ABET EC2000 Evaluation of the Aeronautical Engineering Program at the United States Air Force Academy

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Abstract

Results from the recent ABET visit and evaluation of the aeronautical engineering program at the United States Air Forcer Academy are presented. The ABET visit occurred on 3-5 Nov, 2002, under EC 2000 criteria and was rated Next General Review with a few observations stated. The purpose of this paper is to present the process used by the Aeronautics Department (DFAN), and to describe its effectiveness and impact on the program. Much of the information presented here in extracted from our 350 page Self Study Report, accessible at, http://www.usafa.af.mil/dfan/ABET_selfstudy. Copies of the Gateway Examination and the Comprehensives Examination, which are pre and post student program assessment instruments, plus other detailed information, can be requested from neal.barlow@usafa.af.mil.

Introduction

In preparing for our first program evaluation under ABET EC-2000, our first issue was to understand the EC 2000 criteria, particularly the elements and requirements of Criteria 2 and 3. The aeronautical engineering program at USAFA has been ABET accredited NGR since 1973, so our initial reaction to EC 2000 was: "we're already doing all these things, so all we need to do now is change how we document our work, right?" And, "this is just TQM coming around again, right?" Wrong! In fact, while we regularly conducted internal reviews of courses, and loosely assessed our graduates with an end-of-program examination, the assessment features now in place, and those that we believed we needed to have a successful ABET review under EC 2000, did not exist before 1998. Specifically, our program lacked definition of program objectives and educational outcomes. Aside from anecdotes, we had very little useful data to back-up our opinions. We had no identifiable external group of advisors to help us determine the performance of our graduates, or to help us define our program objectives. Courses in our curriculum lacked well defined educational outcomes, and little was being done to formally evaluate program effectiveness, the educational benefit to our graduates, and the professional benefit to the Air Force.

Things are different now. We have six program objectives that have been developed jointly with, and are regularly evaluated with our Engineering Program Advisory Council (EPAC). Our six program objectives are:

Graduates of the aeronautical engineering program at the United States Air Force Academy will:

1. Possess breadth of integrated, fundamental knowledge in engineering, basic sciences, social sciences, and humanities; and depth of knowledge in aeronautical engineering.
2. Communicate effectively.
3. Work effectively on teams and grow into team leaders.
4. Are independent learners committed to life-long learning.
5. Can apply their knowledge and skills to solve Air Force problems, both well and ill-defined.
6. Know and practice their ethical, professional, and community responsibilities as embodied in the United States Air Force Core Values.

We also have six statements that define our program educational outcomes.

Upon graduation, cadets will have demonstrated that they can:

1. Use fundamental knowledge to solve aeronautical engineering problems commensurate with a Bachelor of Science degree.
2. Plan and execute experimental investigations, and interpret and analyze data from such investigations to formulate sound conclusions.
3. Develop and evaluate an engineering design that meets customer needs.
4. Use oral and writing skills to communicate effectively.
5. Work effectively as a member of a multidisciplinary team.
6. Demonstrate the skills to engage in independent learning.

Moreover, each course in our curriculum (Figure 1) has similarly stated educational outcomes. We now use an assessment process that ties assessment data directly to educational outcomes. Our entire assessment process is maintained by our department oversight accreditation committee called TEBA; the structure and lines of responsibility for TEBA are shown in Figure 2.

Dash-1 Seminar - We have developed a better process for evaluating cadets as they enter and progress through the aeronautical engineering program. In August, we begin each academic year by hosting a kick-off seminar for junior and senior ranked cadets. Called the DFAN Dash-1 Seminar, our purpose is to review with our cadets the program objectives, outcomes, assessment activity, career opportunities, and scholarship programs. The format and agenda for a typical Dash-1 Seminar can be obtained from the web page, pages 253 and 266, respectively.

Gateway Examination - Approximately three weeks into the fall term, the junior ranked cadets are given a gateway examination to assess their performance on prerequisite knowledge in mathematics, physics, aeronautics, mechanics, and thermodynamics. Advisors use the gateway data to develop personal remediation plans intended to improve the needy-cadets' opportunity for successful completion of the upper division course work.

Comprehensive Examination - In the beginning of the 8th term, senior ranked cadets are given a comprehensive examination that assesses their knowledge of aeronautical engineering fundamentals taught in the junior and senior year courses. To become a more effective assessment diagnostic, the comprehensive examination is designed so that every question pertains explicitly to a particular educational outcome pertaining directly to one of the disciplines in the aeronautical engineering program. Each discipline director maintains a question-matrix that targets questions against stated outcomes for that respective discipline. Table 1 shown here presents a portion of the question-matrix for the Flight Mechanics Discipline; others are available from the web page, page 304.

Program Threads - Program threads are a new feature that grew out of our EC2000 development. Program threads provide instruction across our curriculum for knowledge and skills development in: (1) Communication. (2) Use of Modern Tools, and (3) Engineering Design. In practice, program threads provide cadets knowledge and skills gradually, a little bit at a time, in all courses in the curriculum. Near the end of the program, the capstone design and senior laboratory-courses (AE 481, AE 482, and AE 471) are used to put all pieces of the thread into a single product.

Communications Thread - The educational objective of the Communications Thread is:
Graduates will use professional writing and speaking skills necessary to communicate effectively.

We believe the process of developing effective communicators involves consistent and continuous development across the curriculum. Thus, instead of teaching technical report writing in a single course, the pieces of a technical report along with efforts to develop good writing skills are taught in several courses. One course may teach writing an abstract; another teaches writing a technical development to include equations and figures, and so on. The cadets do not write complete technical reports until they enter the senior laboratory or design courses.

The operational plan for the communications thread is shown below in Table 2. The components of a technical report are identified in the left column, and the courses are listed across the top row. The chart is color coded: Red signifies where a communications component is introduced to the cadets. Blue signifies where a communications component is repeated. Green identifies the final "teaching" experience. Yellow shows the location for component integration into a complete technical document or presentation.

Design Thread - The educational objective of the Design Thread is:
Graduates will use the engineering design process to solve problems and, as applicable, to produce engineering designs.

Design inherently involves framing and resolving ill-defined problems, problems that have no single "correct" answer, but require resolution from several considerations. Upon entering the aeronautical engineering program, the common approach cadet use to solve problems is based on finding the "single correct" answer by finding the correspondingly "single correct equation." The Design Thread begins intellectual transforming cadets' away from this approach to that of becoming an effective problem solver using the engineering design process, even for textbook homework problems.

The Design Thread begins with the freshman introductory engineering course, and concludes with the second course in the senior design sequence. Between these two courses, the Design Thread process provides design experiences in a small segments similar to the structure of the Communications Thread, the complexity of each segment increases with each new exposure to the process.

Modern Tools Thread - The educational objective of the Modern Tools Thread is:
Graduates will use modern tools routinely in their work.

Of the many tools available, DFAN focuses on three: (1) Spreadsheets (Excel). (2) Structured programming (MATLAB). (3) Applications packages. Specialized programming occurs for cadets choosing to emphasize computational fluid dynamics applications. Like the two other threads, the process for learning modern tools is woven throughout the curriculum beginning with the freshman introductory engineering course and culminating with extensive use of computational tools in the senior design sequence.

Below are presented overview comments extracted from our self study report regarding ABET Criteria 2 and 3. ABET wording is shown in italicized letters, to which our overview comments are presented as **DFAN Program.**

Program Objectives

ABET Criterion 2.

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

(a) Detailed published educational objectives that are consistent with the mission of the institution and the criteria.

DFAN Program - The USAFA mission statement is:

Inspire and develop outstanding young men and women to become Air Force officers with knowledge, character and discipline; motivated to lead the world's greatest aerospace force in service to the nation.

The institutional educational objectives, called the DF Educational Outcomes (Table 3 below), are seven statements that define the academic capabilities and the professional attributes desired in all cadets aspiring to be Air Force officers irrespective of academic specialization.

The DFAN Program Objectives are published in the USAFA Catalog, a document that is sent to high schools and libraries across the United States. These statements are also displayed in the department lobby and in the Aeronautics Laboratory, and they are published in the Aeronautical Engineering pamphlet (web page, page 253) that is distributed at Majors Night, a special program designed to help all freshman cadets select an academic major.

(b) A process based on the needs of the program's various constituencies in which the objectives are determined and periodically evaluated.

DFAN Program – Our program objectives were developed jointly by our faculty and by EPAC, the external supervisory component of our constituency comprised of commanders, chief scientists, and division and branch managers of the Air Forces engineering agencies to which the DFAN graduates may be assigned. Our program objectives are reviewed biennially by the department faculty and by EPAC.

(c) A curriculum and process that ensures the achievement of these objectives.
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DFAN Program - The process that ensures achievement of our program objectives is embodied in the administration of the aeronautical engineering curriculum. The DFAN curriculum (Figure 1) is comprised of six disciplines: (1) Aerodynamics. (2) Aerospace Materials and Structures. (3) Propulsion. (4) Flight Mechanics, Stability and Control. (5) Experimental and Computational Investigations. (6) Design. Each discipline is led by a senior member of the faculty called the discipline director.

Program Objectives: Assessment, Modifications, Continuous Improvement

Assessment Cycle - The assessment cycle for evaluating the program objectives is shown in Figure 4. The illustration pertains to the classes of 2002-2004; it begins with an electronic survey administered to the class of 2002 in January 2004. The assessment process repeats with electronic surveys being done in January 2005 for the graduates in the class of 2003, and again for a third time in the cycle in January 2006 for the graduates in the class of 2004. The assessment data for all three classes contribute to determining modifications to be enacted in August 2006. The last assessment survey of this cycle (Jan 2006) is also the lead assessment survey for next assessment cycle, thereby overlapping the previous cycle with one class-year.

The electronic assessment survey data are evaluated and reviewed during the spring term. At the end of the term, a report documenting DFAN's evaluation of the data is shared with EPAC. During the summer (Jun – Aug) EPAC is requested to perform a survey of the supervisors based on a list identifying graduates and organizations. In the fall term EPAC convenes biennially at USAFA to review both graduate and supervisor assessment data. Review of program objectives is also done at this meeting.

Following the EPAC Biennial meeting, DFAN begins constructing a plan to implement changes agreed upon at the EPAC meeting. Details to include changes to courses are developed for final review at the TEBA spring meeting. Following TEBA review, the implementation plan is approved by the Aeronautics Department Head to be enacted in August 2006, the start of the Fall term. At the annual DFAN Dash-1 meeting, the cadets affected by the changes are informed about the implementation plan.

Our assessment cycle for program objectives is long for two reasons. First, changes are based on assessment survey data collected for three classes thereby minimizing the affects of anomalous data from one particular class. Second, the assessment evidence collected to date (hard and anecdotal) indicate that the aeronautical engineering program consistently prepares cadets to demonstrate satisfactory performance with respect to the program objectives, so major changes are not anticipated.

Process for Modifying Program Objectives - During the fall term of odd-numbered years (2001, 2003, etc.), DFAN faculty members review the program objectives and make recommendations for amendments. Faculty reviews begin at the department division level where the faculty members assigned to a particular division discuss the program objectives. Summaries of the inputs from each division are given to the Director for Program Accreditation, who in turn, presents the division recommendations to TEBA. Afterwards, TEBA forwards the recommendations to EPAC for external review.

EPAC review of the program objectives is considered against the current Air Force needs in the applicable engineering disciplines. During the biennial EPAC meeting at USAFA, the program objectives and the performance criteria for each are discussed with regard to field-assessment practices and evaluation of assessment data. Also at the annual EPAC meeting, impacts stemming from revisions or pending changes to Air Force needs, institutional issues, and changes to existing ABET EC2000 Criteria or policies are discussed. As applicable, recommendations for amendments to the program objectives and the performance criteria are documented in the annual EPAC Memorandum.

Program Educational Outcomes

ABET Criterion 3

Engineering programs must demonstrate that their graduates have:

a. an ability to apply knowledge of mathematics, science and engineering (**5**).
b. an ability to design and conduct experiments, as well as to analyze and interpret data (**4.2**).
c. an ability to design a system, component, or process to meet desired needs (**4.8**).
d. an ability to function on multi-disciplinary teams (**4.0**).
e. an ability to identify, formulate, and solve engineering problems (**4.8**).
f. an understanding of professional and ethical responsibilities (**4.5**) .
g. an ability to communicate effectively (**4.8**).
h the broad education necessary to understand the impact of engineering solutions in a global and societal context (**3.5**).
i. a recognition for, and an ability to engage in life-long learning.(**3.8**).
j. a knowledge of contemporary issues (**3.5**) .
k. an ability to use techniques, skills, and modern engineering tools necessary for engineering practice (**3.5**).

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

DFAN Program – In 1997, DFAN drafted nine statements that defined the educational outcomes for the aeronautical engineering program. After faculty and EPAC review, the nine statements were adopted, and in 2000, they were reviewed, modified and reduced the six statements shown above. These six statements are specific to the aeronautical engineering program, concurrently support the Institutional Educational Outcomes, and are compliant with the ABET Criterion 3, a-k Outcomes. While all a-k Outcomes are fulfilled by the curriculum, DFAN places a relative importance for coverage on the a-k outcomes as indicated by the numbers in the parentheses to the right of each outcome, (5 = high priority, 1= low priority). These ratings are simple averages of several individual faculty ratings. Matrices that show the correspondences to program, institutional and ABET EC2000 criteria are presented in Chapter 3 of the self study report (see web page).

In addition to defining program level outcomes, DFAN recognized the need to develop course-level educational outcomes with assessable criteria. Phased in over two terms, this activity started in the fall term of 1997 and was completed in January 1998. Course-level educational outcomes provide guidance for instructors and cadets, as well as establishing direct ties to program educational outcomes. Since then, each set of course statements are routinely reviewed and updated at the start of the applicable term, and again at the CD Debriefs, details presented below.

Program Assessment, Evaluation, Continuous Improvement

Process – Assessing and evaluating the educational outcomes of the program is done using course evaluations (CD Debriefs), and the Comprehensive Examination described above. The process is illustrated in Figure 5 below.

The bridge between the semester cycle and the annual cycle occurs between the Discipline Directors and the Director for Curriculum. Approximately midway into the spring term, the Discipline Directors brief the status of their disciplines. Then at the annual Spring TEBA meeting, these reports along with other assessment data are used to make recommendations for program changes, which in turn, are presented to the Department Head for direction. Enactment follows a return path from the Department Head to the Director for Curriculum, then to the Discipline Directors, and finally to the Course Directors who enact the changes in the courses.

CD Debriefs - CD Debriefs are accomplished six to eight weeks into each term by the course directors of the courses conducted in the previous term. The CD Debriefs follow a structured format that link the course to the program objectives, the program educational outcomes, and the ABET Criterion 3, a-k Outcomes. Descriptions for the primary briefing charts is shown are presented Table 4, and Figure 6 shows the lead chart for AE 361 Propulsion I. Colored dots are used as quantifiers: Green means satisfactory, yellow means concerns or weaknesses exist, and red means deficiencies exist. The complete CD Debrief is presented in the web page, pages 294-303.

Summary

In 1997, DFAN began developing and implementing a comprehensive assessment plan that would help us make improvements to our program, and that would be compliant with ABET EC-2000. Our successful ABET program evaluation in Nov 2002 confirms to us that we have and use an effective program assessment process. We have program objectives that are consistent with the USAFA mission, and support our constituency. We have a comprehensive curriculum that provides every graduate the knowledge and skills needed to demonstrate attainment of the program objectives.

To highlight our present status, DFAN has:

(1) Worked interactively with an external body to define six program objectives.
(2) Formalized the external body into a structured working group who

regularly assists the Department in reviews and assessment efforts.
(3) Developed and installed an assessment process.
(4) Used assessment data to identify needs for program improvements.
(5) Developed plans for implementing program improvements.
(6) Developed a set of six educational outcomes that are measurable through assessment of companion program criteria.
(7) Developed an oversight committee responsible for program accreditation. This committee and the process used have evolved from continuous efforts within the Department to improve internal program reviews.

In preparing for ABET EC-2000, we made improvements to our internal program assessment policies and practices, and we improved our methods for evaluating cadets in the program. The design and use of our Program Threads offers opportunities for us further improve specific skills for our cadets: (1) Communication with emphasis on technical writing. (2) Use of modern tools. (3) Critical thinking manifested in engineering design experiences. We believe our current practices for program assessment will ensure continued and valuable effectiveness in the aeronautical engineering program at USAFA.

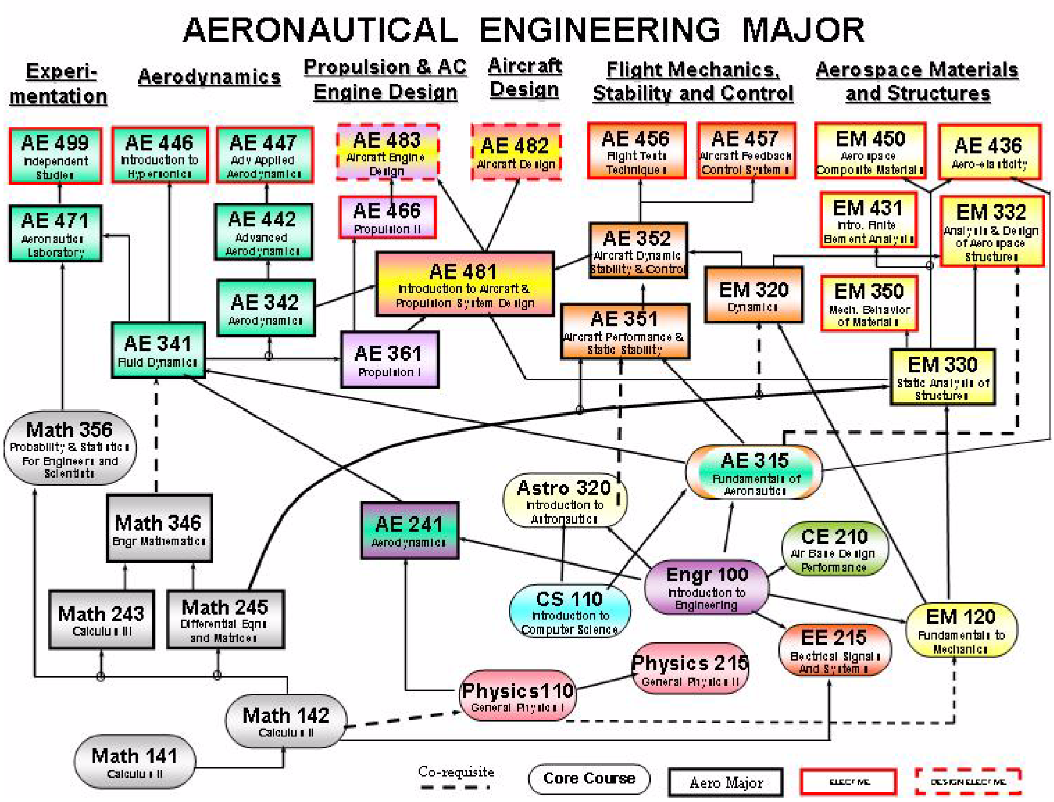

Figure 1 Aeronautical Engineering Curriculum at USAFA

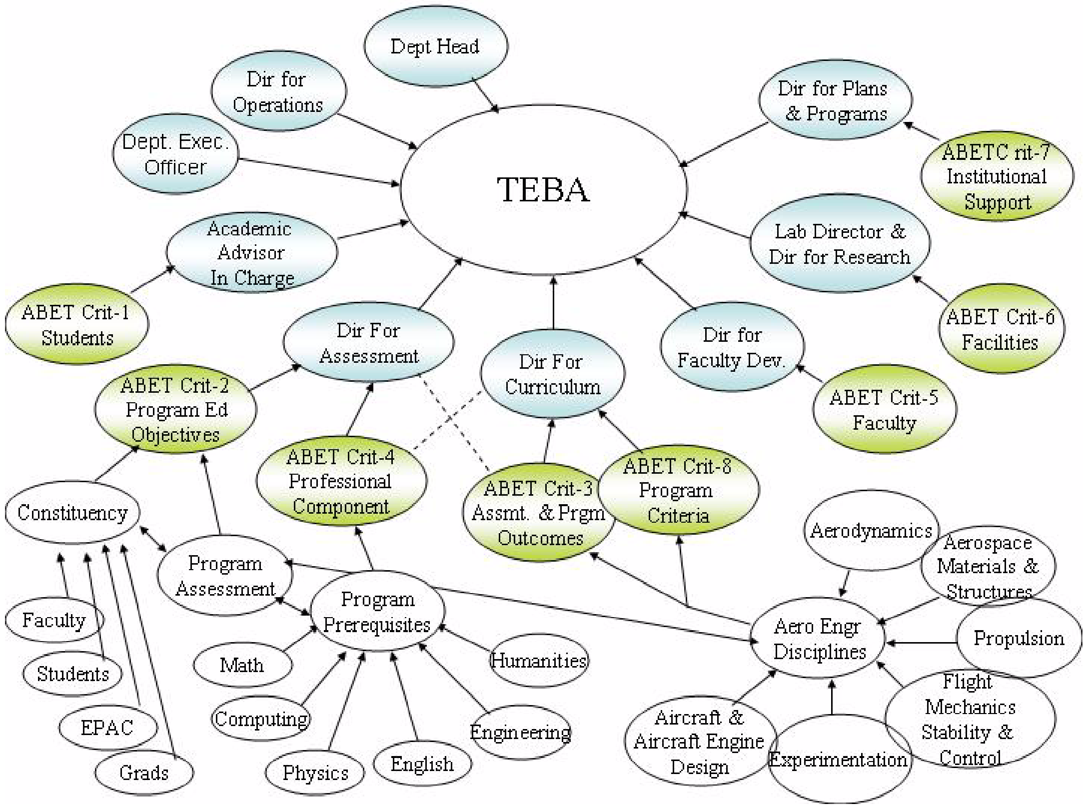

Figure 2 DFAN Assessment Oversight Committee

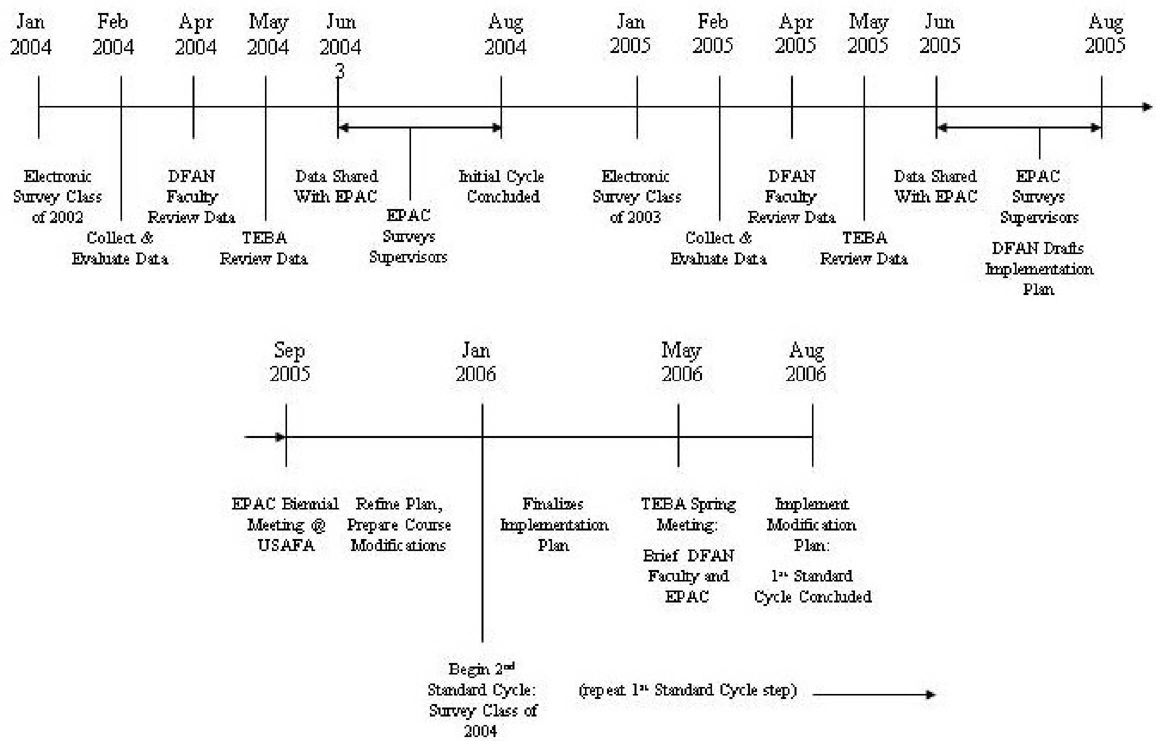

Figure 3 Program Assessment and Reviewed Cycle

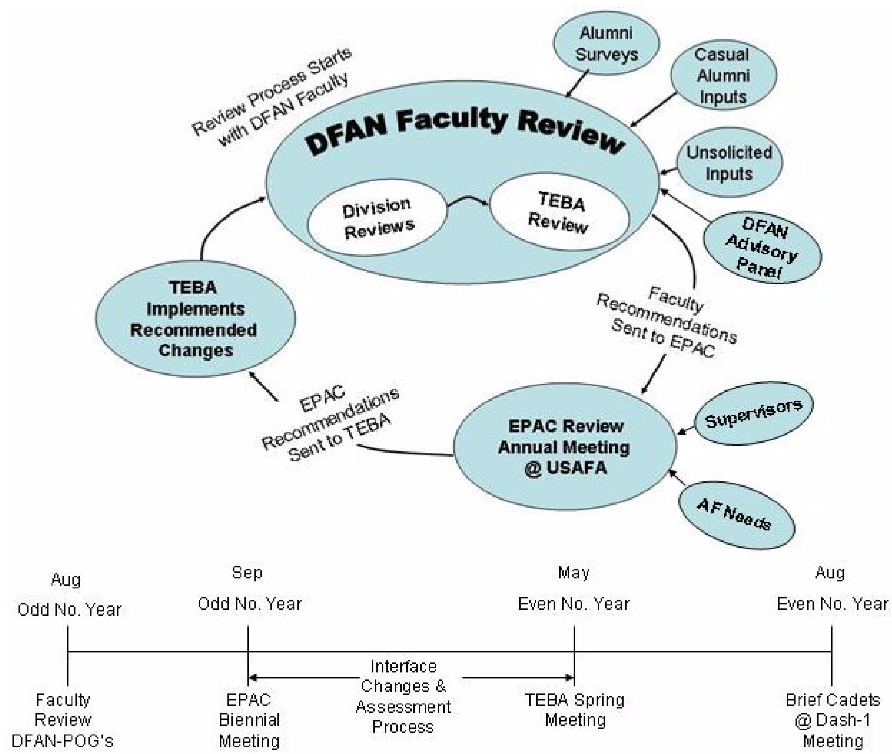

Figure 4 Process for Reviewing Program Objectives

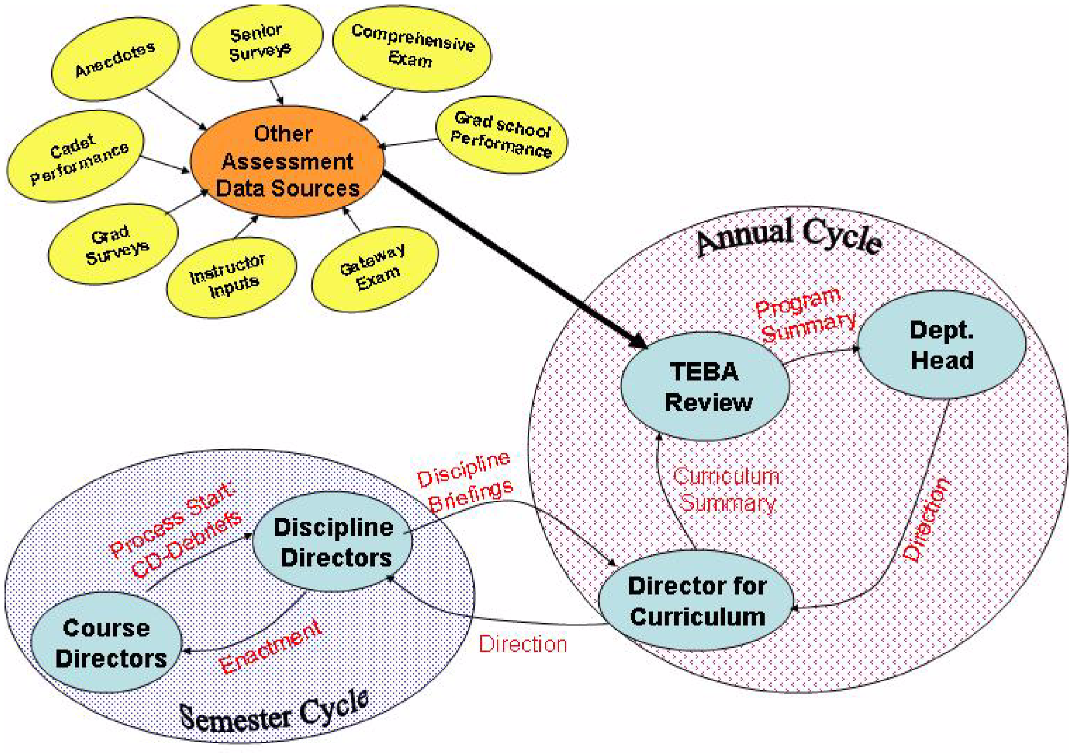

Figure 5 Process for Program Review, Aeronautical Engineering at USAFA

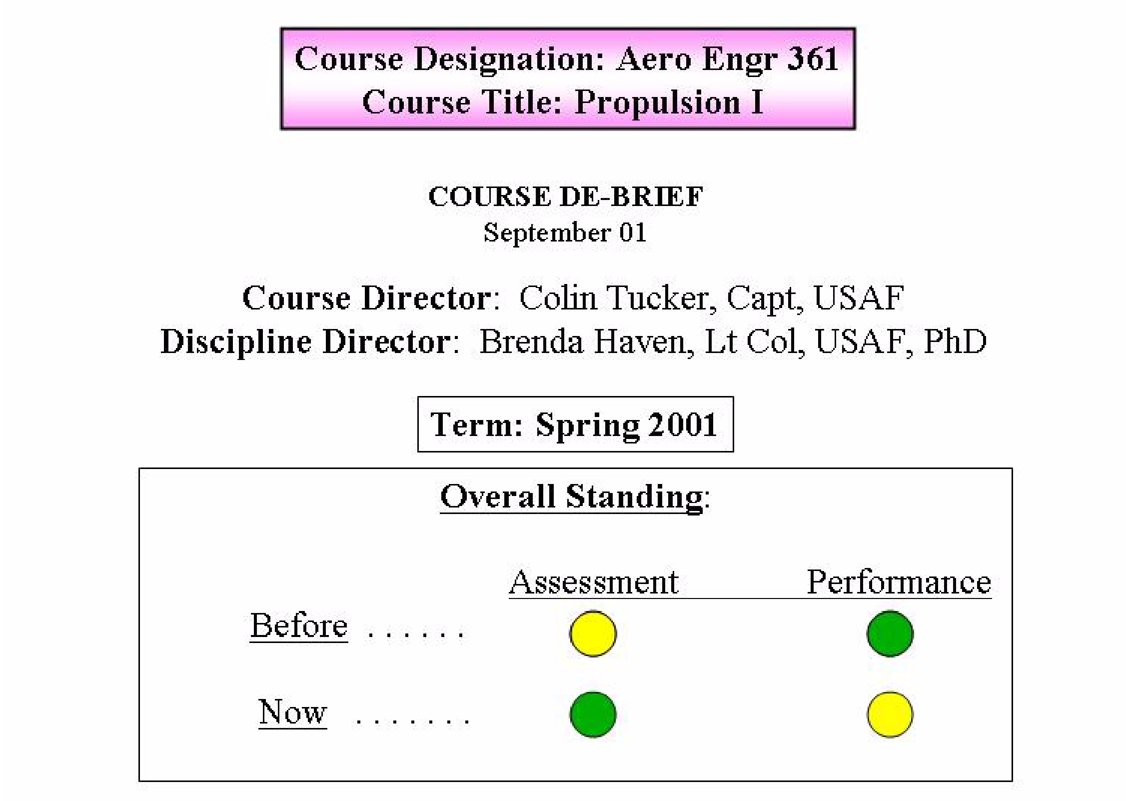

Figure 6 Lead Chart, CD Debriefings, Aero Engr 361 Propulsion I

Table 1 Comprehensive Examination Question Matrix for Our Flight Mechanics Discipline

ITEM	DISCIPLINE OUTCOME	QUESTION	COMMENT
1	Demonstrate an understanding of the fundamentals of aircraft performance, stability, control, and flight test	How many degrees of freedom does an aircraft have and how would you categorize them? a. 3; all rotation. b. 6; 3 translation and 3 rotation. c. 6; all rotation. d. 5; 3 rotation and 2 translation. e. 6; u, v, w, x, y.	AE315 / AE351 (38) This question targets students' understanding that the three translational-modes affect aircraft performance, and the three rotational-modes affect aircraft stability. Understanding these six modes forms the foundation for understanding aircraft flight mechanics. **Ans: b.**
2	Demonstrate an understanding of the fundamentals of aircraft performance, stability, control, and flight test	In general, how will fixed canards affect the static longitudinal stability of an aircraft? a. They tend to stabilize the aircraft. b They tend to destabilize the aircraft. c. They do not affect aircraft stability but have an effect on aircraft control. d. They do not affect aircraft stability or aircraft control.	AE315 / AE351 (40) This question targets students' understanding of longitudinal stability and how longitudinal stability is affected by the position of the aircraft aerodynamic center relative to the center of gravity. Canards cause the aircraft aerodynamic center to move forward, thus longitudinally destabilizing the aircraft. **Ans: b.**
3	Demonstrate an understanding of the fundamentals of aircraft performance, stability, control, and flight test	Increasing the size of the vertical tail on the F-16 would: a. increase its static directional stability (also called weathercock stability). b. decrease its static directional (or weathercock) stability. c. not affect static directional (or weathercock) stability significantly.	AE351 (45) This question targets students' understanding of directional aircraft stability. Aircraft static directional stability depends on the size (surface area) of the vertical stabilizer as well as the location of the vertical stabilizer's aerodynamic center from the aircraft center of gravity. **Ans: a.**
6	Demonstrate the ability to analyze and design simple aircraft and feedback control systems	If pitch rate is the parameter "fed back" in an aircraft feed back control system, the resulting aircraft response will be: a. an improvement in lift to drag ratio. b. a change in the aircraft's longitudinal dynamic stability. c. a decrease in stall speed. d. guaranteed positive longitudinal static stability. e. a change in elevator control power.	AE352 (53) This question targets students' understanding of feedback control systems. Students must recognize that aircraft motion parameters sensed by a control system are used to initiate a corrective action that will affect one or more aircraft dynamic stability modes. In this case, the question targets the aircraft's longitudinal dynamic stability. **Ans: b.**

Table 2 Communications Thread Matrix

TECHNICAL COMMUNICATION COMPONENT	AE3 15	AE 24 1	AE 34 1	AE 35 1	AE 34 2	AE 35 2	AE 36 1	AE 44 2	AE 47 1	AE 48 1	AE 48 2/4 83
"P" portfolio evaluated			P			P		P			P
TITLE PAGE	1	1		2					3		
TABLE OF CONTENTS				1					3		
LIST OF FIGURES AND TABLES				1					3		
NOMENCLATURE LIST				1					3		
ABSTRACT		1		2					3		
INTRODUCTION											
- Purpose				1	2				3		
- Background			1	2	2				3		
-- Literature search methods			1		2				3		
- Problem Description	1	1		2	2				3		
- Approach				1	2				3		
- Scope				1	2				3		
- Expected Results			1		2				3		
THEORY									3		
- Presenting equations			1	2			2				
PROCEDURES											
- Experimental	1		2				2	2	3		
- Computational					1	2		2			
- Figure Development		1		2		2	2		3		
RESULTS											
- Presentation	1			2	2	2	2		3		
- Depth	1			2	2		2		3		
- Comparison to theory / previous work					1		2	2	3		
CONCLUSIONS / RECOMMENDATIONS	1	1		2		2			3		
ACKNOWLEDGEMENTS	1	1							3		
REFERENCES			1	2	2				3		
APPENDICES				1				2	3		
ORAL PRESENTATIONS											
- Presentations Mechanics		1			2		2		3	3	3
- Content			1		2		2		3	3	3

KEY:	
FIRST OCCURANCE - HARD INSTRUCTION	**1**
ADDITIONAL OCCURANCE - INSTRUCTION / REINFORCEMENT / HARD GRADING	**2**
FINAL EVALUATION & INTEGRATION	**3**
COMPONENT INTEGRATION	

Table 3 USAF Academy Educational Outcomes

Educational Outcome	Description
Officers who possess breadth of integrated, fundamental knowledge in the basic sciences, engineering, the humanities, and social sciences, and depth of knowledge in an area of concentration of their choice.	Breadth of fundamental knowledge in these four domains is the essential foundation of intellectual competence and adaptability in a complex and changing world. More than knowing mere facts, integrated, fundamental knowledge refers to competence in solving basic problems characteristic of different disciplines and in discerning key interrelationships among disciplines. This knowledge-base must also provide graduates with an awareness of the technological, social, political, and economic complexities that awareness and the abilities described in the remaining outcomes.
Officers who are intellectually curious.	Beyond possessing knowledge and having abilities to put that knowledge to active use, graduates of the Academy must be inclined to do so. We want to develop an attitude of intellectual curiosity in our graduates that predisposes them to lifelong learning.
Officers who can communicate effectively.	Effective communication is the ability to transmit and receive information with a high probability that the intended meaning is passed from sender to receiver. This requires speaking, writing, reading and listening skills ad may involve symbolic forms as well as natural language, the use of various media and information systems, and the ability to communicate with varied audiences in impromptu as well as planned settings.
Officers who can frame and resolve ill-defined problems.	Ill-defined problems are ambiguous, interactive and ever-changing. Framing means constructing a working model, and revising it based on feedback. Resolving means that an ill-defined problem is never solved for good; rather it is solved again and again (re-solved) as the problem is framed again and again; and each successive solution is more refined (resolution).
Officers who can work effectively with others.	Officers work with people varying in rank, position, gender, race, attitudes, abilities, cultural background, etc. And they do so facing diverse tasks and demands. While there is no simple recipe for success, working effectively with others involves the ability to adapt to a wide variety of working relationships and challenges in ways that foster both mutual respect and long-term unit effectives.
Officers who are independent learners.	Learning independently does not imply learning along. Rather, it means a learner who has learned how to learn. Therefore, the learner can make valid judgments about what to learn and how to learn it, and is capable of assessing the results.
Officers who can apply their knowledge and skills to the unique tasks of the military profession.	This outcome sets us apart from other academic institutions. Our graduates must be able and willing to use the basic intellectual foundations provided by their education to master the art of war.

Table 4 CD Debrief: Chart Explanations

Slide No.	Title	**Description**
1	Cover	Shows the Course, term, and Overall Past and present Assessment Standings: green =satisfactory, yellow=concerns or weaknesses, red=deficiency
2	Linkage	show catalogue description, course goal, prerequisites, and target courses (the subject content of this course used in future courses).
3	Outcomes Map: ABET EC 2000, Criterion3, a-k Outcomes	Maps educational outcomes of course to ABET EC2000 Criterion 3, a-k Outcomes.
4	Outcomes Map: DFAN POG's	Maps educational outcomes of course to DFAN-Program Curricular Outcomes.
5	Assessment/Evaluation	Identifies assessment criteria for each course educational outcomes, the assessment instrument used, and average cadet performance indicators: green-satisfactory, yellow = concern or weakness, red = unacceptable performance.
6	Tracking	Lists problems and remedies. Tracks problems from previous briefings to ascertain improvements
7	Statistics	Presents grade statistics, plus fullness indicator level