# AC 2008-2267: ASSESSING PROGRESS: EVALUATING THE EFFECTIVENESS OF A THREE COURSE INTRODUCTION TO AEROSPACE ENGINEERING AND RELATED CURRICULUM MODIFICATIONS

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# Assessing Progress: Evaluating the Effectiveness of a Three Course Introduction to Aerospace Engineering and Related Curriculum Modifications


## Abstract

A three semester introductory sequence in Aerospace Engineering was implemented concurrently with the 1999 ABET evaluation under ABET 2000 criteria, and was modified considerably to account for curriculum changes through the evaluation period of 2005. As further program modifications have since been made to allow concentrations in aeronautics and astronautics with branching occurring during the last semester of the lower division, this introductory sequence has become a very important influence on the choice of concentration. Additionally, as course prerequisites and content have been juggled, the material content of these introductory courses has been significantly modified. The ongoing assessments of these courses and the related courses that follow are examined, and changes to those courses and the resulting effects are evaluated. The assessment process to meet the criteria currently used for evaluation is not a static process, but rather a dynamic evolution of a process designed to approach a moving target. As the technology of both instruction and industry have changed, particularly with respect to computer software and hardware, the curriculum used to train entry level engineers has evolved to continue to meet accreditation criteria and constituent needs. Computers and software tools in the hands of lower division students are typically different, often much more capable, than the tools in the hands of the students in the upper division. This occurs as incoming students are required to purchase computers that are intended to meet their undergraduate educational needs according to specifications which climb higher for entering freshmen with each successive year. In the introductory sequence, the students will receive the latest licensed software versions available to match the computer specifications, and instructors in the introductory sequence must work hard to insure that not only do the students receive the latest instruction, but that information on software capabilities and limitations are disseminated to other instructors in the upper division in a timely fashion. Thus the evolution of the introductory courses serves to maintain high expectations for students, as well as pushing the technological advancement of the upper division coursework. Through the discussion of the assessment of these courses and related curriculum changes, an effective process is illustrated that has been used through two major ABET evaluations, and that highlights the changing nature of the requirements established by assessment criteria.


## An Introductory Sequence of Courses is Established

A three semester introductory sequence in aerospace engineering was implemented concurrently with the 1999 ABET evaluation under ABET 2000 criteria. Although those courses were not evaluated during that visit because they were an experimental offering, a curriculum review was underway and an implementation plan for updating the curriculum was subject to scrutiny during that visit. As the full plan was implemented, a programming course, an introductory course in flight mechanics, and a graphics communication course were eliminated in favor of including all of the original elements of those required courses into this introductory sequence.[1] The impetus of establishing the introductory sequence was in seeking to increase retention of students by making them feel more connected with the department from their first semester on campus, instead of losing them before they ever really knew what aerospace engineering was about. The sequence involves six contact hours per week for three semesters, or the equivalent of a three hour lecture and lab each week, or two lecture courses. At first the introductory courses were kept fairly light and were primarily experiential in nature. However, as the nature and frequency of use of computer applications changed and the entire college of engineering launched a computer initiative, the importance of this course was increased. The students were required to have a computer with minimum specifications beginning in fall of 1999, the same year this introductory sequence was launched. Within two years the requirements were further narrowed to student possession of a laptop computer meeting certain specifications, and certain software packages were emphasized throughout the curriculum. These included the use of MathCAD, Matlab, Unigraphics, although upper division classes continued to emphasize programming in languages such as Fortran, C, and the like. Further changes to the curriculum were made through the evaluation period of 2005, and some of those changes required changes to the course format and content of the introductory sequence.[2] Most of the early changes to course content were to formalize the inclusion of elements of courses eliminated from the curriculum as the introductory sequence became a mandatory course requirement for aerospace engineering majors. Computer technology was being introduced almost universally to students in high school, including programming in BASIC or other languages, until the programming environment and documentation were no longer included as a part of the computer operating system with the introduction of the Microsoft Windows ME and Windows 2000 environments. Thus, within a few years, beginning freshmen would have a cursory familiarization with computers, including use of the internet and standard office production tools, but little else in the way of computer competencies. Thus the introductory sequence, in addition to being the first engineering course the students would see once they began their studies, took on the added importance of teaching the students just how these tools were to be used in their engineering studies.

**Aerospace Engineering Program Modifications**

The program review that resulted in the initial rearrangement of the curriculum, elimination of some courses in favor of the introductory sequence, and the resulting modifications of course content in other courses have been detailed by the authors in the cited references. As in most implementations of new courses, particularly sequences such as these, modifications continue until a relative balance is achieved between course objectives and assessment that indicates an acceptable level of effectiveness has been attained. More recently, significant program modifications have been made to allow concentrations in aeronautics and astronautics with branching occurring during the last semester of the lower division. The intentions of this dual track establishment were detailed in another paper as those plans were being implemented. This academic year will see the first graduations of students who have completed these new courses of study. Many of these students chose between aeronautics and astronautics based on their exposure to these different paths in the intro courses. Thus, the introductory sequence has become an important influence on the choice of concentration, as the exposure given to the students in this sequence becomes a large window to the world of aeronautics and astronautics as currently dominated by the use of computational tools. Though an initial bent towards studying air or space vehicles might have been formed in their youth, most students lean toward those areas of study that they find of continued interest, and that they feel are still within their grasp of understanding. With the substantial revision of the curriculum into two branches beginning at the end of the sophomore year, the exposure that students received to the tools used in studying fields such as astrodynamics, propulsion, structures, flight mechanics and engineering mechanics would establish a more firm picture of the path of studies ahead, and the roads that must be taken to branch not only to air or to space, but to the various specialization areas within each. In the not-so-distant past, almost all of the aerospace engineering students would graduate with nearly identical transcripts except for the behavioral and human sciences courses. Now it is not uncommon for students to choose a path leading to various specializations of study, certificates of specialization, or to take steps toward professional registration while relatively early in their academic careers. Although individual advisors can assist in charting a curricular path toward a degree or certificate programs such as leadership and material certificates within the engineering college, the larger picture and a measured exposure to the various paths available must be provided to each student. Only if the student chooses the appropriate path for which they prepared and motivated will long term success be indicated by successful employment and advancement within their field of study.

**Course Content Modifications**

Additionally, as course prerequisites and content have been juggled, the material content of these introductory courses has been significantly modified. Mississippi State University has been embarking upon a course to increase enrollment and retention of under-represented students into fields historically dominated primarily by white males who were academically advanced and inclined toward these fields from childhood. Often the advancement of this group, and the avoidance of technically advanced fields of study by the more diverse populations of women and minorities were dictated by chance of geographical or sociological standing. As more students were enrolled with lower ACT or SAT scores, often coming from smaller schools where advanced mathematics and sciences were typically not taught, these students often were not successful in advancing through the lower division of aerospace engineering classes. Students often had not had advanced algebra, geometry, trigonometry, pre-calculus or other mathematically intensive science classes or computer exposure. After an initial attempt to assimilate and advance such students within the mainstream of a packed four-year engineering program, it was realized that very capable students were often being discouraged or eliminated from the program. Not intentionally, but rather incidentally as an impossible pace had to be established if students starting from a lower threshold were to reach the same level in the long run. In order to prevent students ill-prepared to jump in over their heads from certain drowning, prerequisites were established based on minimum test scores or grades in classes such as those mentioned previously. Thus, students would not begin the intro courses unless they met some minimum qualifications, and would not be allowed to advance through the sequence unless they continued to show progress in their studies of mathematics, physics, and engineering mechanics courses. This implementation of prerequisites was not arbitrarily imposed, but rather was the result of recommendations made on end of course evaluations and assessment reviews. Each recommendation was typically proposed by an instructor of record noting a deficiency common to students in a course. All recommendations were reviewed by a departmental curriculum committee, with the final decision discussed and approved by a university committee on curricula and instruction. Deficiencies related to lapses in instruction within a course due to particular circumstances such as the protracted disturbances during the fall, 2005 semester due to two major hurricanes were treated as singular events, and special class sessions and review sessions were conducted to correct problems noted. However, when the class syllabus and schedule were implemented as planned but deficiencies were noted at the end of the course or in subsequent related courses, recommended changes were expeditiously implemented and monitored by the aforementioned committees as well as the instructors of record.

Exceptions to the singular sort of activities outlined above have generally been limited to those times when major program changes were made. The changes to course content to divide the existing structures, controls and design courses to establish the dual track were developed and implemented only after careful consideration and development of individual course plans, and modifications to other existing, related courses. All of those plans for new and changed courses were developed and implemented as detailed by Rais-Rohani, Koenig, and Hannigan[2]. Following the implementation of the dual track, the academic content of the introductory courses was tightened considerably, particularly in the second, focusing on aircraft mechanics, and the third, focusing on an introduction to astrodynamics, propulsion and structures. Of particular note was the necessity to provide much more detailed instruction in programming methodology and particular programming methods to prepare students for the requirements of their upper division courses. The decline in the general computer knowledge of entering freshmen mentioned previously was also a strong motivator in forcing this new focus.

## Assessment of Progress and Compliance

The ongoing assessments of these courses and the related courses that follow were examined, and changes to those courses and the resulting effects were evaluated. The assessment process to meet the criteria currently used for evaluation is not a static process, but rather a dynamic evolution of a process designed to approach a moving target. There are more than 75 pages of documented course evaluations, recommendations, referrals, and syllabi revisions related to just the three introductory courses. They range from noting particular deficiencies due to personnel, facility, and equipment shortcomings, discussions, and solutions to detailed analyses of systematic deficiencies noted with specific recommendations on course revisions. Rather than trying to detail all the particulars, it serves a better purpose to detail the mechanisms utilized, the methods used to actually compile and process the assessment documents, in that those processes may prove useful to others.

Each instructor of record prepared two documents giving their evaluation of their courses, typically within the first month of the following semester. One document was a spreadsheet detailing the use of assessment tools indicating course outcomes related to specific departmental objectives. These spreadsheets could later be compiled to evaluate deficiencies across the curriculum in meeting the stated objectives. The other document was a textual description of the specific course objectives, and indicated how these related to the departmental objectives. Additionally, a narrative description of the teaching experience revealed general areas of accomplishment or deficiency. Concerns and possible improvements were detailed, along with proposed changes to the course objectives and course content. These documents are prepared using templates developed by the departmental accreditation coordinator, and the undergraduate committee (Figure 1). The results are provided to the coordinator, and distributed to the curriculum committee and the faculty as a whole.

**Aerospace Engineering - Faculty Assessment: Part I**

**Course Title:** ASE **Instructor:** **Term:** Spring 2007

| ***On a scale of 1 (poor) to 5 (superior), evaluate course outcomes.*** ( Enter 'N/A' if the outcome does not apply or cannot be assessed.) | Rating (1-5) | Assessment Tools (Check those used): Problem Sets | Quizzes | Tests | Design Projects | Class Discussion | Final Exam | Written Report | Oral Presentation | Individual Discussion | Laboratory Activities | Other |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***Educational Objective I*** | | | | | | | | | | | | |
| A. Understand and apply mathematics to the solution of engineering problems | | | | | | | | | | | | |
| B. Understand and apply basic concepts of chemical processes and elements of physics | | | | | | | | | | | | |
| C. Understand and apply basic concepts of solid and fluid mechanics | | | | | | | | | | | | |
| D. Understand and apply basic concepts of statistics and probability | | | | | | | | | | | | |
| E. Understand the variable nature of experimentally-determined values | | | | | | | | | | | | |
| ***Educational Objective II*** | | | | | | | | | | | | |
| A. Identify and state problem objectives | | | | | | | | | | | | |
| B. Select and apply an appropriate solution strategy | | | | | | | | | | | | |
| C. Understand the uses and limitations of computer-based analysis methods | | | | | | | | | | | | |
| D. Have general-purpose computer skills in word processing, spreadsheet, and solid modeling | | | | | | | | | | | | |
| E. Be able to use aerospace engineering computer application software | | | | | | | | | | | | |
| ***Educational Objective III*** | | | | | | | | | | | | |
| A. Recognize and assess aircraft and spacecraft design needs | | | | | | | | | | | | |
| B. Understand the behavior of aircraft and spacecraft | | | | | | | | | | | | |
| C. Be familiar with FAA and military specifications | | | | | | | | | | | | |
| D. Design specific components into a functional aerospace system | | | | | | | | | | | | |
| E. Apply engineering judgment in evaluating a design | | | | | | | | | | | | |
| ***Educational Objective IV*** | | | | | | | | | | | | |
| A. Compose a concept or idea in clear English with correct grammar and vocabulary | | | | | | | | | | | | |
| B. Compose functional letters and reports | | | | | | | | | | | | |
| C. Make oral presentations and use multi-media elements | | | | | | | | | | | | |
| ***Educational Objective V*** | | | | | | | | | | | | |
| Appreciate the impact of aerospace designs on society | | | | | | | | | | | | |
| ***Educational Objective VI*** | | | | | | | | | | | | |
| Act with personal integrity and assume responsibility | | | | | | | | | | | | |
| ***Educational Objective VII*** | | | | | | | | | | | | |
| Work in a multi-disciplinary team environment and exercise leadership skills | | | | | | | | | | | | |
| ***Educational Objective VIII*** | | | | | | | | | | | | |
| Recognize the changing nature of technology and appreciate the need for continued learning | | | | | | | | | | | | |



***Departmental Educational Objectives*.*** *Our students shall:*

I Demonstrate a good understanding of mathematics, basic physical sciences, and engineering sciences.
II Show proficiency in the use of analytical and problem-solving skills.
III Be able to apply their design skills.
IV Be proficient in written, oral, and graphic communication.
V Demonstrate an appreciation for the arts, humanities, and social sciences.
VI Conduct themselves ethically and professionally, and exhibit personal integrity and responsibility in their actions.
VII Be able to work in a multi-disciplinary team environment, and lead when necessary to accomplish a given mission.
VIII Appreciate the need for lifelong learning.

**For reference only.*

Figure 1: Aerospace Engineering Faculty Assessment Part I

The template for the descriptive document prepared as part two of the course assessment is as follows (Figure 2).

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## Aerospace Engineering - Faculty Assessment: Part II

**Course: ________________________ Instructor:____________________ Term:__Spring 2007___**

### Course Objectives:

*Please list the instructional objectives for this course as stated on the syllabus. For each course objective, state which departmental learning objective it addresses (using numbers I-VIII from Part I)*

a) Start here. *Please refer to each objective with a consecutive letter. You may use numbers for further itemization (e.g., objective b.2).*

### Narrative:

*Please give a short summary of your experience teaching this course. You may include any items that you deem to be relevant, or mention any incident(s) that might have affected the achievement of the course objective(s).*

### Concerns and possible improvements:

*Please mention any concerns that you might have regarding the course content, the appropriateness of course objectives and/or assessment tools, and any ideas you have for improving the overall effectiveness of the instruction.*

**Proposed changes to Course Objective(s):**

*Please list any changes that you would like to propose for the course objectives.*

**Proposed changes to course content:**

*Please feel free to propose changes to course content, in light of your experience teaching this course.* ***If changes in course content were recently implemented, please comment on the effectiveness of the changes!*** *Are we on the right track?*

Figure 2: Aerospace Engineering Learning Outcomes Assessment Part II

## Aerospace Engineering Mission Statement

The Department of Aerospace Engineering at Mississippi State University provides an accredited undergraduate curriculum with the mission of preparing students to enter the workplace as qualified entry-level aerospace engineers or to enter any aerospace engineering graduate program adequately prepared for advanced study. The mission is accomplished by a strong foundation in mathematics and physical and engineering sciences upon which student problem solving and application skills are developed. The curriculum stresses analytical and communication skills, with particular emphasis placed on engineering design throughout the curriculum. A capstone design experience in the senior year provides the opportunity to integrate design, analytical, and problem solving skills along with communication skills in a team environment that emulates aerospace engineering practice.

The mission is accomplished by the following educational objectives, which describe what our graduates are expected to be able to accomplish during the first several years following graduation. Our graduates shall:

1. Demonstrate a good understanding of mathematics, basic physical sciences, and engineering sciences.
2. Show proficiency in the use of analytical and problem-solving skills.
3. Be able to apply their design skills.
4. Be proficient in written, oral, and graphic communication.
5. Demonstrate an appreciation for the arts, humanities, and social sciences.
6. Conduct themselves ethically and professionally, and exhibit personal integrity and responsibility in their actions.
7. Be able to work in a multi-disciplinary team environment, and lead when necessary to accomplish a given mission.
8. Appreciate the need for lifelong learning.

## *Program Outcomes:*

Our Program Outcomes are linked to the Educational Objectives already listed. They describe what students are expected to know or be able to do by the time of graduation.

I. Objective 1

  a. Understand and apply mathematics to the solution of engineering problems

b. Understand and apply basic concepts of chemical processes and elements of physics
c. Understand and apply basic concepts of solid and fluid mechanics
d. Understand and apply basic concepts of statistics and probability
e. Understand the variable nature of experimentally-determined values

II. Objective 2
a. Identify and state problem objectives
b. Select and apply an appropriate solution strategy
c. Understand the uses and limitations of computer-based analysis methods
d. Have general-purpose computer skills in word processing, spreadsheet, and solid modeling
e. Be able to use aerospace engineering computer application software

III. Objective 3
a. Recognize and assess aircraft and spacecraft design needs
b. Understand the behavior of aircraft and spacecraft
c. Be familiar with FAA and military specifications
d. Design specific components into a functional aerospace system
e. Apply engineering judgment in evaluating a design

IV. Objective 4
a. Compose a concept or idea in clear English with correct grammar and vocabulary
b. Compose functional letters and reports
c. Make oral presentations and use multi-media elements

V. Objective 5
Appreciate the impact of aerospace engineering on society

VI. Objective 6
Act with personal integrity and assume responsibility

VII. Objective 7
Work in a multi-disciplinary team environment and exercise leadership skills

VIII. Objective 8
Recognize the changing nature of technology and appreciate the need for continued learning

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Figure 3: Aerospace Engineering Department Objectives

These documents, once compiled and distributed, were used to assess the program as a whole, coupled with feedback from other assessment tools such as end-of-course student evaluations, exit interviews, observations by other faculty and administrative staff, departmental and certification testing, graduate entry exams, alumni surveys, employer surveys/comments and advisory committee discussions. These assessment tools were used as the primary basis for initiating the formal process of continual course review and change. The undergraduate committee and the department head would generally review and summarize the recommendations by the faculty along with other observations and recommendations. Follow up of individual recommendations could then be accomplished in an orderly fashion by the curriculum committee. Appropriate documents could be gathered and forwarded to the appropriate agencies for action or review and approval as necessary. These might include directives to purchase new equipment, coordinate more appropriate facilities, repair or renovate course equipment and material, or to initiate formal requests to modify objectives, course content or perhaps a comprehensive review of related courses. Thus as the technology of both instruction and industry have changed, particularly with respect to computer software and hardware, the curriculum used to train entry level engineers has evolved to continue to meet accreditation criteria and constituent needs.

## Motivation for Continual Change

Computers and software tools in the hands of lower division students are typically different, often much more capable, than the tools in the hands of the students in the upper division. This disparity repeatedly occurs as incoming students are required to purchase computers that are intended to continue to meet their undergraduate educational needs for at least the first two to three years of study. Thus with the evolution of computers continuing, specifications climb higher for entering freshmen with each successive year. In the introductory sequence, the students will receive the latest licensed software versions available to match the computer specifications, and instructors in the introductory sequence must work hard to insure that not only do the students receive the latest instruction, but that information on software capabilities and limitations are disseminated to other instructors in the upper division in a timely fashion. Thus the evolution of the introductory courses serves to establish and maintain high expectations for students, and to push the technological advancement of the upper division coursework as well. Given the rapid rate of development of computational tools, and the continued emphasis on the use of these tools in the design and analysis of aerospace vehicles, this represents a very dynamic challenge. There have been some lapses such as was noted with the general computer programming deficiencies related not to the instruction, but the lack of general preparedness as the fundamental computer applications emphasis shifted from the computer as an evolving toy and tool to a platform on which powerful applications could be implemented. Unfortunately, there is a gap between the knowledge that it takes to develop and maintain or improve those applications, and that required to simply use the tools. For a time, that gap widened as the emphasis was placed on using the tools, but like a pendulum that swings both ways, the emphasis, once shifted, can restore balance and assure that our engineering students are developing the skills to fit in on either side of the spectrum of developers and users.

The computer initiative that has continued through nearly a decade has fundamentally changed the nature of basic engineering education, and is definitely a different dynamic from that of the past. This evolution of the computer as a tool has led to other avenues of curriculum outreach and expansion and has led to remote operation of laboratory equipment, distance offerings of courses from technology classrooms, and alternative paradigms for course construction and implementation[3]. The introductory courses actually led the rest of the curriculum in the development of web-based instruction tools, and teaching assistants for this course have typically been departmental graduate students who have literally grown up accustomed to an expanding interface to the world. They have been of great assistance developing these courses as well as helping upper division instructors to implement products such as WebCT[4] in their course offerings. These graduate students have typically attended courses in web course development as well as general teaching workshops, and have been associate developers and developers of virtual laboratory experiences for undergraduates[5] in the introductory and laboratory sequences. Where time in an upper division course was typically spent introducing computational tools, programs and advanced applications, the addition of these tools, or at least a familiarization with them in the intro sequence has saved valuable time in these advanced courses. Having "home-grown" graduate students knowing how and where they gained certain required skills offers a distinct advantage in determining the needs and capabilities of the undergraduate students. Since these students have been trained in the latest applications in their work with the intro classes, they are able to easily extend their own expertise and assist in teaching the new students how to redesign, revise and implement previous programs in new languages or graphical environments in a very effective manner[6]. In fact, the development of benchmark tasks to gauge student progress in actually applying their computer skills was primarily an independent development spearheaded by the lab and intro course teaching assistants[7].

The graduate program is modest, but has been steadily growing, particularly over the past several years. Due to the cyclical nature of engineering enrollment, it is difficult to determine the immediate effects upon retention within the program or to ascertain the motivation for students to continue into graduate programs. Looking back at running averages, retention of entering students through the sophomore year definitely increased, as losses immediately prior to the implementation of this intro sequence were running close to 50%, and now have stabilized at 65-70% retention. Retention of sophomores to seniors has increased from around 66% to approximately 85%. Prior to implementation of the sequence, students were apt to change their major stating that they had changed their minds about aerospace engineering, though they had yet to take an actual aerospace course. At the same period in time there was much publicity of downturns in the industry, etc., that likely influenced their decisions as much as any other factors. The number of our students continuing on into graduate school has been increasing, and we are retaining more of our best undergraduates. Much of that trend can be immediately traced to the introduction to students of senior research faculty in lectures to the intro classes, and the subsequent employment of undergraduates on research projects that interest them. Building on that interest and continuing into graduate research from undergraduate wage employment is a definite consequence of the familiarity with upper division faculty that did not occur prior to coordinating lectures by each as part of the introductory sequence.

## Conclusions

Through the discussion of the assessment of these courses and related curriculum changes, an effective process has been detailed that has been used through two major ABET evaluations, and that highlights the changing nature of the requirements established by assessment criteria. It is possible to continue to meet the changing needs of constituents in academia and industry only through a concerted effort, and thus repeated assessment and modification leads to a successful evolution of the program

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