3)	
Senior				
	Structures II (3)	Propulsion (3)	Dynamic stability (3)	Propulsion (3)
	ASE lab I (3)	ASE lab II (1)	Astrodynamics I (3)	Tech elective (3)
	Flight mech. III (3)	Structural design (3)	Com. aerodynamics (3)	Tech. elective (3)
	Com. aerodynamics (3)	Sys. design (3)	Structures III (3)	Math/sci. elective (3)
	Astrodynamics I (3)	Tech elective (3)	ASE sys. design I (3)	ASE sys. design II (3)
	Tech elective (3)	Free elective[c] (3)	ASE lab II (1)	

[a]Credit hours shown inside parentheses.
[b]Courses eliminated from the curriculum.
[c]Free elective is chosen from available humanities, social science, or fine arts courses.

The three "Intro-to-ASE" courses described in the subsequent sections of this paper are a direct outcome of the curriculum restructuring effort that began in 1994 with the goal of complying with the ABET 2000 criterion 3 (Table 1) and fulfilling among many the following broad learning objectives:

1. Provide an opportunity for application of fundamentals of mathematics, basic physical sciences, and engineering sciences to problems in aerospace engineering.
2. Allow students to exercise analytical and problem-solving skills and become more proficient in the use of techniques and tools of aerospace engineering on applied problems.
3. Encourage development of design skills in problem solving and experimentation, illustrative of various fundamental areas of aerospace engineering.
4. Enable students to develop proficiency in written, oral, and graphic communication in the development of formal reports, and informal and formal individual presentations and papers.
5. Promote engineering ethics, personal integrity and responsibility and professionalism in the conduct of laboratory activities and individual projects.
6. Develop teamwork and leadership skills through laboratory experiences.

Because of the number, scope, and diversity of topics and related activities, we sought to spread the curriculum over three semesters as opposed to one done elsewhere[4]. Each course combines elements of classroom instruction with hands-on laboratory activities for a period of six hours a week and is taught by a different instructor, often with significant support from a number of graduate and undergraduate teaching assistants and laboratory staff. At the time of this writing, each of these introductory courses has been taught at least three times, thus, providing some experience on which this paper is based.

II. ASE 1013: Introduction to Aerospace Engineering

This introductory course is offered to first semester freshman students. Topics covered in this course include flight vehicle specifications; aircraft components; aerodynamics; flight mechanics; computer essentials including the use of Microsoft Office and Mathcad; and computer-aided design with Unigraphics. In addition, students are introduced to departmental educational and research facilities located on and off-campus.

A traditional textbook is not used because there is not one currently available that fits well with the topics and activities of the course. Instead, a custom-made booklet provides a reference for the students. The booklet contains the following sections:

- Flight Vehicles: A Sampling for ASE 1013 Introduction to Aerospace Engineering
- Business Aircraft: A Reasonably Complete Listing of Business Aircraft Currently in Production
- Gulfstream IV Detail Specification
- NACA Airfoils: A Small Assortment of Amazingly Antique but Uncommonly Useful Airfoils
- U.S. Standard Atmosphere

ASE 1013 has three main components. It provides an overview of flight vehicles and flight, training in engineering software, and development of teamwork and communication skills reinforced by laboratory activities. These components are addressed essentially in parallel, with activities related to at least two components occurring at almost every class meeting throughout the semester. Some activities take place through structured classes. Others include computer or laboratory activities that are carried out by the students themselves. A team of more than ten

faculty, staff and student assistants works directly with the class in order to guide and conduct these activities.

The class meets in the afternoon two days a week for three hours each day. Because of the large number of students involved, the class is divided into smaller groups, and the groups are rotated among activities. All students receive software training for approximately one hour each day. The remaining time is used for overview and/or teamwork activities. The overview lessons occur during the first and last four weeks of the semester. Teamwork activities take place during the middle six weeks.

II.1 *Overview of Flight Vehicles and Flight*

Many of the new students have very little idea of what flight vehicles are actually like. During the first four weeks of class, a considerable amount of time is spent discussing airplanes. The goal is to instill in students' minds a sense of the sizes, capabilities, and costs of flight vehicles. For example, the similarity between a Cessna 172 and a Honda Civic, in terms of weight, interior size, power and performance (but not list price!) is noted. Such comparisons are helpful to students in relating the abstract (i.e., the airplane) to the ordinary experience with an automobile. On the other hand, the students calculate the planform area of the Gulfstream IV horizontal tail and discover that it is larger than the entire main wing of the Cessna 172.

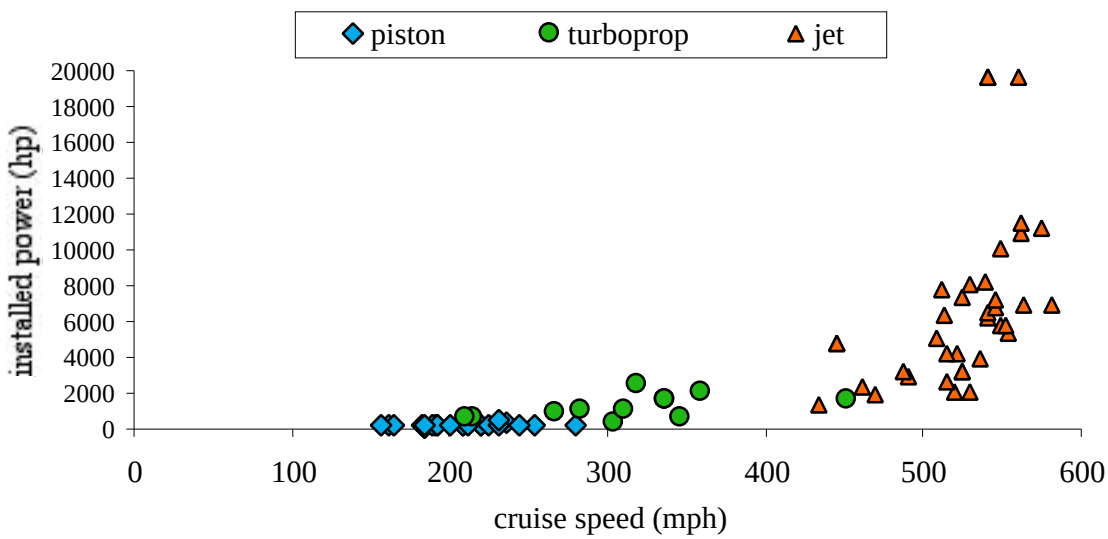

Fig. 2 Aircraft power requirements

People usually associate aircraft with speed. From a spreadsheet of data for over 70 civil aircraft recently or currently in production, the students learn, through plots they make, the enormous costs associated with trying to fly fast. The very rapid increase in installed power, fuel burned and list price as flight speed increases becomes evident to the students through plots such as that shown in Fig. 2.

The students are introduced to Mach number and lift and drag coefficients. The students have ample opportunity to exercise these numbers through homework and quizzes. Basic geometrical and aerodynamic properties of airfoils and wings are also covered.

The class tours the ASE department's Raspet Flight Research Laboratory which operates a fleet of aircraft (shown in Fig. 3) for research, engineering and educational purposes. This tour provides additional insight to the students' understanding of aircraft.

Fig. 3 MSU's Raspet Flight Research Laboratory and its fleet of aircraft

Discussions of the Earth's atmosphere, as well as those of Mars and Venus take place during the last four weeks of the semester. In one exercise, the students obtain current atmospheric data from the National Weather Service for various locations in the US and compare them to the US Standard Atmosphere (Std Atm). An example is shown in Fig. 4 for Jackson, MS (JAN) and International Falls, MN (INL) for a day in late November 2002. The students gain an appreciation of the fidelity and utility of the Standard Atmosphere through activities such as this.

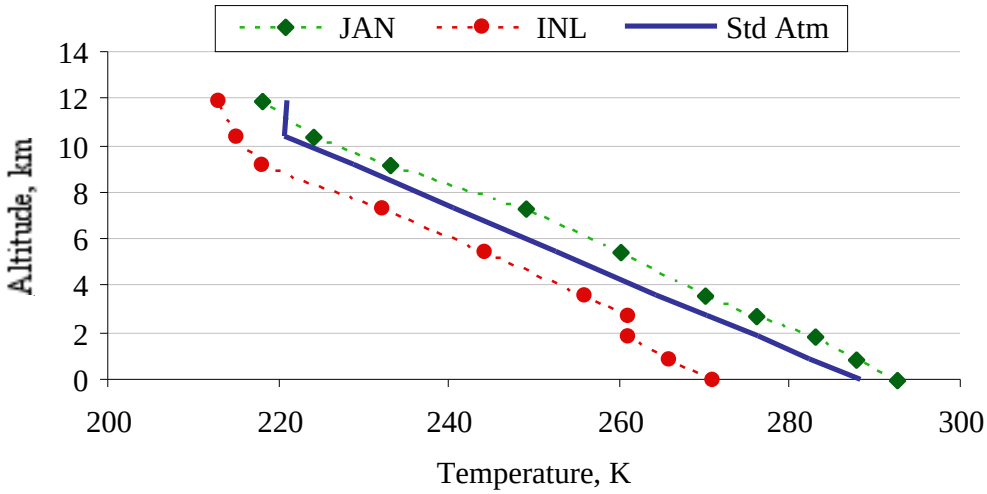

Fig. 4 Comparison of actual atmospheric data with the standard atmosphere model

Helicopters, rockets and satellites are also discussed during the last four weeks. The emphasis is on size and capabilities. Guest speakers are invited to supplement these discussions.

II.2 *Computer Skills*

In ASE 1013, the students are trained in the use of two engineering software programs. Mathcad is taught during the first four weeks with the coverage going as far as basic programming loops. For the remainder of the semester, the software emphasis is on Unigraphics. This instruction advances to the point that the students can create a two-dimensional drawing, import it into the drafting module and dimension it. Three-dimensional drawing is a subject for the next course in this sequence, i.e., ASE 1023. In addition, students with no prior knowledge are given basic instructions in the use of Microsoft Excel, Word, and PowerPoint, which they use in developing their assignment reports and presentation media.

II.3 *Experiential Learning, Teamwork and Communication Skills*

A series of six laboratory activities provides a setting for experiential learning and the development of teamwork and communication skills in the students. The class is divided into groups of four or five students and each group participates in one activity each week. The activities take place on the first day of each week, while report preparation occurs on the second day. Thus, at the end of the six week period all groups will have performed and reported on all six activities.

The activities are designed so that each can be done in 1.5 hours; they are necessarily simple. In that time, the students in any given group must determine what needs to be done, how to do it and what job each person in the group will do. An upperclassman or graduate student oversees or directs each activity. These assistants make sure safety procedures are followed and they provide some instruction and guidance. However, much is left for the students to decide. Report preparation also requires the students to make decisions and organize themselves. The activity directors are available for guidance, but the students are responsible for the substance of the reports. Although the activities are quite simple and the report requirements modest, the limited time available for the students to do the work and report on it forces them to cooperate, communicate effectively, and work as a team.

Each group submits one report for every activity. The reports are submitted once for preliminary evaluation. The students are then permitted to correct the reports and resubmit them for a final grade.

This component of the class has worked remarkably well. The groups have done good work and there have been almost no problems with students not doing their fair share. A discernable esprit de corps has developed among the students.

The six activities complement some of the overview topics. However, because they must both be simple and meaningful, some deviation from the overview topics occurs. A very brief description of the fall 2002 activities follows in no particular order.

Lift: The students measure the dependence of wing lift on angle of attack (α) and freestream velocity. The measurements are obtained using a rectangular wing in the department's 4 ft x 3 ft subsonic wind tunnel. The students also obtain data from the wind tunnel's propeller in order to determine blade tip Mach number. Plots that the students make of lift versus α and lift coefficient versus α for different tunnel speeds demonstrates the utility of non-dimensional coefficients as well as wing behavior.

Drag: Drag is explored using cylinders in a flow. In this activity, a cylinder is suspended as a pendulum at the exit of a duct and the students measure the angular displacement of the cylinder as air flows past it. Knowledge of this angle and the weight of the cylinder allows the drag to be computed. Cylinders of several different diameters are used. Plots of drag and drag coefficient as functions of speed and Reynolds number illustrate the difference between dimensional and non-dimensional properties as well as cylinder aerodynamics.

Free Piston: The combination of an air cannon and a baseball (which normally functions as a tool for baseball/bat impact studies in the department) is treated as a free piston facility. The students measure the speed of the "piston" (the ball) at the exit of the cannon. Measurements are made with various values of reservoir pressure. The students also investigate the effects of a foam plug, to provide a better seal, inserted upstream of the ball. The measured speeds are used to calculate the effective or average pressure driving the "piston" down the tube. The students compare this to the reservoir pressure and from this gain an appreciation of the expansion process occurring in the barrel.

Propeller Wake: The students measure average axial velocity profiles downstream of a small propeller. A pitot-static probe and a liquid manometer are the tools for this activity. Measurements are made at several different axial stations and at different propeller rotation rates. Plots of the profiles illustrate the broadening of the shear layer at the edge of the wake as the flow progresses downstream.

Wing Geometry: Using a tape measure, a laser level and large calipers the students measure the airfoil section at two stations on a real T-37 wing. This is the most demanding of the activities in terms of teamwork because of the large size and crude instrumentation. After studying plots of their measurements, the students select the NACA sections that they think most closely resemble their observations.

Literature Search: Each group is given a short list of topics about which articles in the *Journal of Aircraft* and the *Journal of Spacecraft and Rockets* must be found. In order to truly familiarize the students with these journals, the searches must be made manually, using the annual indices or scanning the outside covers of individual issues—no Internet searches permitted! The reports consist of abstracts of the papers written in the students' own words.

II.4 *Evaluation Method*

The following scheme was used to evaluate each student's performance in this course: Midterm test (10%); End-of-term test (15%); Laboratory activity reports (average of 6) 20%; Lecture-based homework assignments (average of 5) 25%; and Computer-based homework assignments (average of 5) 30%.

II.5 *Assessment*

After the very first offering of this course in fall1999, 37% of students (11/30) changed their major after the completion of the course. However, since then, this course has gradually become more successful in creating and/or increasing the interest of the students in aerospace engineering. Retention from first semester to second semester has improved to 80% or better. In fall 2002, 62 students enrolled in ASE 1013 and 61 stayed till the end. Of those who successfully completed ASE 1013, 51 have enrolled in the next course ASE 1023 this semester (spring 2003). The course has been very successful in building camaraderie among the students, which appears to be having a positive influence in later courses.

It is not clear how much the students have gained from the substance of the course. Carry-over of factual knowledge from first to second semester and beyond appears to be modest. Most students appear to know how lift depends on angle of attack and how to calculate lift coefficient. Beyond these relationships, the students' knowledge varies from those who have a full grasp of the topics of the class to those with only a meager understanding. As a pleasant contrast, by the end of the semester almost all of the students had demonstrated a reasonable ability to use Mathcad and Unigraphics.

The students themselves give the course slightly above average evaluations. Three-hour periods twice a week are unpleasant for students, particularly immature freshmen. Although the staff tries hard to keep the students busy and interested, it is difficult to keep the students entertained for these long periods. Freshmen need entertainment and so they find the course somewhat tedious. There are also a number of older students, mostly junior college transfers, in the class. They also find the course tedious, partly because the discussions are often on a level that is too elementary.

We have had a number of informal, personal positive comments from the students, and based on the success in retention and bonding of the class, there is the sense that the course is fulfilling its general purpose.

Comments by the students on their evaluation of the course range from "*This class is a total waste of time. It is far too easy …*" to "*I learned a lot in this class, although it was very hard …*". These two quotes represent a major dilemma with the course, i.e. how to provide a meaningful experience to a student body with enormous variation in background. We are still struggling with this problem. Despite students such as the author of the first quote above, we have generally had a plurality of positive comments from the students. These comments, plus the success we have had in retention and bonding of the class, give us the sense that the course is fulfilling its general purpose.

III. ASE 1023: Introduction to Flight Mechanics

This course continues the introduction of ASE to second semester freshman students with the primary focus on basic aerodynamics, airplane performance, and an introduction of topics related to airplane static stability and control. Principal topics covered in this course include airfoils,

wings, and other aerodynamic shapes; elements of airplane performance; principles of stability and control; applications of computer modeling, computational tools; and historical perspectives.

The text used for the first offerings of the three course sequence, and used extensively for the ASE 1023 course is *Introduction to Flight, 4th Edition,* by John D. Anderson, Jr., McGraw-Hill. The principle topics of this course are contained in a chapter detailing airfoils, wings, and other aerodynamic shapes, and the two chapters on elements of airplane performance and principles of stability and control.

The material covered on aerodynamics rounds out the introduction to airplanes that is begun in ASE 1013, and builds a base of knowledge concerning the various parts of an airplane, and how they contribute to overall lift and drag of the vehicle. With some knowledge of the basics of airfoil nomenclature, coefficients for lift, drag, and moments, the students are armed with the basic vocabulary they need to assimilate for the understanding of the whole aircraft flight mechanics. Through lectures, wind tunnel and computational experiments, and research into related historical topics, the students gain an insight into measurements of pressure and forces acting on aerodynamic bodies, and the factory influencing those forces.

III.1 *Introduction to Airplane Performance, Stability and Control*

With elimination of Flight Mechanics I course (see Table 2) from the curriculum, a major thrust of ASE 1023 was the coverage of content taught previously in Flight Mechanics I. The various elements of airplane performance are introduced in this course. These include an introduction to the drag polar and equations of motion for an aircraft in flight. A detailed study is conducted of thrust and power requirements for level, unaccelerated flight, for jet propelled and propeller-driven aircraft. This includes factors affecting thrust and power available, and the resulting available thrust and power variations with speed and altitude. Climbing and gliding flight are studied as well, along with determination of such limits to flight as service and absolute ceilings, range, and endurance. Takeoff and landing performance are studied, and turning flight characteristics and V-n diagrams are developed. The concepts of stability and control are introduced, including definition of and explanation/demonstration of some stability characteristics and derivatives. A historical review of related topics is also conducted.

III.2 *Computer Skills*

In this course, students also receive instruction in effective engineering use of personal computers and engineering software. The students are introduced to MATLAB, which is used extensively for programming of solutions such as the horizontal plane performance envelope of a given propeller or jet aircraft. Since vertical plane performance is greatly affected by atmospheric properties, solutions for those properties developed for ASE1013 are utilized in this course as well, and the Mathcad worksheets developed for that class are expanded for solutions to some problem sets.

An introduction to computer programming is accomplished by stepping students through modifications to FORTRAN and BASIC programs used to solve some performance and aerodynamic related problems. Emphasis is placed on the development of programmed solutions

in an orderly fashion, including documentation of the solution method or process. The students are required to state the problem clearly, to describe the input and output, to work an example problem by hand, and to develop a detailed algorithm or pseudo-code prior to coding the problem in a programming environment.

Originally, a PC application, Solid Edge, was used to introduce solid modeling, and students transitioned to Unigraphics on the departmental server during computer laboratory activities in this course. The Computer Aided Self Teach tutorial provided by EDS Unigraphics was to be utilized, and supplemented with classroom demonstrations and sample modeling activities. When Unigraphics was ported to be a native Windows application, the use of Solid Edge was eliminated, and ASE1023 computer lab activities were modified to continue development of Unigraphics skills. As a final project in Unigraphics, the wing of the Piper Twin Commanche was modeled and rendered.

The approximate average hours spent on computer applications are as follows: Mathcad (7.5), MATLAB (12), Unigraphics (9), BASIC and FORTRAN program solutions (6). Additionally, Microsoft Office applications Word and PowerPoint are used by students to develop reports and presentations concerning performance problems and historical topics.

III.3 *Experiential Learning, Teamwork and Communication Skills*

The students initially came from diverse backgrounds and brought various skill levels to the classroom. By using team learning and specifically pairing up students who were observed to have good people skills and technical knowledge with the weaker students, all of the students were challenged to complete assigned problems. The additional task of explaining their comprehension challenged the stronger students while aiding the weaker students. Students showed a rudimentary understanding of the basic concepts; however, there seemed to be a general lack of knowledge concerning the equilibrium condition.

For some classroom lecture diversions into group problem solving, a simple count-off method of selecting arbitrary groups was utilized, while at other times, natural selection was used as the classroom generally was sectioned by tables of 4-5 individuals. To insure that teams grouped for research projects and presentations or experiments were balanced with practical minded as well as intellectually capable individuals, careful observation was made during the arbitrary diversionary groupings to identify learning strengths and weaknesses of individuals. An attempt was made to balance all subsequent groups on projects for class credit.

Small groups were utilized during almost every lecture and problem-solving activities, and specific groups were assigned for the wind-tunnel testing and reporting, and for research activities. It was found that the students then naturally formed effective groups during assignments to develop a computer solution to a problem. The camaraderie among the students was apparent and useful to maintaining effectiveness of the working teams.

When responsibility for team organization was rotated among small group leaders, the inherent ability of the individuals was easily seen. After the first several assignments, leadership responsibility was rotated among members of teams comprised of individuals with varying

degrees of ability. The problem of having a group with all weak individuals was thus avoided. Careful attention to this must be paid early if benefits are to be realized in this area.

Six weeks are spent pertaining to aerodynamics, and ten weeks are spent pertaining to flight mechanics. In addition to theoretical discussions, students engage in hands-on activities and experiential learning with some examples given below.

Basic Aerodynamics: A NACA 0012 airfoil section is tested in the subsonic tunnel at varied speeds and angles of attack. Force and pressure measurements are recorded and compared to theoretical data from FoilSim, a NASA educators' tool available online at http://www.grc.nasa.gov/WWW/K-12/aerosim/, and a locally developed FORTRAN code. In another lab, the drag on bluff bodies are examined and compared.

Flying Experience: Using three of the airplanes (i.e., Grumman AA5B Tiger, Piper PA-30 Twin Commanche, and Cessna 319) at Raspet Flight Research Laboratory, students are given first-hand experience of flight. Although sparking an immense excitement in students, these flights provide a great learning opportunity as topics related to airplane performance and stability and control are explored. Airplane stall, maneuver characteristics take on physical meaning and significance through these flights.

Flight Simulation: Although not as exciting as flying a real airplane, some airplane flight characteristics are also demonstrated and basic control principles are illustrated using RealFlight R/C simulators. These simulators are the next best thing to flying your own carefully constructed model airplane, without the fueling and starting problems, and with no crash hazard!

R/C Airplanes: Supplementing the experience of riding in a real airplane and flying one on a simulator, students are introduced to R/C airplanes and given the opportunity to fly an airplane in a controlled and safe environment. Current departmental planes used for demo and instruction range from entry-level trainers to high-performance aerobatic and competition aircraft.
Computational Endeavors: The systematic solution of performance profiles was not easily accomplished by some students. By working together on some assignments, those not thoroughly grounded in programming basics were able to learn more rapidly from their peers.

Historical Presentations: Some preliminary topics introduced in ASE 1013, and historical perspectives not covered were reviewed by small group presentations of those topics. This review identified conceptual shortcomings and strengths.

III.4 *Evaluation Method*

The primary means of evaluating the student's performance during the initial phase introducing the course was through review of the student notebook. Specific classroom activities and assignments were documented on worksheets which the students maintained in a notebook that was turned in for review by the instructor and teaching assistant at mid-term, and at the end of the course. As the scope of the course and its activities became further defined, group and individual activity reports were turned in for review and grading, and midterm and final exams were given during the first formal offering of the course in spring 2001, in addition to notebook

review. Subsequently, in spring 2002, grades were given for programmed assignments (5), individual presentations (2), and periodic short quizzes (8), as well as two exams at midterm and final. Programmed assignments were propeller and jet horizontal plane, vertical plane and maneuvering flight performance. Group and individual projects were assigned for research and presentation on historical and review topics. Quizzes tested retention and understanding of material prior to continuing lectures. Exam content varied, but generally covered a combination of terms and problems on airplane performance and related lab activities.

The following scheme was used to evaluate each student's performance in this course: Midterm test (10%); End-of-term test (10%); Quizzes (8) 10%; Presentations (2) 25%; Computer-based homework assignments (5) 25%.

III. 5 *Assessment*

In this subsection a narrative self-assessment of the course is accomplished after the first experimental offering. Actions taken to change the course are indicated, and student feedback is summarized. Comments gleaned from a review of subsequent assessments are also included.

Attempting to teach flight mechanics prior to or concurrently with engineering mechanics might not be a good idea. Perhaps the teaching of those elements formerly associated with the Flight Mechanics I, performance class should be delayed until the third semester of the sequence. In discussions with the students, it became apparent that most were co-enrolled in the second calculus course, and were generally unprepared for discussions of integral solution methods. Those calculations requiring applied solutions involving integral calculus resulted in confusion on the part of many of the students. Students seemed to grasp the fundamental nature of uncertainty well enough, and could readily determine necessary constants through linear regression using several different applications. There was no shortage of anomalies and errors to discuss during the experimentation and flight testing. Since most experiments were repeated multiple times, the variable nature was easily demonstrated, and the techniques used to minimize uncertainty were realized.

Generally, the students seemed unprepared to solve open-ended problems of any degree. Specific problems requiring development of the method of solution must be sought. When the students were given a choice of solving problems by hand, or by the use of several software applications, they were able to readily take advantage of the most effective means of solution. In the choice of making calibration plots, for example, some members of small teams would reduce data in one application, while another would use a different application. As a result, the students were able to compare in the small group setting, the differences in efficiency (time) or ease of use features of the various software and methods of solution. The students experienced the disparity between analytical solutions with computer programs, and experimental measurements of the flow field around an airfoil section. The limitations of computer solutions were illustrated by completing the same solution at various Reynold's numbers, with a resulting over, under or near agreement between solution and experiment. Students did develop basic skills in using Word, Excel, and built upon their Solid Edge knowledge with the tutorials for Unigraphics. All students were observed to master the fundamentals of these tasks. Particularly, the Unigraphics basics were well illustrated. Additionally, a FORTRAN program was utilized to obtain a 2D, inviscid, incompressible solution for flow around an airfoil. The students were exposed to the

language of modern software applications in an effective manner. The necessity for self-familiarization through tutorials and on-line documentation was emphasized

Despite the discomfort experienced during discussions of analytical methods of solving equilibrium problems (inexperience with engineering mechanics and calculus), the students were able to express rudimentary understanding of basic aircraft behavior and response characteristics. The students did become more familiar with aeronautical expressions during this course. More problems need to be developed requiring component design and/or integration. This concept was poorly illustrated in this class. A design problem requiring integration of competing specifications needs to be developed to illustrate design integration.

The students had to do oral and written communications as a part of this course. The basics of technical communication were illustrated. More specific writing assignments should be developed. The students participated in making small group (3 or 4 person) presentations using multi-media. They effectively grasped the fundamentals of these assignments, and in some cases, exceeded the expectations considerably in regards to the quality of presentations anticipated.

Discussions of aerospace history and development illustrated the impact on general society. Through discussions and illustrations of the difficult advancements in the field of aeronautics, they seem to be coming to a more complete understanding of the potential for dramatic impact on society.

The students did in fact conduct themselves with a high degree of self-motivation and expressed a distinct sense of responsibility, particularly in the small group assignments. There were a couple of exceptions though, in students who were actively concerned with only the minimum required effort.

When responsibility for team organization was rotated among small group leaders, the inherent ability of the individuals was easily seen. After the first several assignments, leadership responsibility was rotated among members of teams comprised of individuals with varying degrees of ability. The problem of having a group with all weak individuals was thus avoided. Careful attention to this must be paid early if benefits are to be realized in this area.

Especially with regards to computer hardware, and software applications, the students gained an appreciation of the rapidly changing nature of technology. The use of tutorials and on-line documentation accelerated the learning process, but also illustrated the way in which to stay abreast of software changes. Similarly, using the technology of equipment in the lab, the evolution from analog to digital equipment was illustrated. Specific problems involving discrete measurements of analog signals should be developed to more fully illustrate these principles.

Student feedback to the original course indicated that having only a notebook review for credit was not challenging. Most of the students indicated that they would rather see traditional testing and graded assignments. Surprisingly, there were a number of students who did not bother to keep the notebooks anywhere up-to-date or complete, and there was a clear delineation of those individuals who completed all, a majority, a few or none of the assignments, so the grade spread

was typical of most aerospace classes. As more graded assignments were added, there were no complaints on the number or content of quizzes and exams, except for complaints when there was an emergency change of instructor at mid-term in spring 2002, concerning the use of the class notebook during quizzes and exams.

IV. ASE 2013: Astrodynamics, Propulsion, and Structures

In this course, students are presented with a general overview of astronautics focussing on space flight and orbital mechanics. They are also introduced to various propulsion systems including reciprocating and jet engines as well as liquid- and solid-propelled rockets. Instruction in aircraft structures includes in-depth discussion of structural materials and exploration of structural properties affecting stiffness, strength, and stability. Approximately 60% of the course is devoted to topics related to materials and structures while the remaining 40% is focused on astronautics and propulsion in equal portions.

The in-class instructions are combined with laboratory activities based on computer simulation as well as physical experiments. Field trips are taken to facilities where students can see real world examples of large aircraft structures many of which have been subjected to severe corrosion and fatigue damage. An overnight trip to the National Museum of Naval Aviation caps a study of aircraft structures and propulsion development.

The subject of ethics in engineering is explored with the help of scenarios involving two imaginary characters portraying a young engineer and a medical technician. The situations these two individuals find themselves in and the ethical dilemmas they are faced with help explore this important topic in a manner that students feel comfortable discussing. The students are also introduced to the concept of moral judgment as related to engineering issues. Excerpts from AIAA and NSPE Codes of Ethic bring the discussion of this topic to conclusion.

No textbook is used in this course as detailed handouts related to each major topic developed earlier are distributed to students during the semester. Each handout contains several blank sections scattered throughout that students fill in upon attending the lectures. In addition, each handout contains a collection of questions that the students need to answer as an exercise with the understanding that some of the same questions could appear later on the final exam.

IV.1 *Introduction to Aircraft Structures*

The discussion of aircraft structures begins with an in-depth examination of engineering and physical properties of commonly used structural materials. The students are introduced to different alloys of aluminum, steel, and titanium with the definition of the numbering system used for each material. Advantages and disadvantages of these materials are discussed. With the help of several examples, students realize why one material is preferred over the others for a specific application. Definitions of material properties such as Young's modulus, yield strength and ultimate strength are given, and stress-strain curves of various materials are used to highlight the difference between material stiffness and strength. Characteristics such as ductility and brittleness are explored including the influence of temperature on material behavior. Failure modes such as creep and fatigue are introduced. A simple in-class experiment with paper clips

gives students a clear demonstration of cyclic fatigue as well as variations in the number of cycles to failure. Incidents involving the in-flight explosion of two De Haviland Comets in the 1950's as well as the Air Hawaii Boeing 737 several decades later bring realism to the nature of fatigue failure and its terrible consequences.

Strut-braced wing airplanes such as the Cessna 140 and 188 are used as precursor for the discussion of column buckling. Without going too deep into the theory of column instability, the students are presented with the Euler buckling formula, and given the opportunity to explore the interaction among geometric, boundary, material, and loading conditions in determining the buckling strength of a column. This discussion helps set the stage for a hands-on laboratory activity involving the buckling of columns with different cross-sectional geometries. There will be more about this later in the paper.

Using a diverse group of airplanes such as the triplane Fokker Dr-1 of the 1910's and the Boeing 767 of the 1980's, structural anatomy of various airplanes is explored. The differences between the classic fabric-covered wood wing structure of the former airplane and the advanced skin-stringer-spar metallic wing structure of the latter design help guide the discussion of structural design and the role each structural part plays in supporting the external load on the wing. Similar examinations are made of the fuselage and empennage structures.

Additional topics covered in this part of the course include nondestructive testing of materials and structures; principles of product design and manufacture; commonly used manufacturing processes in aircraft industry; introduction to composite materials; and a general overview of various aeroelastic phenomena and its importance in design of aircraft structures.

Guided discussions are used as means of furthering students' understanding of select topics. In some instances these discussions follow a video or a seminar presentation by an invited guest speaker.

IV.2 *Introduction to Astronautics*

This segment of the course begins with an hour-long seminar on the history of astronautics and its roots in the science of astronomy. Students learn about such pioneers as Ptolemy, Al Batini, Tusi, Copernicus, Galileo, Kepler, and Newton. The launch of Sputnik by the former Soviet Union in 1957, the early U.S. space program of the late 1950's, and the Apollo missions of the 1960's are used as background for the discussion of space flight and orbital mechanics which examines the basic elements of two-body systems and Kepler's laws governing planetary motion. The description of classical orbital elements helps set the stage for a basic study of orbiting satellites and the relationship between eccentricity and the orbit geometry as an example. Simple problems are used to illustrate the calculation of orbital period and distances to apogee and the perigee. The Kennedy Space Center, Florida and the Vandenburg Air Force Base, California are introduced as the two major launch sites in the U.S., and the relationship between the launch site and satellite orbit geometry is explored.

Several video presentations of the Apollo missions provide the opportunity to examine the challenges that had to be overcome to make the moon landing in 1969 a reality. Presentation by

a guest speaker and excerpts of published articles give the students some insight into some novel and futuristic ideas under consideration for future space travel and the engineering challenges posed by them.

IV.3 *Introduction to Propulsion*

This segment of the course begins with the discussion of different types of propulsion systems. This is continued with the discussion of how a rotating propeller generates thrust and differences among airplane propeller, helicopter rotor, and prop-rotor of a tilt-rotor aircraft such as the V-22. The students are introduced to the relationship between engine power, torque, and rpm, and propeller efficiency and advance ratio are used to learn about propeller characteristics.

Following the discussion of reciprocating engines, the gas turbine engine is introduced. The students learn about the internal components of various jet engines (i.e., turbojet, turboprop, turbofan, and turbojet with an afterburner), and examples of airplanes that use each type of jet engine are shown. High and low bypass turbofan engines are compared with emphasis on thrust and engine efficiency. The students also learn about the supersonic and hypersonic propulsion and the use of such airbreathing engines as ramjet and scramjet.

The discussion of airbreathing engines is followed by that of liquid and solid-propelled rockets. Different types of liquid and solid propellants are introduced with advantages and disadvantages of each system examined. Furthermore, the students are introduced to the basic components of a rocket engine and the relationship between exit velocity and thrust.

IV.4 *Computer Skills*

The Unigraphics training that began in ASE 1013 is continued in this course with students learning more about modeling of complex geometries. In addition, they are introduced to a FORTRAN-based laminate analysis program as well as a NASA-developed jet engine simulator. Both software programs are used later in support of experiential learning activities. The students also continue to utilize spreadsheet, word processing, and presentation software programs for homework assignments and project report presentation.

IV.5 *Experiential Learning, Teamwork and Communication Skills*

Teamwork and communication skills are emphasized throughout the semester as students work in teams in performing a specific activity and the writing of the report. Attention is made to how students are grouped together with the desire to give all students an opportunity to be a team leader in at least one activity. Also students are rotated among the groups to develop a stronger friendship and to realize that in the real world they do not necessarily choose their teammates and they need to learn how to get along and work with others on the team. Some of the group activities are described next.

Material Testing: It is important for students to learn about how materials are tested and how some of the material characteristics are obtained. For this, the students observe the tensile testing of a dog bone specimen at the material testing laboratory of the ASE department. The

students also learn about what information is collected and how the data are stored in the computer. Without knowing what material is being tested, the students are given the stress and axial deflection data. Working in groups of five, the students are asked to examine the data, plot the stress-strain curve, and calculate such material properties as the Young's modulus, proportional limit, yield strength and the ultimate strength. Using the available published information on various metallic materials, they then have to determine the material of the specimen.

Column Buckling: This activity is geared toward analytical prediction and experimental measurement of column buckling strength. Working in groups of four or five, the students examine the cross-sectional geometry of three different columns and calculate such properties as area, moment of inertia, and radius of gyration. The students then use a beam bending apparatus to measure the tip deflection of a cantilever beam or the mid deflection of a simply-supported beam that is made of the same material as the columns under consideration. Using the load and deflection data along with the beam's length and cross-sectional shape, they estimate the Young's modulus of the material. With that information, they predict the load at which a simply-supported column would buckle using the Euler buckling formula. After the analytical predictions are made, the students carry out an actual buckling experiment by slowly placing lead weight on one end of the column. They then continue the loading by pouring sand into a bucket that rests on end of the column and the previously placed lead weights. They continuously monitor the column for excessive lateral deflection. Upon observation of column buckling, they record the measured load and compare it with the predicted value. The use of columns with three different cross-sectional shapes but nearly the same cross-sectional areas reinforces the influence of moment of inertia on buckling strength. In the event when the analytical predictions and measured values do not agree, the students are asked to examine the procedure they used for the experimental calculation of the Young's modulus, the actual loading of the column in the testing apparatus as well as the column support condition to identify possible sources of the discrepancy. The importance of rigor in conducting experiments and the limits of analytical tools help the students learn an important lesson about engineering.

Composite Materials: Using an in-house FORTRAN-based laminate analysis program, the students examine the effect of such parameters as material properties, ply fiber orientation angle, and the laminate stacking sequence to learn more about the anisotropic behavior of composite materials. This activity is not part of a homework assignment, but rather part of an active learning exercise conducted in conjunction with a lecture the students receive on the topic of composite materials.

Satellite Tracking: In conjunction with the discussion of astronautics and orbital mechanics, the students working in teams use the available orbit data on several commercial and weather satellites and try to make naked-eye observation of the same satellites as they pass overhead after sunset. They use a compass to help direct the line of sight and use a tripod with a target finder on top to help track the satellite in its orbit. Prior to making actual observations, the students must first use a star chart that shows the travel path of each satellite. Although the exact location of a satellite at a particular time is available, it is still difficult to make a proper observation as the light reflected by some satellites is very dim. In addition, interference of light emanating from buildings and roads nearby could add to this difficulty. However, in two of the past three

attempts, the students were successful in making such observations. This activity is part of an assignment that also includes exercise problems related to orbital mechanics.

Engine Simulator: The purpose of this activity is to study the performance characteristics of various jet engines using the EngineSim simulator (www.grc.nasa.gov/WWW/K-12/airplane/ngnsim.html) developed by the NASA Glenn Research Center. This simulator uses an interactive module to demonstrate various parts of a jet engine with primary focus on turbojet, turbofan, ramjet, and afterburner systems. Used primarily as an active learning exercise in conjunction with a lecture on the topic, the students working in teams examine the characteristics of four different engines, and identify unique features of each engine and its relative efficiency. Using the plot of pressure variation through the engine, they identify the station with the maximum pressure and examine the variation of pressure with airspeed and altitude. Similarly, the students learn about the variation of temperature through a jet engine.

Water Bottle Rocket: Perhaps the activity that the students enjoy the most and manage to engage in a spirited competition is the water bottle rocket experiments. In this group activity, students use a 2-liter plastic soda bottle, fill it with water and pump air in it before it is launched. Besides having fun, the students learn about the influence the mass of the bottle, the internal pressure, the shape of nose geometry, as well as the effect of tail fins in determining the maximum height reached by the rocket.

In this activity, the students in each team are given different tasks that are common among the groups. The students from different groups who are given the same task are joined and help carry out their duty. For example, some students work to measure the amount of water poured into the bottle and the amount of air pressure pumped inside while others standing at four different positions try to make measurements of the maximum height reached by the bottle or the rocket in this case. Using simple devices such as a long tape measure and a tripod with a target finder mounted on top, the students measure the distance from the tripod to the launch site and the angle of target finder relative to horizontal plane. This information is used to estimate the maximum height reached by the rocket in each experiment. Using the measurements made by students from four different positions helps reduce the error in analysis and provide an opportunity to review once again concepts related to statistics and uncertainty.

Field Trips: An average of three field trips are taken during the semester this course is taught. They include a trip to the large aircraft salvage facility in Greenwood, Mississippi, the aircraft modification and refurbishment facility in Birmingham, Alabama, as well as a trip to the Naval Air Museum in Pensacola, Florida.

Each field trip is focused on a specific theme and is organized into a team project requiring students to perform a myriad of activities. For instance, in the trip to the salvage facility, the students get to climb inside such airplanes as the Boeing 747, 737, as well as 727 in order to take measurements of real aircraft structures as shown in Fig. 5. This also provides the students with an opportunity to get a sense of the size of the individual parts as compared to that of the whole airplane.

Fig. 5 Students taking measurements of structural parts at the cutout section of a B727 wing

The trip to the modification facility enables the students to explore issues related to aircraft service life, non-destructive testing of structures as well as other aging aircraft issues. They also consider the economic trade-off between the purchase of new and the keeping of old aircraft airworthy and operational.

The Naval Air Museum houses a large collection of military aircraft and the engines used in each. In the trip to this museum, the students work in teams and seek to identify the various components of real jet engines and the connection between airplane design and the engine(s) used to provide it with the required propulsive power.

IV.6 *Evaluation Method*

The primary method of evaluation is students' homework assignments and research projects. A total of five homework assignments are given. These assignments are based on group activities and are submitted in a technical report format. In each assignment, the students are graded based on the level of participation in the group activity and the writing of the report. The research project is done by students working individually using a topic related to one of the three major parts of the course (i.e., astronautics, propulsion, and structures). The grade for the research project is based on the written report and the oral presentation. The project is counted as two homework assignments and along with the other five homework assignments make up 75% of the student's grade. The students are tested only at the end of the semester with a comprehensive final exam that makes up 20% of the student's grade. The remaining 5% is based on student's class attendance and participation in the field trips.

IV.7 Assessment

As with the other two introductory courses, the main objective of this course is to expose the

students to various topics in the field of aerospace engineering in a manner that is informative, engaging and interesting without being too overwhelming. The heavy emphasis on aircraft structures is intentional and consistent with the treatment of aerodynamics and flight mechanics in the other two courses. Currently, 60% of the course emphasis is on materials and structures while the remaining 40% is split fairly evenly between astronautics and propulsion.

We are not satisfied with the current three-to-two ratio between in-class and laboratory / hands-on activities. This sentiment is shared by the students as well, and is a subject that is being addressed with the selection of additional sites for field trips as well as the development of additional laboratory and experiential learning opportunities.

Through evaluation of homework assignments, research project, and the final exam, as well as classroom discussions with the students indicated that all the learning objectives were fulfilled to the instructor's satisfaction.

Near the end of the semester, the students were asked to answer a questionnaire that sought their feedback on questions related to the various aspects of the course. In addition giving an indication on how well each course objective was met, the students had the opportunity to evaluate each of the guest lectures, field trips, handouts, video presentations, lab experiments, and computer simulation /analysis activities on the individual basis. The responses presented in Table 3 below are from the students who took this course in fall 2001. The student's response to each question was measured on the scale of 1 (strongly dissatisfied) to 5 (strongly satisfied).

Table 3. Students' evaluation of ASE 2013

Question	Average	Standard Deviation
Objective 1	4.27	0.64
Objective 2	4.20	0.66
Objective 3	3.60	0.81
Objective 4	4.30	0.70
Objective 5	3.83	0.95
Objective 6	4.20	1.00
Guest lectures	3.51	0.42
Field trips	4.28	0.74
Handouts	4.27	0.69
Videos	4.60	0.50
Lab. experiments	3.83	0.53
Simulations	3.36	0.75

As indicated by Table 3, the students were generally pleased with the course and their learning experience. In addition to scoring a question on the scale of 1 to 5, the students were asked to make general comments related to the topic in question. Some samples of students' comments are given below:

- *I thought the field trips were very helpful in understanding the material.*
- *Field trips were informative but long distance to travel.*
- *I think it is easier to learn visually from the videos than by just listening to lectures.*

- *Overall, I think the idea of handout was very helpful. Both in the sense of not having to take as many notes and learned more by being able to focus more on class and group discussions.*
- *The handouts were helpful to follow the lecture. They also make a good reference for later use.*
- *Videos such as "From the Earth to the Moon" are very inspiring to young Aerospace Engineers. It reminds me of why I chose this particular field of study.*
- *Even though the satellite experiment was unsuccessful this semester, it was an awesome idea.*
- *Water bottle rockets were fun and interesting. This might make a good student group design project.*
- *More hands-on experiments.*
- *I would have liked more experience with Unigraphics.*

Similar to the sentiment expressed in the previous two courses, the students find it difficult to meet for six hours a week. This is a concern that we hope will be less of a burden as more hands-on activities and field trips are incorporated into the course. Otherwise, steps will be taken to reduce the contact hours to a sustainable level.

Although the course has been taught three times already, it is still experimental in nature with the content subject to further revision. The mixture of disciplines makes the teaching of this course by a single instructor with background primarily in one discipline somewhat challenging. Also the day-to-day management of this course is rather demanding, especially during the initial offering of the course with the course material not fully developed.

V. Enrollment Trends

As with many curriculum changes and revisions, the initial transition phase is rather difficult and the changes can cause more problems than they intend to remedy. We had the same experience with these introductory courses.

Initially, while we were attempting to develop the curriculum and include various hands-on activities in each course, we perhaps managed to scare or bore some students away from the program. At the same time, some of the students left the program as a result of finding engineering difficult or choosing a different engineering major. However, through the dedication of the instructors who have been assigned the responsibility of teaching these courses and updating the curriculum, the trend is gradually changing. We have reached a point where we are noticing positive signs about the program as measured by the growth in student enrollment (see Table 4) as well as enhancing our students' interest in and enthusiasm for aerospace engineering.

There are still some remaining challenges that need to be addressed such as the long contact hours in each course. The students generally find the six-hour a week format unpleasant. We hope that through creative thinking we can develop and integrate additional activities into each course to stimulate students' interest while making a better use of the class period. If not, then steps will be taken to reduce class time to perhaps a standard 3 hours a week schedule.

It is also important to point out that the intent of these introductory courses is not necessarily to have a 100% retention rate after the first or second year. After all, there are some students who

have a wrong impression of engineering, and after a semester or two, they choose to pursue their education in another field. Our goal is mainly to keep the talented students and those who have the potential to complete the program and become successful aerospace engineers from leaving.

Table 4. Enrollment trends in the three introductory courses

Year	Semester	ASE 1013	ASE 1023	ASE 2013
1999	Fall	30	-	-
2000	Spring	-	19	-
2000	Fall	38	-	11
2001	Spring	-	32	-
2001	Fall	53	-	32
2002	Spring	-	41	-
2002	Fall	62	-	25
2003	Spring	-	51	-

VI. Conclusions

An overview of the three recently developed freshman/sophomore Intro-to-ASE courses taught in the Department of Aerospace Engineering at Mississippi State University was provided in this paper. As part of an overall undergraduate curriculum improvement effort that began in fall 1994, these courses were developed with the goal of keeping students engaged and interested in the aerospace engineering program while complying with the departmental objectives and ABET 2000 Criterion 3.

While sharing common learning objectives, these courses focused on different aspects of aerospace engineering with varying distribution of classroom instruction, laboratory and other hands-on activities that ranged from wind-tunnel testing and the experience of flying in different airplanes to testing of structural members and satellite tracking. The students also received training in the use of such software programs as Unigraphics, Mathcad, and MATLAB as well as several in-house and NASA-developed simulation tools. Elements of teamwork and communication skills were integrated into group assignments and laboratory activities.

The initial assessment of these courses indicates that students are benefiting from the early introduction to aerospace engineering and that the percentage of students who have stayed in the program beyond the freshman and sophomore years has increased by an appreciable amount.

Through an on-going evaluation and assessment of learning outcomes, improvements are introduced in the program that we hope will continue to boost interest in our undergraduate program and attract additional talented students to aerospace engineering.

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