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American Institute of Aeronautics and Astronautics Graduate Design Competitions*

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This paper describes in detail the family of American Institute of Aeronautics and Astronautics (AIAA)/industry graduate student team design competitions. Competition benefits are grouped into individual, institutional and national categories. The graduate design competitions are discussed within the framework of AIAA student programs in general, and against the background of the long-term AIAA undergraduate design competition history. The discussion focuses on the role of AIAA (Student Activities Committee/Technical Committees), universities and industry in developing a successful graduate student design competition format. This discussion also describes the university–industry partnerships formed by these competitions. In addition, the mechanics of the competition are described, as are the benefits derived therefrom by the students, AIAA, industry and the nation. The program described herein clearly meets a recent National Research Council articulated need for professional engineering societies to contribute to the development of improved design instruction within university curricula. Although the national design competition format discussed herein was developed by AIAA for aerospace engineering students, it is fully portable by any professional society to its particular discipline.

INTRODUCTION

DESIGN is the essence of engineering. It is the combination of art and science that results in new products. According to Woodson [1], design is 'an iterative decision-making activity to produce the plans by which resources are converted, preferably optimally, into systems or devices to meet human needs'. By reducing the design process to the elements of creative synthesis, analysis and decision-making, Nicolai [2] has illustrated the iterative character of the design process with the schematic shown in Fig. 1.

Until relatively modern times science had little to contribute to the practice of engineering and even less to engineering design. For several millennia, engineering was essentially a construction art, employing long-proven structural concepts, typically executed with abundant natural materials such as wood, stone and brick. Within the last few centuries, as it evolved and/or developed, science has been increasingly able to contribute to the growth and development of engineering, in general, and design, in particular [3].

In the mid-1950s it was recognized that more science was needed within all engineering curricula. This need was formally articulated in the so-called Grinter [4] report. Table 1 summarizes the undergraduate curricula content recommended in the Grinter report and contrasts those recommendations with recent accreditation criteria promulgated by the Accreditation Board for Engineering and Technology (ABET) [5]. It should be noted that ABET is recognized by the US Department of Education and the Council on Postsecondary Accreditation (COPA) as the sole agency responsible for the accreditation of US educational programs leading to degrees in engineering. The Grinter report, for example, appears to have had a significant impact on accreditation criteria/requirements. The Grinter recommendations for a full year of mathematics and basic sciences as well

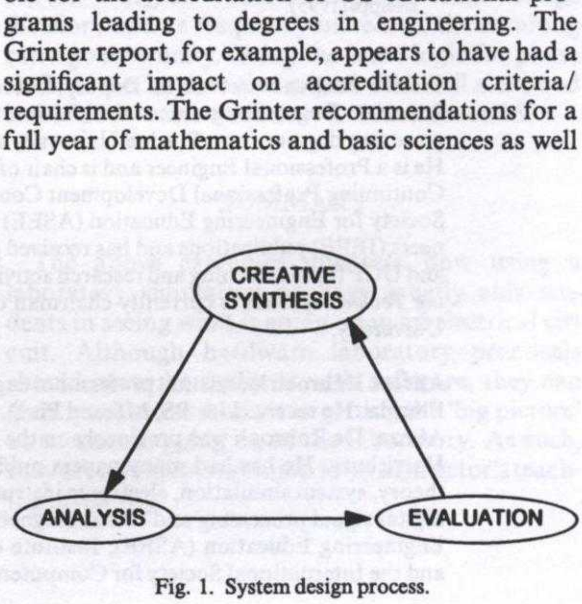

Fig. 1. System design process.

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Table 1. Undergraduate subject matter distribution

Subject Area	Grinter Recommendation (yrs)	ABET Requirement (yrs)
Humanities & Social Sciences	0.8	0.5
Mathematics & Basic Sciences	1	1
Engineering Sciences	1	1
Engineering Systems/Design	1	0.5
Electives	0.4	–

as a full year of engineering sciences have been fully accepted and implemented by ABET. The Grinter recommendation for a full year of engineering systems/design was translated into an ABET requirement of only a half-year of design. ABET requires less than the Grinter report recommended 0.8 years of humanities and social sciences, and has no requirement regarding electives. The Grinter report recommended 0.4 years of electives.

In retrospect, Tribus has noted that the Grinter report vision for changing engineering education was to provide a solid theoretical (scientific) foundation for a career in *design*. Tribus also notes that the passage of time has shown that this vision has not been fulfilled [6].

CRISIS IN ENGINEERING DESIGN EDUCATION

In contrast to an earlier era, most engineers in the US workforce now possess at least a baccalaureate degree in engineering. If one assumes that the engineering capabilities of these engineers reflect their education, one can easily develop the argument that within engineering schools and colleges there is a crisis in engineering design education. There are several salient features to such an argument: (i) most engineering faculty understand neither the role of design nor the design process [7]; (ii) the overall quality of engineering design in the United States is poor [8]; US engineers have difficulty competing in the world marketplace as illustrated by the continuing international US trade deficit; (iii) US aerospace engineering design capability is continually being lost [9]; (iv) new ABET (general) accreditation criteria appear to offer the potential for exacerbating diminished levels of design content in engineering curricula; (v) there is no recognized program in place for staunching diminished national design capability; and (vi) the US government has not recognized the development of national industrial design capability as a national priority [8].

Industry–university interactions

Several significant findings concerning engineering design education have been identified in a recent US National Research Council (NRC) report. One such finding, of particular interest here, indicates that partnerships and interactions among industry, research and education are so limited that the relevant needs of each are poorly served by the others [8].

It is noted that, with few exceptions, engineering design education is divorced from the needs of industry. Ways need to be found that will incorporate industry's needs within engineering design education paradigms. Industrial advisory boards, the evaluation of student design work by industry judges, and industry-defined design projects are but some of the ways that university–industry interactions can be developed and enhanced [8].

Product realization process (PRP)

Another significant NRC finding, of particular interest herein, is that university graduates are generally ill-equipped to use their analytical skills together with their knowledge of both basic and engineering science in the design of high-quality engineering systems and subsystems [8]. Nicolai has noted that current university undergraduate programs produce great scientists but mediocre engineers [2,10]. The NRC report also indicates that few university graduates have experienced design as part of a team, understand the multiple goals that motivate design, or possess an adequate understanding of cost accounting and product lifecycle considerations. National team-oriented system design competitions can be helpful in reducing the significance of this NRC finding.

Graduate design education

Accreditation visit data shown in Table 2 support the above assertion that engineering faculty understand neither the role of design nor the design process. Table 2 indicates that in US university undergraduate engineering programs receiving less-than-favorable accreditation actions, nearly 50% lack sufficient design content. It should be noted that one efficient way to hide this fact is to eliminate the need for specific design content. There are some who believe that the new ABET general criterion, one and one-half years of engineering topics, has the potential to effectively hide and further denigrate the design content in engineering curricula.

As a fact of policy, ABET will accredit a program at either the basic (normally undergraduate) level or at the advanced (typically graduate) level in an engineering discipline, but not both. Whereas accreditation requirements direct some attention

Table 2. Selected deficiences of engineering programs receiving less-than-most-favorable accreditation action 1987–1991

	Percentage of programs cited				
Specific Deficiency	1987	1988	1989	1990	1991
Engineering Design	44	44	49	50	43
Laboratory Plan	50	33	34	43	31
Laboratory Equipment	34	30	30	36	29
Resource Allocation	36	34	27	16	20

Note: The percentages total more than 100 because the programs were in most cases cited for more than one deficiency.

to basic-level competency, there is almost nothing which directs further attention to advanced-level competency in engineering design. It should be noted that very few graduate programs are accredited. Most universities do not seek accreditation for their graduate programs. It is AIAA policy, for example, not to provide (i.e. through ABET) advanced-level (graduate) program accreditation in aerospace (aeronautical/astronautical) engineering.

The findings of the recent NRC study indicate a significant need for graduate design education. According to the NRC report, graduate design education should include the development of competence in advanced design theory and methodology, familiarize graduate students with state-of-the-art ideas in design and provide graduate students with working experience in design. The report also notes that 'a continual stream of design-oriented doctoral graduates with new design knowledge is needed to supply faculty, who can teach undergraduate engineering design' [8]. National graduate design competitions provide one venue for incorporating engineering design into graduate curricula.

AIAA DESIGN COMPETITIONS

The purpose of the AIAA is to advance the arts, science and technology of aeronautics and astronautics, and to nurture and promote the professionalism of those engaged in these pursuits; to foster education in engineering and science; and to effect close co-operation with educational institutions to encourage high standards of technical education and to assist in the development of future scientists and engineers [11]. Although the AIAA has several standing committees which impact on education, perhaps the two with the greatest impact are the Academic Affairs Committee (AAC) and the Student Activities Committee (SAC). Whereas the AAC is the focal point for issues such as accreditation, the SAC is the focal point for student branch programs such as national design competitions.

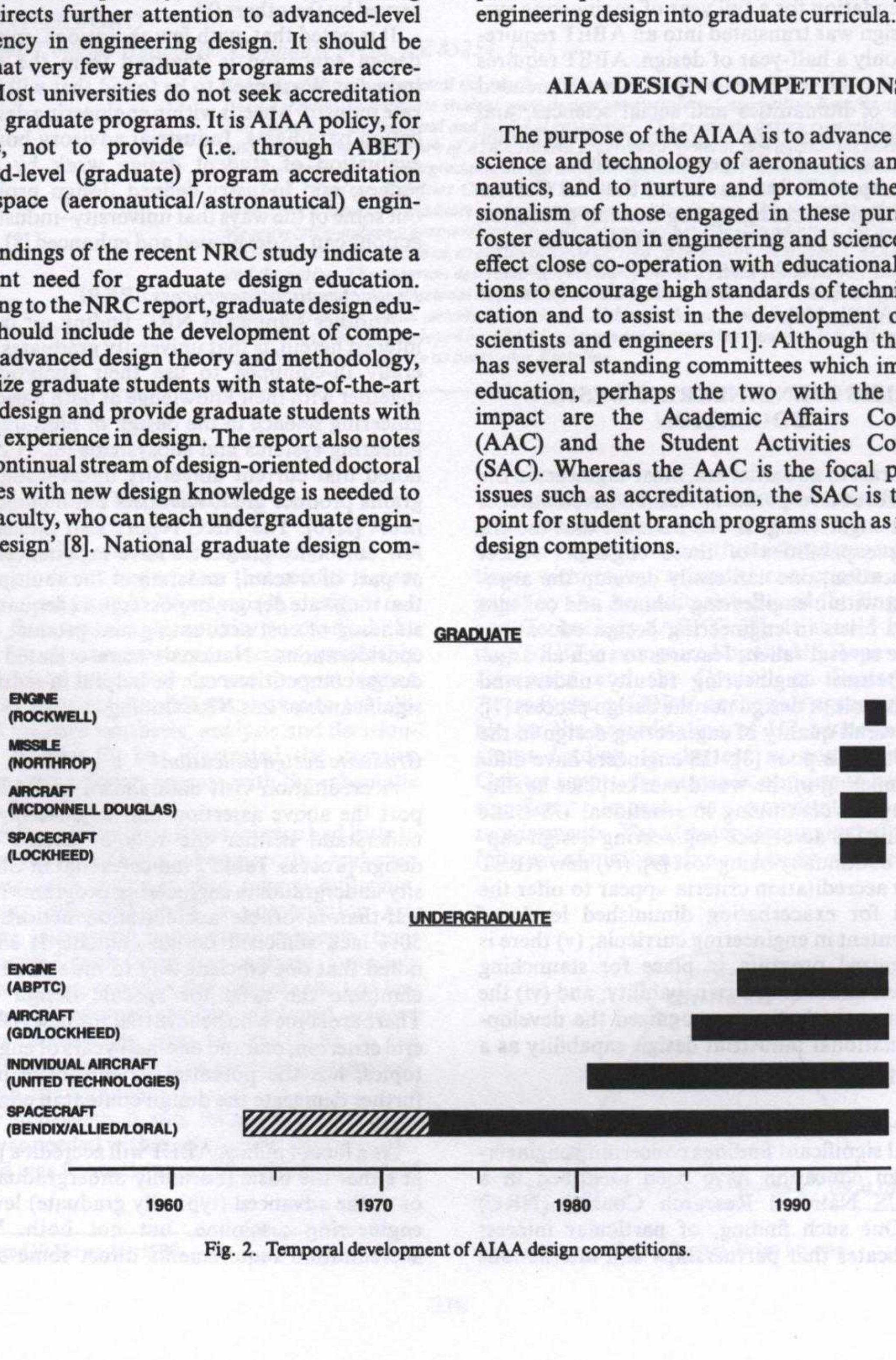

Fig. 2. Temporal development of AIAA design competitions.

The AIAA national design competitions represent only one (of many) student programs sponsored by the AIAA to fulfil its professional commitment to higher education. In addition to national design competitions, the SAC promotes, among its many other activities, the development of new student branches, annual student conferences as a venue for the presentation of student research and 'Getaway Special' research payloads aboard Space Shuttle flights.

The initial AIAA national student competition was provided in 1963 for undergraduate students. These national competitions did not focus on design until the 1972–73 academic year (AY). Figure 2 indicates the temporal continuum over which both undergraduate- and graduate-level competitions have been developed. Although it is not necessary that these design competitions be a part of the formal university curriculum format, formal university class utilization is encouraged. In fact, most of the competition participation is by subunits (e.g. design teams) of official university design classes.

It should be noted, highlighted and underscored that it normally takes 3–5 years or more for a national AIAA design competition to attract consistently six or more participants (e.g. each design team is a participant), regardless of the design competition topic. The 'birthing pains' associated with these design competitions arise from a variety of sources, including, but not limited to, faculty interest, student interest, length of the capstone design course or design course sequence, and design topic.

Prior to 1992, the AIAA, with two minor exceptions, conducted four annual national aerospace student design competitions: individual aircraft design, team aircraft design, team spacecraft design and team engine design. In each of these undergraduate design competitions, students (individually or as a 3–10 member team) submitted a page limited proposal in response to a Request-for-Proposal (RFP).

It should be noted that in recent years the AIAA Ground Test Technical Committee (TC) has sponsored a ground test design competition for either individuals or teams. Furthermore, in the 1981–82 academic year the Soaring Society of America teamed up with the AIAA to sponsor an undergraduate self-launched sport plane design competition [12]. These two sometime competitions are the two minor exceptions noted above.

The AIAA TCs interested in developing an RFP for one or more of these competitions submit brief proposals to the AIAA SAC; upon SAC approval, the interested TC fully develops an RFP based on their initial proposal. The proposal is then reviewed by the SAC and released to the universities. Student responses to the RFPs are returned to the AIAA Director of Student Programs, who forwards them for judging to the respective TCs who initiated the RFPs. The student proposals that score the highest are declared the winners (first, second and third in each category). Prize funding is provided by corporate sponsors. The AIAA, via Student Programs, administers the entire activity.

The growth and development of the undergraduate student competitions has been reported by Newberry *et al.* [13]. Typically, several hundred (200–400) aerospace engineering undergraduates participate each year in national AIAA design competitions. Many of the winning design efforts are presented at appropriate AIAA national professional conferences.

It should be noted that there are five phases in each design competition: a simple comprehensive RFP must be prepared by an interested TC; students must develop a comprehensive response to the RFP; the interested TC must evaluate the student responses (proposals); the awards must be announced and presented; and, finally, the winning design efforts are typically presented at appropriate AIAA professional conferences. The TC and student contributions in this endeavor require more than considerable effort.

AIAA GRADUATE DESIGN COMPETITIONS

In 1990 the senior author submitted a proposal to the AIAA SAC for four annual graduate student team-oriented national design competitions in the general categories of aircraft, missile, engine and spacecraft design [14]. The proposal utilized essentially the same RFP development and administrative format used by the then existing undergraduate design competitions. Graduate design professors from eight universities supported the proposal. The national graduate design competition proposal was approved by SAC at its 1990 summer meeting. Implementation was to take place as soon as appropriate RFPs and corporate funding could be secured. The graduate team aircraft, missile and spacecraft competitions were initiated for the 1992–93 academic year. The graduate engine design competition was added for the 1993–94 academic year.

It should be noted that the AIAA is not the only professional society to sponsor graduate design competitions [15,16]. The American Helicopter Society (AHS) sponsors an excellent national helicopter design competition. However, the AIAA competitions cover a broader range of the aerospace product line than does the AHS. Due to the excellent quality of the AHS helicopter competition, AIAA (SAC) chose not to offer an AIAA competition in this area. Between the two organizations there is complete graduate design competition coverage of the entire spectrum of major aerospace product systems: aircraft, helicopters, missiles, spacecraft and engines.

Purpose of the competitions

The graduate design competitions provide a wide variety of benefits at several levels: individual, institutional and national. The SAC considers the design competitions to contribute to and/or enhance the following aspects.

Individual

- Strengthening the design experience of each student.
- Providing the student with a specific design task (RFP response) of current professional interest.
- Further developing the open-ended problem-solving skills of the individual student.
- Improving the decision-making capability of the student.
- Developing individual reporting skills (oral and written).
- Requiring the students to include the effect of economics (i.e. lifecycle cost) in their design and engineering decisions.
- Enabling students to develop a broad 'hands on' understanding of how all of their other subject matter courses (including those external to engineering) impact the development of an aerospace vehicle system.
- Enabling students to experience the interactions among the several subject matter areas of the curriculum, as they develop a specific aerospace product.
- Providing an interaction (however insulated) between students and AIAA professionals (TC members).
- Providing students with a microenvironment of industry by asking them for an open-ended response to a societal need within a given timeframe, wherein the students must make choices based on incomplete databases, conflicting requirements and risk assessment.
- Focusing student consideration on the total product realization process.
- Understanding the multiple goals that motivate design.
- Providing students with a design experience as a part of a team.

Institutional

- Providing a focus for aerospace engineering design.
- Improving the design experience of university engineering programs.
- Providing the cognizant design professor with an appropriately simple but comprehensive RFP that can be effectively used in the required design class (more often than not this professor is a junior professor who has little or no design experience and has been assigned the design class because the senior faculty members do not want to be contaminated by design activities and/or do not know any more about design than the junior faculty member).
- Providing media recognition and name identification for corporate sponsors.
- Providing identification of design research areas.
- Providing one venue for incorporating design into graduate curricula.
- Better educating engineering students.

National

- Identifying and utilizing the best engineering design practices.
- Encouraging the effective use of design.
- Utilizing design education as an incubator of design talent.
- Ultimately, enhancing the competitiveness of US industry.

It should be noted that these benefits of design competitions directly address many of the issues raised by the NRC committee on design: industry articulation of its design requirements; support changes in engineering design curricula; treat design education as an incubator of design talent; focus student consideration on the total PRP; revitalize university research in design; define and/or identify best engineering design practices; and indirectly educate those design professors who have little or no design experience and are unaware of current design techniques [8].

It seems probable that national design competitions can, at best, make only a small to moderate contribution to improving design education within the United States. The significance of these contributions, however, should not be overlooked.

Competition mechanics

As noted above, the AIAA graduate design competitions are similar in structure to the AIAA undergraduate design competitions. They represent important industry–university partnerships. Industry and government, via their AIAA TC memberships, articulate a national design problem of interest. TC members develop a simple, comprehensive RFP defining this design problem, and evaluate student responses to the RFP. Corporate members of the AIAA fund the very nominal administrative, prize and travel costs associated with these competitions. University professors and/or students make the conscious decision to develop page-limited responses to the RFPs. The winning design efforts are typically presented at appropriate professional AIAA technical conferences and/or meetings.

Although the AIAA design competitions were primarily developed to enhance design education within the United States, they are open to any (international) group of AIAA student members. Currently there are 10 international AIAA student branches (Belgium, Chile, Egypt, India, Israel, Italy, Japan, Puerto Rico, Russia and Turkey). Undergraduate student design teams from the Academia Politecnica Aeronautics in Chile have participated in two different aircraft design competitions to date. More recently, the undergraduate aircraft design competition was entered by a student design team from the University of Naples. No international graduate student design competition entries have, as yet, been received. Nevertheless, they are always invited to enter.

Rules/prizes. Design teams are limited to groups of 3–10 AIAA graduate student members. Five copies of each design proposal (response to the RFP) must be submitted by each design team for AIAA judging. Design proposals can be part of formal classroom requirements. In fact, the AIAA encourages design professors to use the RFPs for their classroom projects.

Cash prizes are awarded to the student design teams in each competition: first place $1000, second place $500 and third place $250. Furthermore, following the practice initiated in the undergraduate engine design competition in 1986–87, the student design team faculty advisor (project advisor, design professor) for each winning design team receives the same cash award as the winning design team that the faculty members has advised, i.e. first place $1000, second place $500 and third place $250.

Certificates are given to the universities represented by the winning design teams, and individual certificates are given to all members of the winning design teams and their respective design project faculty advisors. More than one design team from each university can enter each of the respective design competitions. Lastly, proposals submitted by each design team are page limited and may not exceed 100 pages (including appendices) in length.

Schedule. The AIAA specifies competition schedules and activity sequences. RFPs were initially scheduled for release by 15 August for the following academic year. The AIAA is currently moving this release date to 1 July in order to permit student responses from more universities and/or to provide design professors with more lead time to select the appropriate RFP for their design course project. Letters-of-intent (LOIs) from the student design teams have to be submitted to the AIAA Director of Student Programs by 15 March of the academic year. LOIs provide the SAC and AIAA Director of Student Programs with an advanced estimate of the extent of participation in each design competition. Proposals (graduate student responses) must be submitted to the AIAA Director of Student Programs by 15 June of the academic year. Judging is then performed by AIAA TC members in time for the AIAA to announce the respective competition winners by 1 September (the following academic year).

Competition requirements. Current competition requirements reflect design proposal process improvements and refinements made in the undergraduate competitions over the past 20 years. Each graduate student proposal is expected to reflect the student's thorough understanding of the RFP. Students should specify the proposal technical approach(es) for complying with each requirement of the RFP (including the phasing of tasks). Particular attention should be directed to the legibility, clarity and completeness of the technical approach(es). Automated design tool descriptions should also be provided. It is expected that graduate students will direct particular design emphasis to the identification of critical, technical problem areas. Furthermore, descriptions, sketches, drawings, systems analyses, methods of attack and discussions of new technologies should be presented in sufficient detail to permit an engineering evaluation of the proposal. Tradeoff studies supporting design decisions should be included in the proposal. Exceptions to RFP technical requirements should be identified and discussed in terms of their technical feasibility (or lack thereof) as they pertain to the proposed design solution.

Student proposals are expected to contain an implementation plan for producing the final product. This plan should demonstrate an awareness of manufacturing capability and include a description of the facilities required for manufacturing and assembly. Methods and techniques for maintaining schedules, cost and product quality should be described.

The management organization for delivering the proposed product on time and at or under cost should be described in adequate detail. This discussion should also include a brief biography of the management staff members in responsible charge.

Judging. As noted above, aside from the task of developing the RFP and the effort by the students to prepare an adequate response to the RFP, the most difficult task remaining is that of proposal evaluation. A consistent, systematic judging procedure was evolved and refined with the growth of the undergraduate design competitions. The current standardized procedure [17] is considered to be as satisfactory as competition system constraints will allow. Graduate competition judging is performed in four major categories: technical content, organization and presentation, originality, and practical application and feasibility.

Technical content represents 35% of the evaluation score. Consideration is given to the correctness of the theory, validity of reasoning, apparent understanding of the subject, etc. Have the students considered all of the major factors impacting the design and have they made a reasonably accurate evaluation of these factors? Figure 3 illustrates the scoring sheet for the technical content aspect of the judging.

Organization and presentation represents 20% of the evaluation score. Consideration is given to the design as an instrument of communication. Particular attention is given to the organization of the proposal, clarity of exposition and the inclusion of pertinent information. Figure 4 illustrates the scoring details of the organization and presentation aspect of the judging.

Originality represents 20% of the evaluation score. Primary attention is directed to original or at least non-textbook information and approaches. The proposal should illustrate independence of thought and a fresh approach to the design space solution. Consideration is given to the extent to

REVIEW OF TECHNICAL CONTENT

	SUGGESTED POINT DISTRIBUTION Average	SUGGESTED POINT DISTRIBUTION Maximum	Judge's score
1. Completion of RFP Requirements...(total)........	14	20	____
a) If total RFP requirements were not met, was an alternate solution (s) supplied?.........		Yes____ No____	
b) Was the reasoning used for alternate solution(s) valid?..		Yes____ No____	
c) Was the theory of alternate solution(s) correct?..		Yes____ No____	
d) Are the benefits of each alternate solution weighed against original RFP requirements fully substantiated?..		Yes____ No____	
2. Determination of critical problems....................	8	12	____
3. All major and related parameters considered......	8	12	____
4. Well balanced analysis of complete system.........	8	12	____
5. Assumptions clearly stated and logical...............	5	8	____
6. Reasonably accurate evaluation.........................	5	8	____
7. Validity of reasoning..	5	8	____
8. Correctness of theory..	5	8	____
9. Direct relations of technical approach to RFP problems..	4	6	____
10. Technical sketches relevant, necessary, complete..	4	6	____
TOTAL POINTS			____

Scale Factor = 0.35

Scale Factor x Total Points = TECHNICAL CONTENT FINAL GRADE ____

11. Did the technical presentation illustrate an overall understanding and grasp of the subject? Yes____ No____

12. Any additional comments regarding judge's score________________________________

____

____

____

Fig. 3. Technical content scoring.

which the proposal's methods and solutions show creativity. Comment should be made relative to the adaptation or creation of automated tool design. Figure 5 illustrates the scoring details of the originality aspect of the judging.

Practical application and feasibility represents 25% of the evaluation score. The proposal should present a design solution that is both feasible and practical. The design solution should be realistic in terms of lifecycle cost. Where appropriate, the design solution should include environmental impact studies. The proposal design solution should be shown to be acceptable from a societal perspective. Figure 6 illustrates the scoring details of the practical application and feasibility aspect of the judging.

Funding. Funding is required for prizes, administrative expenses and student travel. Each graduate design competition has a total funding of $7000: $3500 for prizes, $1500 for administrative expenses (AIAA staff, certificates, etc.), and $2000 for student travel [14]. Student travel is required to provide assurance that at least one member from each of the winning design teams will be financially able to attend an appropriate design conference to present their teams' design solution. As noted above, prizes may be awarded for the best three entries (first, second, third) in each graduate design competition, if the judges determine that the quality of the entries so warrants.

Regardless of the number of entries in each competition, the judges may determine that the quality of the individual design solution warrants giving only a first place award, or perhaps only first and second place awards.

It should be noted that funding for the undergraduate design competitions does not include student travel monies, whereas such monies are included for the graduate competitions. Student presentations before the professional membership are now considered to be a very important terminal phase of the design competition learning experience. Students benefit from the professional environment of such a presentation and the professional membership is able to make some level of judgement as to both the level and effectiveness with which design is considered within the environs of academe.

ORGANIZATION AND PRESENTATION

It is suggested that the judges fill in Part I as a basis for an accurate point evaluation before filling in Part II.

PART I - ADEQUATE BASIS FOR PRESENTATION

	YES	NO
1. Does paper avoid short, choppy sentences/paragraphs?	___	___
2. Is paper free from unneccesary footnotes?	___	___
3. Is paper free from numerous/unnecessary "bullet lists"?	___	___
4. Is paper free of excessive parenthetical comments?	___	___
5. Is paper of minimum feasible length?	___	___
6. Does paper contain unimportant details that could be deleted?	___	___
7. Are all mathematical symbols defined?	___	___
8. Are mathematical analyses/derivations clear?	___	___
9. Is each figure and table relevant?	___	___

PART II - ORGANIZATION and PRESENTATION POINT EVALUATION

	SUGGESTED POINT DISTRIBUTION Average	Maximum	Judge's Score
1. Conclusions are concise and fully substantiated..	14	20	___
2. Paper alerts reader to controversial material, major contributions, key results.........................	11	15	___
3. Continuity of topics......................................	11	15	___
4. Introduction clearly defines purpose of paper......	7	10	___
5. All pertinent information included.....................	7	10	___
6. Figures, graphs, tables are uncluttered and are easy to understand..	7	10	___
7. All previous relevant work cited........................	7	10	___
8. Overall neatness of report................................	7	10	___
TOTAL POINTS			___

Scale Factor = 0.20

Scale Factor x Total Points=ORGANIZATION/PRESENTATION FINAL GRADE ____

9. Any additional comments regarding judge's score______________

Fig. 4. Organization and presentation scoring.

ORIGINALITY

	SUGGESTED POINT DISTRIBUTION Average	Maximum	Judge's Score
1. Design concept shows originality..............	25	35	___
2. Treatment of problem shows imagination..	17	25	___
3. Results illustrate a unique solution...........	14	20	___
4. Appearance of report shows originality......	14	20	___
TOTAL POINTS			___

Scale Factor = 0.20

Scale Factor x Total Points = ORIGINALITY FINAL GRADE ____

5. Any additional comments regarding judge's score______________

Fig. 5. Originality scoring.

APPLICATION AND FEASIBILITY

	SUGGESTED POINT DISTRIBUTION Average	Maximum	Judge's Score
1. Consideration of simplicity in manufacturing	14	20	____
2. Current and advanced technology levels are realistic	14	20	____
3. Feasibility of meeting certification requirements	12	17	____
4. Discussion of advantages and disadvantages of proposed design versus operational requirements	10	14	____
5. Consideration of additional applications other than solely meeting RFP	10	14	____
6. Environmental impact discussed and justified	3	5	____
7. Social acceptance of solution	3	5	____
8. Demonstration of cost effectiveness	3	5	____
TOTAL POINTS			____

Scale Factor = 0.25

Scale Factor x Total Points = APPLICATION/FEASIBILITY FINAL GRADE ____

5. Any additional comments regarding judge's score____

Fig. 6. Application and feasibility scoring.

Conference presentations. Since 1988, most winning design competition teams have managed to have at least one representative from each of their respective teams attend the designated professional conferences for the presentation of the summaries of their design efforts. This has been difficult for students in the undergraduate design competitions because travel funds were not included in the initial competition funding. Alternative, and so far inadequate, methods of funding undergraduate student travel have been sought and necessarily utilized. This problem was avoided with the graduate competition funding formula.

There are at least three other, as yet unresolved problems (relative to conference presentations) that occur with both the graduate and undergraduate competitions. First, some of the appropriate AIAA professional conferences, e.g. aircraft design, are held in the same timeframe during which competition judging is being completed and competition winners are being announced. Finding student team leaders and/or team members at short notice is nearly impossible since, in most situations, the team members have all graduated and are scattered across the country.

Second, professional member attendance at student sessions of AIAA conferences is unpredictable and does not always meet expectations. This problem exists at any professional conference where several simultaneous sessions are scheduled. However, students sometimes consider the paucity of attendance to indicate a less than enthusiastic attitude on the part of the professional membership.

Third, the appropriate conference for the student presentations may be held nearly a year into the future. For example, it would be appropriate to present the winning engine design presentations at the AIAA/ASME/SAE/ASEE Joint Propulsion Conference. However, the winners are announced in September whereas, the Joint Propulsion Conference is typically held in June–July. Should the students be asked to wait nearly a year to make their design summary presentations or should their presentations be made at a less appropriate but more timely professional conference?

RFP development. Within the TC structure of the AIAA, there are eight TCs in the Aircraft Systems Group (e.g. Aircraft Design, V/STOL Aircraft Systems, General Aviation, Multidisciplinary Design Optimization), six TCs in the propulsion group (e.g. Airbreathing Propulsion, Solid Rockets, Liquid Propulsion), one missile TC (Missile Systems) and six space-related TCs (e.g. Space Systems, Space Automation and Robotics, Space Transportation). Although these 21 AIAA TCs provide the primary support for the design competitions, any of the 65 AIAA TCs can propose RFP concepts. There is a year-long planning cycle for the development of the graduate student design competition RFPs.

At mid-year (June) the AIAA Director of

Student Programs asks each of the 65 AIAA TCs to consider the desirability of that TC developing (by early September) a concept for one or more of the graduate student design competitions. Abstracts of these initial concepts are submitted to the SAC for consideration and final selection by early September. The selected concept abstracts are returned to the respective TCs in early November. Fully developed graduate student RFPs, based on the selected concepts, are due to the office of the AIAA Director of Student Programs in late spring for release to the universities in late June or early July for the following academic year competitions, following a final review by the SAC.

It should be noted that the TCs are sometimes slow in transmitting the fully developed RFPs to the AIAA Director of Student Programs. This may be expected, since the TC is a voluntary membership organization. However, such delays may impede, to some degree, the effective utilization of some of the competitions by university design teams. Effort is being directed to the successful resolution of this problem.

Student response. Graduate student design team members responding to any one or more of the RFPs must be AIAA student members. These graduate student design teams may be formed at any time during the academic year. Furthermore, these design teams may be an integral part of a formal classroom activity or they may be part of an extracurricular activity of the AIAA Student Branch. Design professors are encouraged to incorporate the RFPs and the corresponding competitions within their formal graduate design classes. In every case, each graduate design team must send an LOI (to participate as a design team) to the AIAA Director of Student Programs by 15 March of the academic year. Should the team decide at a later time that they wish to withdraw from the competition, they are expected to so notify the AIAA Director of Student Programs.

The AIAA Director of Student Programs needs to be in receipt of all student proposals by or about 15 June of the academic year. Multiple graduate design teams from any university may enter the same or different competitions. Proposals must be limited to 100 double-spaced typewritten pages (including graphs, drawings, photographs and appendices, on $8\frac{1}{2} \times 11$ in. paper). Up to five of the 100 pages may be foldouts (11 × 22 inches, maximum). Winners are announced on or about mid-September (note that this is generally after the start of the next academic year).

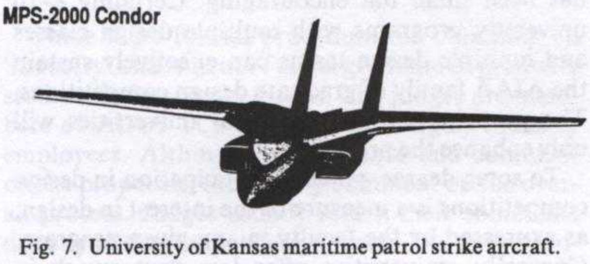

Fig. 7. University of Kansas maritime patrol strike aircraft.

SPECIFIC GRADUATE COMPETITIONS

As noted above, there are currently four graduate student annual design competitions. Three (aircraft, missile and spacecraft) were implemented for the 1992–93 academic year. The fourth (engine) was initiated for the 1993–94 academic year. The rules, prizes, schedules, etc., are essentially the same as for the undergraduate competitions.

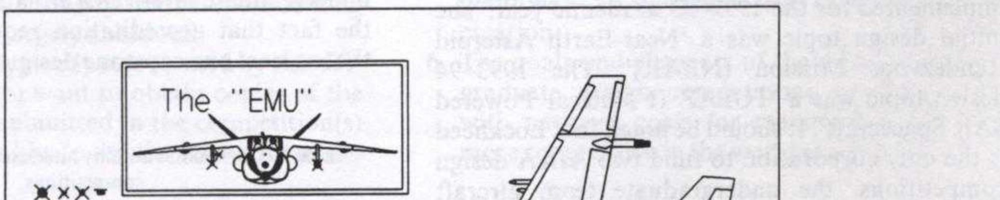

Fig. 8. Naval Postgraduate School maritime patrol strike aircraft.

Aircraft

The AIAA/McDonnell Douglas Corporation Graduate Team Aircraft Design Competition was implemented for the 1992–93 academic year. This competition, as suggested by the name, is funded by the McDonnell Douglas Corporation. The first design topic was a 'Global Range Transport for Global Mobility'. The 1993–94 design topic was a 'Maritime Patrol Strike Aircraft'. Two examples of the maritime patrol strike aircraft proposed in this competition are shown in Figs 7 and 8 [18,19]. The graduate aircraft design topics are expected to be generally the same as, or similar to, the undergraduate team aircraft design topics. However, the graduate competition is expected to have more stringent design requirements than the undergraduate competitions.

Missiles

The AIAA/Northrop Corporation Graduate Team Missile Design Competition was implemented for the 1992–93 academic year. This competition is, as suggested by the name, funded by the Northrop Corporation. This initial design topic was a 'Light Weight Terminal Interceptor for Theater Missile Defense'. The 1993–94 design topic was an 'Advanced Combined Arms Missile System (ACAMS)'. It should be noted that there is no equivalent undergraduate missile design competition. The winners of the 1992–93 academic year competition were expected to make design summary presentations at the 3rd Annual AIAA/BMDO Interceptor Technology Conference held in San Diego, California on 12–14 July 1994.

Spacecraft

The AIAA/Lockheed Corporation Graduate Team Spacecraft Design Competition, funded by the Lockheed Corporation (Headquarters), was implemented for the 1992–93 academic year. The initial design topic was a 'Near-Earth Asteroid Rendezvous Mission (NEAR)'. The 1993–94 design topic was a 'TOPAZ II Nuclear Powered SAR Spacecraft'. It should be noted that Lockheed is the only corporation to fund two AIAA design competitions: the undergraduate team aircraft design competition (Lockheed Fort Worth) and the graduate spacecraft design competition (Lockheed Headquarters).

Engine

The AIAA/Rockwell International Graduate Team Engine Design Competition, funded by Rockwell International, was implemented for the 1993–94 academic year. An 'Advanced Upper Stage (AUS) Conceptual Design' was selected as the initial engine design topic. Rockwell International has expressed an interest in helping develop the RFP as well as in helping evaluate the student proposals.

STUDENT PARTICIPATION

Historically, it takes from 3 to 5 years to establish firmly a new AIAA design competition. Even though these graduate design competitions have been well advertised within the AIAA print media for the past 2 years, one can still find design professors who are unaware of them.

At the time the graduate competitions were proposed to the SAC, eight universities expressed interest in such competitions (Table 3) [14]. A later survey [20] indicated that a similar number of universities were still interested in graduate design competitions and that such interest was fairly uniform across the four areas in which the competitions are offered. Only three universities participated in the graduate competitions during the initial offertory year (Table 4). It should be noted that two of the universities participating in the 1992–93 competitions had not indicated an initial interest in this activity. Multiple entries were submitted by some participants. The 1992–93 AIAA graduate design competitions involved some 50–60 graduate students. Greater participation is expected during the second year of the competitions.

It is hoped that all graduate aerospace programs will find a way for their students to participate in the AIAA graduate design competitions. The start has been small but encouraging. Certainly 8–10 university programs with multiple design classes and multiple design teams can effectively sustain the AIAA family of graduate design competitions. The participation of additional universities will only enhance the program.

To some degree, student participation in design competitions is a measure of the interest in design, as expressed by the faculty in any given program. Generally, universities offer less coursework in design at the graduate level than they do at the undergraduate level. This situation may be due to the fact that accreditation requirements specify that at least one capstone design course is required

Table 3. Universities initially interested in graduate design competitions

Air Force Institute of Technology
California State Polytechnic University, Pomona
George Washington University
Georgia Institute of Technology
Texas A&M University
Stanford
University of Kansas

Table 4. Universities participating in the 1992–93 AIAA graduate design competitions

Catholic University of American
Naval Postgraduate School
University of Tennessee Space Institute

at the undergraduate (basic) level, while there is no such requirement at the graduate (advanced) level [5] for unaccredited graduate programs.

IMPROVING GRADUATE DESIGN COMPETITIVENESS

The 1991 NRC Report comments on the dearth of design in graduate programs and the national need for more design at the graduate level [8]. The graduate design competitions offered by the AIAA are intended to support existing, and to encourage additional, graduate design efforts. With time, the family of AIAA graduate team design competitions is expected to develop a vigorous life of its own and contribute significantly to a competitive national capability in aerospace design.

The 1991 NRC Report [8] further states that professional engineering societies should, 'through their education arms and with participation of engineers practicing in industry, encourage the further education of design teachers and increase the awareness of all faculty members of the importance of engineering design'. These elements and concerns are embodied in the AIAA design competitions at both the undergraduate and graduate level.

INDUSTRY FEEDBACK

There is no formal procedure for obtaining an 'industry' assessment of undergraduate or graduate student design competitions. The judges are members of AIAA TCs and thus are largely industry employees. Although judges score and comment on the proposals, they rarely comment on the overall process. Judges usually return their comments directly to the student design teams. Industry sponsors are typically not involved with either the judging and/or administration of the design competitions. Thus, industry feedback concerning the competitions is largely anecdotal.

Some sponsors (typically represented by the 'college relations' office) want to obtain copies of the student proposals submitted in the competition(s) they sponsor. They like to see the creativity of the students and the different design methodologies employed by the different design teams. Some sponsors consider that they are supporting design education as well as familiarizing the students with their corporate name. Many sponsors view the competitions as a way of enhancing student awareness of the value of design.

Student presentations of their design effort at professional AIAA conferences are generally well attended by industry conferees. Typically, these conferees have nothing but positive comments about the various design projects. Overall there is a sense that the students do commendable work and that the competitions are quite worthwhile. Perhaps the most eloquent manifestation of this positive attitude is the continued renewal of the competition sponsorships by the several corporations (industrial sponsors).

CONCLUSIONS

1. Four (aircraft, missile, engine, and spacecraft) fully funded AIAA graduate team design competitions now exist for student/university utilization.
2. These four competitions represent university–industry partnerships for enhancing engineering design education.
3. More efficient TC participation would enhance the administrative and logistic elements of the AIAA/industry graduate design competitions.
4. Although participation in the initial graduate design competitions was light, it was not unexpected. Greater participation is expected next year and further into the future.
5. The number of universities who have expressed an interest in the graduate design competitions is adequate to sustain the graduate design competitions at an acceptable level of student participation.
6. The goals and elements of the AIAA/industry graduate design competitions are consistent with national goals for making US industry more competitive in the world marketplace.

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