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Progress Report on Grant NASA-NGT-10014

Aerospace Engineering Curriculum for the 21st Century

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The second year of the study was devoted to completing the information-gathering phase of the effort, using the conclusions from that activity to prepare the initial structure for the new curriculum, publicizing our activities to a wider engineering forum, and preparing the department faculty for the roles they will play in the curriculum redesign and implementation. These activities are summarized briefly below.

The progress report from last year discusses the procedure that was followed in developing a survey of aerospace professionals on what a new curriculum should include. The survey that was constructed based upon those efforts was distributed to more than 600 aerospace engineering professionals in government, academia, and industry during the late summer of 1994. By December of 1995, nearly 200 responses had been received, and these were entered into a database for ease of compilation. The data and the conclusions drawn from these data are summarized in the attached manuscript entitled "Educating Aerospace Engineers for the Twenty-First Century: Results of a Survey," which was presented at the 1995 ASEE Annual Conference in June (pp. 66-75 of Volume 1 of the Proceedings) and which has been submitted to the *Journal of Engineering Education.*

Among the conclusions from the survey results were the following: 1) The new curriculum must introduce more design content at an earlier level than is traditional for aerospace programs. 2) A means must be developed for providing instruction and experience in such nontechnical skills as critical thinking, technical writing, and oral presentation. 3) Integration of subject matter across the traditional disciplines of aerospace engineering must take place, but not as a substitute for a strong disciplinary background, which provides a disciplinary foundation for the students and is the basis from which the students can choose to specialize by taking additional elective courses.

The Long Range Planning Committee (LRPC) of the Department, which is responsible for carrying out the curriculum redesign, then organized a half-day faculty retreat (held in early April, 1995) to discuss these conclusions and to involve the entire Department faculty in the process of planning for the curriculum redesign effort. Using the input from these discussions, the LRPC began formulating the first structure for the new Aerospace Engineering curriculum. This structure includes a Design course sequence that will be required for all Aerospace majors, with the sequence beginning in the second year of UC's five-year engineering program, and continues with a course in essentially every academic quarter through the first two quarters of the senior year, when all Aerospace students are required to take 5 credit hours each quarter of a "capstone" Design course that involves designing (on paper) a complete aerospace system (either an engine, an airplane, or a spacecraft). This Design sequence is novel to Aerospace programs in the USA, which will make it a challenge to develop.

We summarized our efforts to date in two papers that were presented at the 1995 ASEE Annual Conference in June. One of these is cited above. The other paper, which describes the steps we have taken and the philosophy that we are using in developing the new curriculum, is entitled "Designing a New Aerospace Curriculum: The Process," (pp. 76-83 of the Conference Proceedings), and a copy of it is attached. Like the first paper cited, this paper has also been submitted to the *Journal of Engineering Education*. The presentations of both of these papers at the ASEE meeting spawned considerable comment and feedback, with the result that we have corresponded with colleagues at Rensselaer Polytechnic Institute, the University of Florida, the Naval Postgraduate School, and McDonnell-Douglas Aircraft on various aspects of our curriculum redesign. Additionally, members of the LRPC who attended the ASEE meeting were asked to participate in a forum discussion of future Aerospace education programs that was videotaped, and is now being distributed for sale, by ASEE.

We have also made presentations on our efforts to several UC faculty committees outside the Department, including the Curriculum Committee for the entire College of Engineering. The feedback we have received from these committees is uniformly positive, and we anticipate collaborating on part of the new curriculum development at the College-wide level.

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Educating Aerospace Engineers for the Twenty-First Century: Results of A Survey

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Abstract

This paper describes the results of a survey that was conducted by mail by the Department of Aerospace Engineering and Engineering Mechanics at the University of Cincinnati (UC) to determine the views of industrial, government, and academic aerospace professionals on the required content of future aerospace curricula and the skills that will be needed by aerospace graduates in the Twenty-First Century. The survey is one step in the ongoing process to redefine the UC Aerospace Engineering curriculum. The rationale underlying this process is described in a companion paper. This paper focuses on the contents of the survey, the results of the survey, and preliminary conclusions that have been drawn from these results. The survey included questions on such issues as introducing design experience throughout the curriculum and presenting subject matter on a more interdisciplinary basis than has traditionally been followed. The survey was constructed primarily to gather information specific to the UC curriculum redesign effort, but the results are relevant to aerospace programs nationwide, many of which are considering or pursuing similar redesign efforts.

Introduction

In 1992, a Long Range Planning (LRP) committee was formed from among the faculty members of the Department of Aerospace Engineering and Engineering Mechanics at the University of Cincinnati (UC). The charge of this committee was to examine the current UC Aerospace Engineering curriculum and to develop a strategy for revising it to respond to the needs of the "customers" for our Aerospace Engineering graduates after the year 2000. The activities of the LRP committee are described in a companion paper [1].

One result of the committee's work was the decision to survey aerospace professionals (including our own faculty) on what skills, in both technical and nontechnical areas, would be critical to the success of aerospace engineers in the early Twenty-First Century and on the means by which those skills would best be taught. Following considerable LRP committee planning and some discussions with experienced pollsters from UC's Department of Education and from the UC Institute of Advanced Policy Research, the decision was made to conduct first a preliminary phone survey of a selected number of aerospace professionals, and then to combine information from that exercise with input from the department faculty to arrive at a written survey that could be mailed to a reasonable cross-section of the aerospace engineering community. The phone survey and the LRP efforts to encourage and incorporate department faculty input are also described in the companion paper [1].

In this paper, we focus on the written questionnaire that was developed and the results of the mail survey. We conclude with some preliminary conclusions that were drawn from these results.

The Survey Questionnaire

As noted above, the specific questions for the survey were developed on the basis of data obtained from a preliminary telephone survey, which is described in [1]. The telephone survey data were used to formulate ten nontechnical skills and ten technical skills that the telephone survey respondents or department faculty mentioned as being important for future aerospace engineers. The written survey therefore included questions regarding the level of perceived importance of these skills. Comments on the telephone survey regarding the content of the curriculum were also used to formulate questions regarding the ideal content of a redesigned curriculum, the means by which the curriculum is taught, and the possibility of including some specific nontraditional areas of instruction in the curriculum.

The survey questionnaire consisted of six sections. The first section asked each respondent to provide information about him/herself including: educational background (highest degree held, year, field, and whether any degrees are in Aerospace with year and school), current job description, and technical discipline(s).

The second and third sections asked the respondents to evaluate on a seven-level scale the importance of providing training to future aerospace undergraduate students in each of the ten nontechnical areas and ten technical areas, which were determined by the

LRP on the basis of the phone survey data and input from the department faculty. The respondents were also asked to evaluate their preferred mode for providing the training in each of these areas on a seven-level scale ranging from classical, separate courses to an integrated, "across the curriculum" approach.

The ten nontechnical areas listed were:

Technical writing	Teamwork
Oral presentation skills	Leadership
Critical thinking	Library skills
Time management	Ethics
Cultural awareness	Goal setting and organization

The ten technical areas listed were:

Computer programming	Design skills
Computer simulation	Concurrent engineering
Modeling of physical systems	Graphics usage (excl. programming)
Problem definition	Statistical design skills
Mathematical analysis	Experimentation skills

The fourth section provided an approximate breakdown of the current UC Aerospace Engineering curriculum in terms of the proportion of effort spent on analytical, computational, experimental, and design training in each of the four primary aerospace disciplines (fluids, propulsion, dynamics and control, and structures and solid mechanics). For instance, the current fluids program was broken down as 50% analytical, 25%

computational, 20% experimental, and 5% design. The respondents were then asked to provide their "ideal" distribution by marking a percentage scale for each component in each of the disciplines.

The fifth section requested information on some specific changes in the aerospace curriculum that were suggested by phone survey respondents and which have been the subject of discussion recently among aerospace educators. The first question asked whether the traditional boundaries separating the training in the aerospace disciplines should be maintained, modified, or eliminated and requested comments on the answer. The second question asked whether design should be taught as a "capstone" course (as currently required by ABET) or spread throughout the curriculum (or some of both) and requested comments. Finally, the last question asked whether nontraditional areas that have recently become relevant to aerospace engineering should be included in a revised curriculum and asked specifically about human factors, concurrent engineering, and radar technology, and then requested the respondent to fill in any other areas.

Finally, the sixth section allowed respondents to volunteer to provide additional information later in our curriculum redevelopment exercise.

We formulated the survey such that it was easy to fill out, with most questions requiring the respondent only to circle a letter (or several letters), check a checkbox, put a mark on a preprinted scale, or fill in a bubble. This allowed the respondents to complete the survey in just a few minutes (more if they chose to write extensive comments) and it minimized the labor involved in entering the data from the responses into the database.

The Survey Respondents

As noted in [1], the survey was sent to all current members of several AIAA Technical Committees, numbering approximately 700 in all. **We do NOT claim that this group represents a scientific sample of the aerospace engineering community.** Therefore, our preliminary conclusions are not to be construed as scientifically based. However, members of AIAA Technical Committees are chosen with an eye toward representing the complete spectrum of interests in the aerospace community. Therefore, we feel that they represent a reasonably accurate cross-section of current aerospace interests.

Of the approximately 700 surveys that were mailed out, 215 were returned, yielding a return rate of approximately 31%. Professional pollsters on campus have indicated to us that 31% is a relatively high return rate, with 20% more typical. The high return rate might reflect the degree of commitment to the aerospace profession of people comprising the AIAA Technical Committees. In any case, we were gratified that a significant fraction of the surveys were returned, and we thank all of the respondents.

Of the 215 responses received, 24 were mangled in transit, incomplete, or provided information in a manner other than that requested. These responses were discarded from the analysis. The information from the remaining 191 responses, including the written comments, was entered into a Reflex 2.0 database for analysis.

The current jobs of the-191 respondents and the highest degree held by the respondents within each job group break down as follows:

Research & development:	43 (8 BS, 16 MS, 19 PhD)
Technical manager:	55 (15 BS, 31 MS, 9 PhD)
Educator:	55 (0 BS, 2 MS, 52 PhD)
Design:	8 (3 BS, 3 MS, 2 PhD)
Corporate manager:	7 (0 BS, 2 MS, 5 PhD)
Other:	23

The breakdown of the highest degree held by the respondents is:

93 PhD (with at least 48 in Aerospace)

65 MS (with at least 32 in Aerospace)

29 BS (with at least 13 in Aerospace)

4 other or unclear

The areas in which the respondents' highest degree was awarded included 97 in Aerospace Engineering, 41 in Mechanical Engineering, 11 in Engineering Science or Engineering Mechanics, 8 in Electrical Engineering, 5 in Chemical Engineering, and 6 in Physics or Mathematics. 121 of the respondents (63%) hold at least one aerospace degree. There are no more than 10 respondents holding aerospace degrees from any one university, and degree holders from at least 40 different aerospace programs are represented.

The average year for the highest degree awarded to the respondents is 1974. The respondents therefore have an average of approximately 20 years of working experience (assuming they have been working continuously in the field since their highest degree was granted). Broken down by highest degree, the average year of award for BS degree holders is 1969, 1975 for MS holders, and 1975.5 for PhD holders. It is interesting that only 14 of the 121 respondents holding aerospace degrees received their highest degree between 1970 and 1974, while more than 8, and frequently more than 10, received their degrees in <u>each</u> of the 5 years on either side of this period. This "gap" in the years that degrees were awarded to the survey respondents corresponds to the early 1970s downturn in the aerospace industry, at which time low enrollment was the norm for most aerospace programs.

The technical disciplines listed by the respondents reflect the diversity that has become prevalent in the aerospace field. Only 98 of the respondents indicated a single discipline while the other 93 indicated at least two disciplines. The following breakdown indicates how many respondents indicated each area as their only discipline and how many indicated each area as one of several disciplines:

Discipline	Only disc.	One of many
Fluid mechanics	32	48
Structural analysis	18	26
Dynamics and control	16	31
Propulsion	15	26
Systems engineering	16	29
Computer science	1	9
Mathematics	0	7

13 of the 16 unidisciplinary systems engineers are technical managers, but none of the systems engineers are educators. The propulsion discipline also produced a high fraction of technical managers (7 of 15) with only 2 educators. In contrast, more than 50% of the respondents indicating fluid mechanics, dynamics and control, or structural analysis as their sole discipline were educators. Among the multidisciplinary respondents, 14 of 93 identify propulsion and fluid mechanics as two of their disciplines. Fluid mechanics and dynamics and control is next with 9. No other combinations of disciplines included more than 6 respondents.

Notably, 115 of the 191 respondents provided their names and addresses to contact them for further information.

Survey Results

Table 1 shows the average (Avg) and standard deviation (SDev) of all responses to the questions on the survey regarding the importance of the ten nontechnical skills listed above. The results are listed here in order of the average importance assigned to each skill area, as opposed to the order on the questionnaire. Table 2 is the analogous table for the ten technical skill areas listed above.

Table 1. Average and standard deviation of responses on degree of importance (1 = highest) of technical skill areas and degree to which they should be taught in an integrated setting (7 = most integrated).

SKILL	Importance		Degree of Integration	
	Avg	SDev	Avg	SDev
Problem Development	1.81	0.97	4.28	2.01
Design Skills	1.87	0.97	4.66	1.94
Modeling Skills	2.09	1.08	3.52	2.03
Concurrent Engineering	2.37	1.25	4.92	1.82
Mathematical Analysis	2.51	1.16	2.43	1.51
Computer Programming	2.54	1.31	2.76	1.79
Computer Simulation	2.61	1.00	3.62	1.84
Experimental Skills	2.84	1.24	4.03	1.87
Graphics Skills	2.98	1.27	4.16	1.89
Statistics	3.14	1.20	3.22	1.72

Note that the nontechnical skills of critical thinking, technical writing, and oral presentation are given the highest average importance. Furthermore, all three of these skills are higher in average perceived importance than any of the technical skills. The average scores for the degree to which the nontechnical skills should be taught in an integrated setting show that the average respondent favors all but ethics be taught in an integrated setting. On the other hand, the average response for the technical skills tends to suggest teaching some of them in separate courses, in particular mathematical analysis and computer programming. Aside from these two, however, many of the technical skills produced average degree of integration responses near the middle of the scale, suggesting that formal coursework in these areas can be partially replaced by instruction in these skills in an integrated setting.

Table 2. Average and standard deviation of responses on degree of importance (1 = highest) of nontechnical skill areas and degree to which they should be taught in an integrated setting (7 = most integrated).

SKILL	Importance		Degree of integration	
	Avg	SDev	Avg	SDev
Critical Thinking	1.44	0.73	4.94	1.97
Technical Writing	1.61	0.89	4.15	2.10
Oral Presentation	1.77	0.95	4.68	1.93
Teamwork	2.05	1.12	5.73	1.70
Ethics	2.35	1.29	3.53	2.09
Goal Setting	2.47	1.08	4.52	1.96
Time Management	2.82	1.19	4.86	1.89
Leadership	2.91	1.26	5.30	1.69
Library Skills	3.54	1.35	4.73	1.82
Cultural Awareness	4.18	1.51	4.82	1.98

The standard deviations and distributions of the responses provide additional insight. The largest standard deviations in the importance responses were for cultural awareness, library skills, computer programming, ethics, and graphics. This suggests some disagreement on the part of the respondents regarding the importance of these areas. By the same token, a strong consensus exists regarding in particular the importance of critical thinking and technical writing skills. These trends are reflected in the distributions of the responses, which are shown in Tables 3 - 6 below.

Table 3. Distribution of responses on level of importance (1 = highest) of nontechnical skills. All values are percent.

SKILL	Response Distribution						
	1	2	3	4	5	6	7
Technical Writing	56	31	11	2	1	0	1
Oral Presentation	49	31	17	2	1	0	1
Critical Thinking	66	26	5	2	1	0	0
Time Management	13	26	35	21	1	2	2
Cultural Awareness	5	8	17	35	15	12	8
Teamwork	38	34	19	6	2	1	1
Leadership	14	26	30	21	6	3	1
Library Skills	5	13	33	28	10	8	2
Ethics	34	24	23	14	3	2	1
Goal Setting	18	38	28	14	1	1	1

From Table 3, we see that an overwhelming percentage of the importance responses were either 1 or 2 (highest importance) for the nontechnical skills of critical thinking (92%), technical writing (87%) and oral presentation (79%). The only nontechnical skills for which more than 6% of the importance responses were at the lowest three levels were leadership (9%), library skills (20%) and cultural awareness (36%).

Table 4. Distribution of responses regarding degree to which nontechnical skills should be taught in an integrated setting (7 = most integrated). All values are percent.

Skill	Response Distribution						
	1	2	3	4	5	6	7
Technical Writing	13	10	14	18	13	12	19
Oral Presentation	8	9	8	18	17	17	23
Critical Thinking	8	8	4	19	12	19	30
Time Management	6	8	6	21	14	16	27
Cultural Awareness	8	6	8	25	8	13	32
Teamwork	3	3	3	13	11	16	51
Leadership	4	4	3	16	18	23	31
Library Skills	6	9	6	26	14	15	24
Ethics	20	20	11	18	6	10	14
Goal Setting	6	10	9	23	14	15	22

The respondents indicate that most of the nontechnical skills should be taught as part of an integrated curriculum. The exceptions to this are ethics, for which more than 50% favor the formal course approach, and technical writing, where the responses are almost evenly distributed across the degree of integration response range.

Among the technical skills, Table 5 shows that the overwhelming majority of respondents name problem development, design skills and modeling as the areas of most importance (79%, 75%, and 73%, respectively, of responses either 1 or 2). The only technical skills with at least 8% of the importance responses at the lowest three levels are graphics (11%), statistical skills (9%), computer programming (9%) and (surprisingly) experimental skills (9%). No other technical skill has more than 4% of the responses at

Table 5. Distribution of responses on level of importance (1 = highest) of technical skills. All values are percent.

Skill	Response Distribution						
	1	2	3	4	5	6	7
Computer Programming	25	30	23	14	7	2	1
Computer Simulation	16	27	39	16	2	0	0
Modeling	34	39	17	6	4	1	0
Problem Development	48	31	15	4	1	1	0
Mathematical Analysis	23	28	31	15	2	2	0
Design Skills	45	31	18	5	1	1	0
Concurrent Engineering	29	29	24	14	1	2	1
Graphics Skills	10	25	33	19	9	2	1
Statistical Skills	8	18	38	26	5	4	1
Experimental Skills	13	29	35	15	5	3	1

the bottom three importance levels.

Regarding the instruction of technical skills through formal courses vs. an integrated approach, Table 6 shows that the responses give clear indications for some skills and show considerable disagreement on others. A large majority of the respondents indicate concurrent engineering and design skills should be taught in an integrated setting. Large majorities also favor teaching mathematical analysis, computer programming, and statistics through formal courses. For the other technical areas, the indication is not so clear, with experimental skills producing the most ambiguous responses.

Table 6. Distribution of responses on degree to which technical skills should be taught in an integrated setting (7 = most integrated). All values are percent.

Skill	Response Distribution						
	1	2	3	4	5	6	7
Computer Programming	27	27	12	17	5	5	5
Computer Simulation	13	19	14	22	12	10	9
Modeling	20	20	12	18	6	13	11
Problem Development	10	14	11	22	10	13	20
Mathematical Analysis	30	35	12	14	4	3	3
Design Skills	10	6	7	23	13	18	23
Concurrent Engineering	6	5	9	20	15	19	26
Graphics Skills	9	14	14	24	11	11	17
Statistical Skills	18	22	16	23	7	7	6
Experimental Skills	10	14	15	21	11	20	10

When the results just summarized are broken down by highest degree received, year of highest degree, the field of the highest degree, or the current technical discipline, differences among the groups of respondents are not apparent. However, the breakdown of the responses between educators and noneducators produces some significant differences.

The first of these differences is the high degree to which academic respondents indicate that the listed skills, both technical and nontechnical, should be taught in an integrated instructional setting. Every skill (with one notable exception) reflected this trend on the part of educators. Let the statistical significance of the difference in any result be defined as the difference between the two average responses divided by the standard deviation of all responses. Then the most statistically significant response differences between educators and noneducators occur for the degree to which an integrated setting should be used to teach oral presentation, ethics (second largest statistical difference), goal setting, time management (largest statistical difference), problem development, concurrent engineering, and experimental skills. The experimental skills responses are noteworthy because they are the single exception to the pattern, in that academic respondents indicate more of a preference for a formal, course-based approach to teaching these skills than did the noneducators.

Notable also are differences between educators and noneducators in their assignment of priorities to the various skills. In particular, educators attach considerably more importance to library skills, modeling skills and mathematical analysis skills than noneducators and less importance to concurrent engineering. The average importance responses for educators also indicated less perceived importance than the nonacademic responses for every nontechnical skill except ethics and library skills and more importance for every technical skill except concurrent engineering.

Table 7 summarizes the responses to the questions in Section 4 on the makeup of the curriculum. Altohough the standard deviations of the responses preclude definitive conclusions regarding an ideal breakdown, the respondents clearly indicate a preference for more design content than the current program includes in all four disciplines, particularly Dynamics and Control and Structures and Solid Mechanics. Considerably more experimental content is also suggested in Dynamics and Control. Apparently, the

Table 7. Responses (in percent) on ideal curriculum content for each disciplinary area and comparison to the current UC Aerospace Engineering curriculum content (CC).

	CC	Avg	(SDev)		CC	Avg	(SDev)
Propulsion / Heat Transfer				Dynamics / Control			
Analytical	45.	42.1	(11.4)	Analytical	60.	49.9	(11.8)
Computational	15.	21.2	(12.8)	Computational	25.	25.8	(12.2)
Experimental	30.	25.4	(9.9)	Experimental	5.	14.9	(10.7)
Design	10.	19.2	(11.9)	Design	10.	20.6	(12.3)
Fluid Mechanics / Aerodynamics				Structures / Solid Mechanics			
Analytical	60.	44.9	(12.1)	Analytical	50.	47.7	(11.7)
Computational	10.	26.0	(12.8)	Computational	23.	21.5	(13.2)
Experimental	20.	24.4	(10.8)	Experimental	23.	19.5	(9.0)
Design	10.	16.1	(14.3)	Design	3.	20.6	(14.1)

increase in design and experimental content should replace some of the analytical content in Dynamics and Control, where a significant reduction is suggested. Also, the responses suggest a significant increase in the computational content in Fluid Mechanics and in Propulsion and Heat Transfer. For Fluid Mechanics, a large decrease in the analytical content is suggested, while in Propulsion and Heat Transfer a significant reduction in experimental content is apparently desirable.

One interesting (perhaps ironic) note on the results regarding content: The average survey response values in each discipline sum to a value greater than 100%, typically around 110%. Interestingly, in all four areas, the average response values for noneducators sum to a larger value than those of educators. Some educators might argue that this reflects a real paradox, namely that industry and government want educators to provide undergraduates with 110% of the engineering education that they currently get in 90% of the time now required.

Table 8. Percent for each response regarding elimination or retention of discipline boundaries.

	All	Noneducators	Educators
Eliminate	12.0%	13.2%	9.1%
Modify	48.2%	50.7%	41.8%
Eliminate or Modify	0.5%	0.7%	0.0%
Retain	35.1%	32.4%	41.8%

Table 8 summarizes the responses to the question regarding the elimination, modification, or retention of current discipline boundaries. A majority suggest eliminating or modifying the boundaries, but 35% suggest retaining them. This is a bit surprising because the phone survey results suggested that a large number of the respondents would strongly indicate the need for interdisciplinary education.

Apparently, what is considered the best scenario by a significant fraction of the respondents is cross-disciplinary training for the students without necessarily eliminating the boundaries between disciplines. This is reflected in the comments that accompany the responses to this question, several of which suggest that each student should acquire a strong background in a particular discipline, but should also be involved in interdisciplinary educational activities, with team design and team problem solving sessions mentioned in several comments.

Table 8 also shows the breakdown of the responses from educators and noneducators, which again is the only distinction among the respondents that appears to produce a significant difference in the results for this question. A significantly larger percentage of the educators favor retaining the discipline boundaries, though a number of these respondents also made comments regarding the inclusion of interdisciplinary experience in the curriculum.

Table 9. Number of respondents indicating each answer on question regarding design across the curriculum, broken down partially by current job. Values are number of responses.

	All	R&D	Tech. Mgr.	Educator	Other
Across curriculum	106	22	39	23	22
Some of both	65	14	11	28	12
Capstone	18	7	5	4	2

Table 9 shows the responses for a question regarding the best means for teaching design. These responses are partially broken down according to the current job of the respondents. Only a small minority believe the capstone design course approach, which is used in many current aerospace curricula including UC's and is the current ABET requirement, is the best approach. Overwhelmingly, the respondents favor the integrated approach or at least some of both (with the comments mostly suggesting that open-ended problems be examined throughout the curriculum and that a capstone course still be required). The comments also suggest the introduction of open-ended design experiences into the curriculum as early as possible. Interestingly, educators seem to have the more conservative view here, with a small majority favoring a little of both approaches.

Finally, on the question of adding nontraditional areas to the aerospace curriculum, the responses regarding the three areas listed on the questionnaire are presented below:

Include?	Yes	No	Other
Human factors	45%	46%	9%
Concurrent engineering	66%	29%	5%
Radar technology	18%	69%	13%

Other areas that are mentioned in the comments accompanying this response include (in approximate order by number of appearances, which are indicated in parentheses): Manufacturing (11), Economics/Cost Analysis (9), Ethics (7), Business and Marketing (6), and Systems Engineering (5).

Conclusions

Note again that no attempt was made to survey a scientific sample, nor has statistical significance been evaluated for the results presented here. Nevertheless, the survey results do suggest some cautious conclusions.

One conclusion is that high levels of importance are attached to instruction in several nontechnical skills (critical thinking, technical writing, and oral presentation in particular) that are not emphasized in most current aerospace curricula. Some of these skills are considered even more important than some of the technical skills that are traditionally taught in aerospace curricula. Furthermore, aerospace professionals who are not educators place an even higher level of importance on these nontechnical skills than educators do. On the technical side, problem development and modeling skills are considered very important, along with design skills, which are discussed further below. On the other hand, experimental, graphical, and statistical skills are not considered to be as vital, nor are the nontechnical skill associated with library research and cultural awareness.

Another clear conclusion is that more emphasis should be placed on developing the students' design skills, in particular by introducing them across the curriculum instead of confining them to a single capstone course, although the consensus appears to be that some form of capstone experience should still be included. This essentially agrees with the educational philosophy that underlies the current redesign approach to the UC Aerospace Engineering curriculum.

Finally, the results indicate that there is a wide range of opinions on how best to present the desired skills in the curriculum. The results indicate that our current curriculum does not include enough design in essentially all areas and that more experimental or computational content is desirable in certain areas with less emphasis on analysis. The results on including new areas in the curriculum are inconclusive.

We continue to analyze the survey data to draw further insight on the appropriate direction for our curriculum redesign effort. One possibility that the LRP committee is considering is to follow up with those respondents who indicated they would be willing to help further. This would clarify some of the points suggested by the survey responses, and it would help to solidify the list of specific topics that must be included in a redesigned aerospace curriculum and the means by which they should be included.

Acknowledgement

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References

[1] P.D. Orkwis, S.M. Jeng, B.K. Walker, G.L. Slater, P.K. Khosla, and G.J. Simitses, "Designing a New Aerospace Curriculum: The Process," 1995 Annual Conf. Proc. (Anaheim), ASEE, June 1995.

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Designing A New Aerospace Engineering Curriculum: The Process

by
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Abstract

The Aerospace Engineering curriculum revision currently in progress at the University of Cincinnati is described. The rationale for change and the associated faculty mandate to support such change are described, including the development and improvement of a guiding educational philosophy. A brief description of the techniques used to survey the state-of-the-profession from the viewpoint of an internal and external knowledge base of academic, industrial and government experts is then included. However, a discussion of the results of these surveys is presented in a companion paper. The development details of the new curriculum and the approach taken to immerse both faculty and administrators in the processes of change are described. Discussions of the anticipated curriculum improvement benefits, the potential pitfalls and the metrics of success are also included. It is anticipated that the dissemination of the knowledge gained from this experience will guide successful improvements in other aerospace engineering programs.

Introduction

During the Spring of 1992 a volunteer committee was formed in the Department of Aerospace Engineering and Engineering Mechanics at the University of Cincinnati for the purpose of Long Range Planning (LRP). This committee was ostensibly formed for the purpose of overall departmental direction, including the revision of both the undergraduate and graduate curricula. The undergraduate curricula were chosen to be revised first because of the following imperatives:

1. Our curriculum has not changed appreciably since the dawn of the jet age.

2. Aerospace engineering is a particularly dynamic field, with novel challenges that have becomes more demanding with each generation of engineers.

3. Space engineering is an emerging field that has not been adequately addressed by most aerospace curricula, including our own.

4. Total high school and college enrollments are declining, while education has become more expensive.

5. Total quality principles have not been extensively applied to most engineering curricula.

These items have spurred the LRP committee to reexamine the relevance of our current curricula in relation to what our "customers," accreditation groups, and colleagues at other universities view as important.

This paper describes the efforts undertaken at the University of Cincinnati to explore, develop and revise our Aerospace Engineering curriculum. This begins with a brief review of other notable efforts at similar institutions; our experiences in using these data to start our process of change; the development of an education philosophy to guide our efforts; the approach we took to ask the "right" questions of ourselves and our peers; our current actions to develop a new and improved curriculum; and finally the methods used to generate support for these efforts, both within our own faculty and administration, and from outside funding agencies.

Background

Curriculum revision has taken place many times at virtually all universities. Therefore, it is not the intent of this paper to provide a history of this process, but rather to highlight the efforts of our peers that have directly affected our approach to change.

To that end, the Massachusetts Institute of Technology (MIT) has reported probably the most talked about changes in their approach to education[1,2]. Paramount to this change is the recognition that aerospace engineering is a systems effort and hence is product based. Their proposed curriculum is based, like most others, on fundamental or "core" courses. These courses support the "pillar" courses that are directly associated with certain aeronautics or space related disciplines. The final "capstone" layer consists primarily of the typical final design course. What is different about this approach is the choice given to students at the pillar course stage. This was mandated by the strategic plan of the school which apparently favors depth as opposed to breadth. The pillar courses are divided into six disciplines and a student is basically required to take courses in at least three of these, while upper level electives can be used potentially to take course in the other disciplines. This differs from many other programs which require exposure to all taught disciplines. This apparently produces a program that does not rigorously satisfy the ABET accreditation criteria. However, the MIT faculty state that if their program does not satisfy the accreditation criteria they will pursue accreditation as an experimental program.

A second example of change comes from the University of Maryland[3] which also stresses the integrated design of the aerospace vehicle. Choice in this program is provided by a split between the aeronautics and astronautics tracks and hence is at a broader level than that in the MIT approach. This can be considered a less ambitious change than that at the MIT but does apparently still satisfy the ABET criteria.

A somewhat smaller scale revision was undertaken at the Air Force Academy (AFA)[4], in which total quality management (TQM) principles were applied to the thermodynamics course. The authors pointed out that whereas TQM has been applied at many universities, it has been implemented primarily at the administrative level and not in the classroom. This should prove to be an interesting experiment as the AFA thermodynamics course is not provided solely to engineers; virtually their entire student body takes this course. Also, as a core course it is typically less popular.

What becomes clear from even the above brief review of approaches is that there are many possible aspects, levels, and approaches to change. The curriculum optimization problem must include the talents of the current faculty and the desired directions that a department wishes to take. For these reasons the next step in the process was the development of an education philosophy to use as a set of guiding principles for curriculum revision.

Educational Philosophy

In the authors' minds the educational philosophy was the transformation of the driving forces for change into useful information. The eventual philosophy came from what each individual initially felt and was modified based on the detailed discussions of the committee. This input took into account those efforts described above and added a decidedly University of Cincinnati flavor. The committee believe that a philosophy for a sound educational experience in aerospace engineering should include

1. A co-op experience to instill appreciation of current engineering practice in industrial, government and academic facilities.

2. High quality education in the fundamentals of mathematics, basic sciences and engineering sciences.

3. High quality education in a broad spectrum of disciplinary topics.

4. Experience in creative synthesis, ie. the application of disciplinary knowledge to solve open-ended problems. This experience should occur in each year of study (Freshman to Senior) and be commensurate with the student's problem solving background.

5. Hands-on laboratory and computer experience in all major disciplines to familiarize and expose students to current experimental techniques, state-of-the-art instrumentation, and computers.

6. Clear presentations of what engineering is and what it takes to be an engineer. This should begin at the Freshman level and continue throughout the degree program.

7. Faculty development and reeducation. Each year a subset of the faculty will take courses and/or work with professionals in emerging areas.

The above philosophy represents the first step in revising the curriculum. It reflects the University of Cincinnati's tradition in cooperative education and a view of what the educational experience should be. It is equally applicable to other engineering disciplines and as such is not strictly an aerospace perspective. However, it is only the basis for change and as such does not provide details. The development of the philosophy also made it clear that the tough questions were yet to be asked.

Surveys

To implement the above philosophy the committee still needed to ask the question; what do we need to know to improve? It was determined that the perspective to this point was based primarily on academic input, and that the voices of the engineers in the field and their employers, the users of our product, had not been heard. However, it proved to be very difficult to decide what information was actually needed for improvement. From a course development point of view, it was first proposed that we survey individuals on the topics that should be covered in the ideal curriculum. However, this was deemed to be not enough information and it was decided that questions about the necessary skills must also be included. The emphasis shifted many times in the deliberations because the committee was determined to produce a quality survey that would

1. provide useful information,

2. take as little time to fill out as possible,

3. require relatively little effort to compile.

The efforts became even more complicated when the committee undertook the task of designing the survey questions. After several unsuccessful attempts it was decided that the committee should seek the advice of experts at the university. This proved to be quite useful since we as engineers are not in the business of writing surveys. It also enlightened the committee to the effort that would have to be undertaken to prosecute such a detailed information gathering exercise. The committee then agreed to undertake a trial survey to see just how the process might work.

Phone Survey

It became clear that a large scale survey of aerospace engineers would have to be conducted by mail, because of the volume of responses and the potential for surveyor interpretation. However, it was decided to perform a preliminary survey over the phone to help structure the larger effort. The general approach was to ask each committee member to contact three persons, one from a government lab, one from industry and one from academia. The process began by sending an introductory letter to each participant advising of the upcoming call and detailing the questions that would be asked. In this way those surveyed would have a chance to consider the details of the question and give a considered opinion. The surveyor was then instructed to call and to allow the participant as much time to answer the questions as possible. In that way, the conversation would not be skewed toward the preconceived notions of the questioner. In addition, the surveyor was asked to record all of the comments at the time of conversation or shortly thereafter. All committee members made their calls and the comments were sent to one member for compilation.

The questions themselves were written in as open ended a manner as possible, so that as much new information could be obtained. In this way, ideas other than from committee members would be obtained. The following four questions were asked:

1. What technical skills will aerospace engineering/engineering mechanics graduates beyond the year 2000 need?

2. What technical topics must be included in courses to develop these skills?
3. What nontechnical skills will aerospace engineering/engineering mechanics graduates beyond the year 2000 need?
4. What nontechnical topics must be included in courses to develop these skills?

It should be noted that this survey was conducted for both the aerospace engineering and engineering mechanics programs, although the larger survey was conducted only for aerospace engineering.

The answers to this survey were quite informative and helped to guide the development of the larger survey. Considerable detail was obtained about each topic, which generated an analysis phase to attempt to quantify the responses. Hence, the first lesson learned for the larger survey was to ask questions with a numerical answer. The answers to the above questions were grouped into similar responses under each category. This proved reasonably easy to do but began the first phase of interpretation, in that answers similar to that interpreted by the data reviewer might not be similar to what those surveyed had in mind. This became more apparent when the interviewer was asked to reread their comments and try to assign a numerical value to each topic/skill to ascertain relative importance. This helped to quantify the obtained data but began to blur the effectiveness of the survey as it became less scientific. Even so, the results obtained from the phone survey closely mirror those obtained with the larger survey. However, because of the potential for interpretation biases these results will not be reported.

Faculty Survey

Although the phone survey results were not considered final, they did provide a basis for evaluating potential questions for their effectiveness in obtaining the desired information. It was decided that the phone survey information should be augmented by input from our own faculty. Although not highlighted earlier, **faculty input must be sought at each stage of the revision process.** Hence, this became an ideal time to pursue faculty interaction. As such, the respective disciplinary groups within the department were asked to meet to brainstorm the technical topics questions. These meetings took place over a few weeks time. The faculty was then brought together as a group and split up into smaller groups that each contained at least one member from the respective disciplinary areas. Committee members served as facilitators. This approach was quite successful at generating interest and additional perspectives. However, it was again rather nonscientific and hence the results of those meetings will not be resported here.

The general results of the phone and faculty surveys were then compiled by the LRP committee members. The lessons learned about surveying and the opinions drawn centered primarily on the idea that the large survey should seek to answer questions about skills rather than topics. If after this survey additional information was required a new survey could be developed. The preliminary surveys also showed how important it is to ask simple questions that can be answered numerically rather than in writing. The data from the three person per member survey was quite extensive and required several hours to read thoroughly. This approach was a good way to gain significant insight into the opinions of those questioned, but did not help to reveal larger trends. In addition, it focussed the committee members on determining the questions needed to gain the necessary information for curriculum renewal.

Larger Survey

The results of the above surveys made it apparent that a larger survey was needed. It was agreed that the large survey should provide some input about the importance of the current disciplines and the need for cross discipline training, but should focus primarily on skills and the approaches needed to teach those skills. In each individual discipline the survey would ask what aspects were most important, ie. should the discipline be analytical, computational, experimental, or design oriented. However, no questions would be asked about what topics should be included. A rather extensive list of skills was developed from the previous surveys. Skills questions then involved learning what those surveyed thought of the relative importance of each skill and how those skills should be included in a curriculum, ie. separate courses or within other courses.

These questions were asked in as simple a manner as possible to allow easy compilation of data. In addition, a small amount of space was provided to allow for comments. The details of these questions and the results obtained are found in the companion paper[5]. The results will be used to aid the faculty in curriculum development decisions and in the development of more in depth surveys if necessary.

Those Surveyed

Of importance to any survey is who to ask. The preliminary surveys were quite biased in that those questioned were all personal acquaintances of the committee members. It was felt that a broader spectrum of practicing engineers was needed to allow other perspectives. However, it was recognized that too broad a spectrum would run the risk of producing the opinions of too many nonaerospace engineers. On the other hand, that might be desirable because not all aerospace professionals are aerospace engineers. It was decided that the most appropriate approach would be to make use of those members of the aerospace professional society, the American Institute of Aeronautics and Astronautics (AIAA). However, the membership roles number in the thousands and it was determined that that large a sample size would be unnecessary. Rather a more appropriate sample might come from a smaller more involved set of AIAA members, those on technical committees. Hence the survey was sent to all individuals who were currently on the roles of appropriate AIAA technical committees.

It is the opinion of the authors that these surveys were extremely valuable to the curriculum revision process. However, it is just a part of the overall effort to revitalize the aerospace curriculum. A more general description of the total process follows.

The Curriculum Revision Process

The motivation, direction and information gathering aspects described above were the preliminary steps needed to begin the curriculum revision process. The more difficult task of changing courses remains. However, the approach to change has been well thought out, albeit the details have yet to be determined. With this in mind, it should be noted that the survey process is an ongoing one. The LRP committee is committed to a continual reassessment of external opinion to gauge performance. Additional surveys are expected that will be geared toward understanding the various remaining issues related to the initial curriculum revision. In addition, a state-of-the-profession survey will likely be needed every five to ten years to ensure a relevant curriculum. Deliberations with the faculty are currently in progress at the time of this writing.

The curriculum revision itself will be prosecuted on a year to year basis. That is the freshman class entering in the 1996-97 academic year will be the first to experience the new curriculum and changes will coincide with their progress. This approach allows a more gradual introduction of wholesale changes, since the earlier years are dominated by core courses taught outside the department. However, an alternative first year has been proposed for the incoming aerospace students to test the new ideas on a trial basis. Successful implementation will then be transferred to the remainder of the college.

The entire process will require five years (UC is a 5 year program) for the implementation of the initial changes and will involve roughly five to six faculty members designing new courses per quarter. The initial revision for a given year will likely be followed up by a second revision to correct any deficiencies. Since UC is on a split year program due to the mandatory coop, this revision will take place immediately after the new courses are taught for the first time. It will likely require the services of at least two faculty members and will form the basis of a continual quality improvement program.

Another continuing improvement effort will involve faculty retraining. Clearly, even if a new curriculum and courses were developed by committee members, the entire faculty must still teach those courses. Hence, the improvements will only be as good as those delivering the education. Therefore, the faculty will not only be involved directly with curriculum changes during the revitalization process, but also with changes in their personal approach to teaching. This process has already begun as the majority of aerospace engineering faculty have taken the College of Engineering Effective Teaching Institute program.

It should be noted that regular reevaluation will be a major part of the curriculum revision process. Hence, a regularly scheduled faculty retreat is envisioned to evaluate the direction of both the profession and the department.

Note also that the time scales inherent in the above processes make it clear that success can not be measured in the near term, indeed it won't be until after the turn of the century that the first graduates will emerge from the new program. Hence, definitive success metrics cannot be viewed until well into the twenty-first century. The success of these students, and hence of the program, will be measured primarily by improved employment opportunities, although program accreditation, improved student interest and enhanced recruitment will also provide valid criteria for comparison.

The general approach to change clearly indicates that the process will be a long one. In addition, the opinions of the end users are recognized to be at least as important as that of the faculty. Support must therefore be maintained and results waited for patiently.

Generating Support

Lastly, the above efforts were made possible by a variety of support from faculty, administration and outside agencies. The development and importance of this support will now be discussed.

The process of change provokes fear in many people, including faculty members. However, faculty members must all agree that change is necessary before it can be prosecuted. The acceptance of a committee for the purpose of long range planning is not tantamount to a faculty mandate. The question of why change should be pursued is always present. However, once that aspect is understood a LRP committee can take it into account when trying to develop support for change. The development of the education philosophy was performed in part for this reason. The citation of the underlying pressures for change was also done for this reason. In addition, **the faculty must be made aware of and have a stake in the process.** This should be helped along by an administration that fully supports the effort. Indeed, the administration's support will feed off of the faculty's involvement and hence the two are intrinsically tied. However, administration support in the form of course relief and incentives is certainly needed. The respect given to these needs is improved by obtaining outside support for the effort, both monetary and moral. Again, the issue of support is synergistic, in that outside agencies will not view change as serious unless administration and faculty show a strong desire to improve.

The initial impetus for change came from departmental administration and was quickly followed by select faculty during the formation of the all volunteer LRP committee. Initial input from the entire faculty was minimal until the phone survey had been completed. It was felt that the involvement of the total faculty should proceed at a slow pace initially and then ramp up as the need for change crystallized and the needed effort increased. In particular, it was recognized that curriculum change as a whole could not be done by the committee alone; **the entire faculty must be involved.**

As stated earlier, administrative support at the departmental level was the driving force for change. College and University level support was not sought until significant progress and interest was obtained. The benefits had to be clearly articulated to gain higher administration support. This benefit became very clear when the curriculum change process began to be considered, since a considerable number of core courses would need to be modified to implement the educational philosophy at the earliest levels. The input of the Associate Dean for Academic Affairs was also enlisted. Support at the earliest stages primarily involved cost sharing for external funding, a necessary component for the enlistment of outside support.

Finally, to obtain outside support the benefits to the agencies had to be made clear. The importance of aerospace to the state of Ohio, to the country, and to the competitiveness of businesses had to be highlighted. In addition, the support of the faculty and administration was vital. In total, a complex web of support and effort had to be woven to successfully obtain external support.

Conclusions

The process of curriculum revitalization has begun in the University of Cincinnati Department of Aerospace Engineering and Engineering Mechanics. An educational philosophy has been developed to guide the revision process. The opinions of practicing engineers in government, industry and academia have been sought to understand the direction of the profession. Details of the revision process including the motivation behind a profession wide survey were discussed. The guiding principles for successful change were found to be; generating the motivation to change; obtaining the information needed to be successful; developing the support of the faculty, administration and external sources; acting to improve the curriculum; continually monitoring the quality of the programs; and measuring success.

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