Virginia Tech's New Practice-Oriented Aerospace Engineering Master's Degree

W.H. Mason and B. Grossman
Department of Aerospace and Ocean Engineering
and
Multidisciplinary Analysis and Design Center for Advanced Vehicles
Virginia Polytechnic Institute and State University
Blacksburg, VA 24061

Abstract

This paper describes a new graduate degree program in Aerospace and Ocean Engineering at Virginia Tech. Responding to strong industry comments, five engineering departments (AOE, ME, ISE, MSE, and ESM) at Virginia Tech have established a new practice-oriented master's degree (MEng). The new degree fit within existing guidelines so that no new administrative approval was required. On an individual department basis the addition of several new courses each would have been impossible. By working together it became possible to add two new college-wide courses. *We believe that the new program is unique in that it is truly multidisciplinary. Students from the five different college of engineering departments will be taking classes together and working on the design project teams together.* The program will be offered for the first time in the fall of 1996.

Introduction

As educators, we are constantly being told that increased international competitiveness has created a need for engineers with a better understanding of design methodology and concurrent engineering. Probably the most significant documentation of the need is contained in a National Research Council Report.[1] Representatives of Boeing,[2] Lockheed Martin,[3] and McDonnell Douglas[4] have also voiced strong opinions. To prepare engineers for careers in design requires not only learning about these specific topics, but an understanding of the broad context of the practice of engineering, experience in solving problems with realistic industrial constraints, and an awareness of the world of product development.

Listening to our customers, several departments at Virginia Tech have started to work together to establish a new practice-oriented master's degree. Although our implementation is different, we are not the only school establishing this type of program. The national trend has been described recently in the *ASEE Prism*.[5] We are aware of several other programs in Aerospace Engineering. MIT has established a Master's degree for students who expect to become practicing aerospace engineers.[6] Michigan and Cornell also have programs. In the case of Aerospace and Ocean Engineering, this type of degree was also recommended in a recent outside review of our graduate education program. The program fits within existing guidelines so that no new legislative approval is required. On an individual department basis the addition of many new courses within the available budget would have been impossible. By working together it became possible to add a small number, initially two, to the college program.

We think our program is unique. Students from the five different participating departments (Engineering Science and Mechanics, Industrial and Systems Engineering, Materials Science and Engineering, Mechanical Engineering, and Aerospace and Ocean Engineering) will take several core courses together, and will work in teams composed of students from various departments on the degree-completing final design project.

The Practice-Oriented Master's Degree (POMD) program in Aerospace and Ocean Engineering is part of an emerging curriculum wide focus on design and engineering practice in our department.[7] This includes having freshmen work with the seniors on their capstone design project as part of a SUCCEED project,[8,9] and continues through Ph.D. level research in design and optimization conducted in the Multidisciplinary Analysis and Design (MAD) Center for Advanced Vehicles at Virginia Tech.[10] This emphasis led to the recent addition of an Aerospace Manufacturing Course,[11] and a formal course in Multidisciplinary Optimization.[12]

The Program

The POMD program is a twelve-month program directed toward the student who wants an in-depth exposure to the design process and the multidisciplinary aspects of engineering. Each student will be enrolled in a specific department, and will receive a degree with a major in that discipline. However, the educational experience will be much broader than the normal research-oriented graduate degree. The essence of the idea behind the educational program is illustrated in Figure 1, as conceived by Ron Landgraf. This program is essentially a fifth year of school. To complete the program in twelve months a student will take four courses a semester, and will not have time to be a research or teaching assistant.

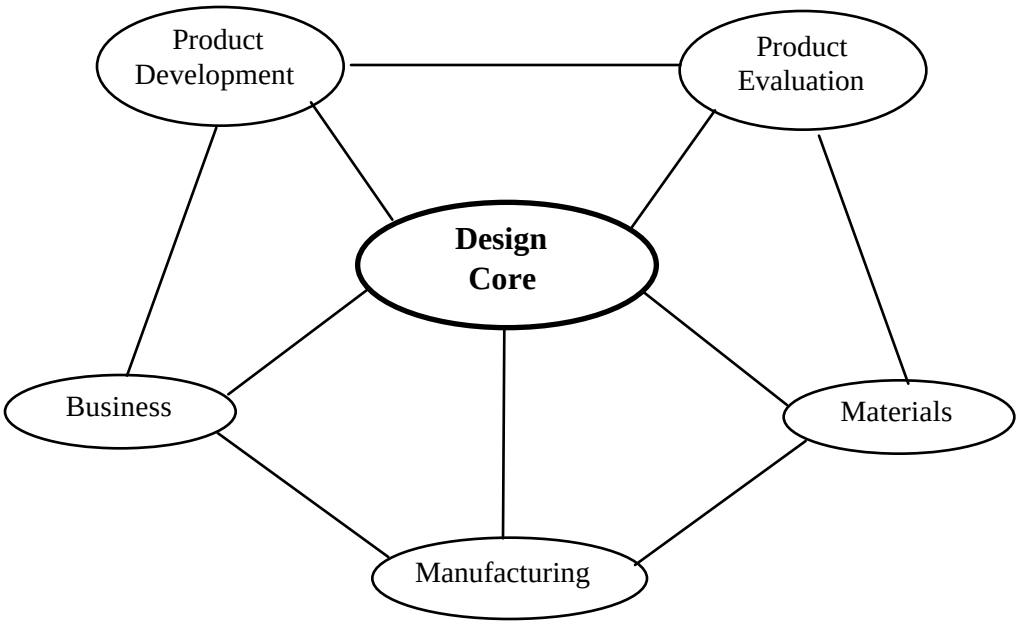

Figure 1. The Practice-Oriented Master's Degree Concept (R. Landgraf)

How It Works

To complete the program in twelve months, as opposed to the usual two years for a Master's degree student supported by an assistantship, we have a fairly formal schedule. It is shown in Figure 2. We are using a

“2 + 2 + 4” course concept. Two common courses will be required of all students regardless of their particular major, two courses will be selected from a list of electives common to students in all majors, and four courses will be selected from a list of courses specific to a particular major. With this approach a student can design a highly individual program within our somewhat rigid framework. As currently envisioned, the first common course will stress modern engineering design practice. The second course will be professional issues in engineering, and includes legal and business considerations in engineering. The two courses from the list of common electives include existing courses in manufacturing, quality, systems engineering, optimization and business. The areas are similar to those required for our design research degree described in Ref. 12.

In the last part of the program, students from the different departments will do a project together as a team (we are thinking of 4 or 5 member teams) in the final summer. Our plan is for the projects to be based on industry suggestions and to be reviewed by industry.

POMD Schedule

Fall (15 weeks)	Spring (15 weeks)	Summer (12 weeks)
ENGR Core 1 [3 cr]	ENGR Core 2 [3 cr]	Team Design Project [6 cr] (report/ presentation)
Core Elective 1 [3 cr]	Core Elective 2 [3 cr]	
Technical Focus Elective 1	Technical Focus Elective 3	
Technical Focus Elective 2	Technical Focus Elective 4	
Team Project (selection/planning)		
Design Seminar		

Figure 2. The program and schedule for the Virginia Tech Practice-Oriented Master’s Degree

Our Starting Point: Initial Specific Program Requirements

Thirty semester credit hours are required to complete the program. This is a university requirement that won’t change. Most of the other specific requirements may evolve as we gain experience. Eighteen hours of the requirements are common to all majors. Within this framework the program has been designed to provide a very broad and flexible individual program through the selection of a wide variety of Design Core and Technical Focus Electives.

Design Core [12 cr]:

- Core 1: Modern Engineering Design Practice
- Core 2: Professional Issues in Engineering
- 2 courses from the Core Electives List.

Technical Focus [12 cr]:

- 4 courses from the Technical Focus Electives List developed for each major by the major department.

Team Design Project [6 cr]:

- The project will mainly be during the final summer, with teams consisting of members with different majors.

The Design Core Courses

Two courses are required of all students in the program. These courses cover the themes that industry has been stressing as the global marketplace experience has demonstrated the need for a foundation in areas previously omitted from most science-oriented graduate degree programs. To be offered for the first time in the 1996-97 academic year, these courses are currently being developed, primarily by Norm Eiss and Ron Landgraf. We expect to use team teaching to give these courses. The course contents are being developed to address the following topics:

ENGR Core 1: Modern Engineering Design Practice

- The Product Realization Process
- Design Theory and Methodology
- Creative Problem Solving
- The Role of Specifications/Standards
- Life Cycle Cost
- Concurrent Engineering and Collaborative Design
- Survey of Design Tools/Techniques
- Team Design Project

ENGR Core 2: Professional Issues in Engineering

- Professionalism/Ethics
- Global Engineering
- Intellectual Properties
- Product Liability
- Environmental Issues
- Team Building
- Project Organization Design
- Business Aspects of Engineering
- Communications
- Technology Leadership
- Life-long learning

Core Electives List

Two core electives are required. We have identified a wide variety of existing courses which meet our objectives, as illustrated in Figure 1 above. The initial list is given below.

Business/Management

ISE 4224	Advanced Engineering Economy
Econ 5504	Economics of Business Decisions
MSci 5404	Management Science
ISE 5134	Management Information Systems
ISE 5124	Management of Quality and Reliability
Fin 5004	Fundamentals of Legal Environment of Business
MGT 5304	Social, Legal and Ethical Environment of Business
MGT 5804	Strategic Leadership in Technology-Based Organizations
Psyc 4024	Industrial and Organizational Psychology

Technology in Society

Hist 4216	History of Technology
Hum 4304	Contemporary Issues in Humanities, Science and Technology
PAPA/STS 5614	Introduction to Science and Technology Policy
Soc 4814	Sociology of Technology

Engineering/Mathematics

Engr 5105	Applied Systems Engineering
ISE 5204	Manufacturing Systems Engineering
AOE/ESM 4084	Engineering Design Optimization
AOE 5244	Optimization Techniques
ISE 5154	Applied Human Factors Engineering
Stat 4604	Statistical Methods for Engineering
ESM 4614	Reliability Methods in Engineering
ISE 4404	Statistical Quality Control
ISE 5444	Quality & Reliability Engineering
Math 5725	Mathematical Methods in Engineering I
ESM 4714	Scientific Visual Data Analysis with MultiMedia

Technical Focus Electives List in Aerospace Engineering

Twelve credits specific to a particular major are required. Each participating department has developed its own list, appropriate for that major. In Aerospace Engineering, we have identified the following list from our senior/graduate level courses. Because so many options are available, the student will work closely with his/her course advisor to make sure that the specific program of study has a coherent focus.

Structures:

AOE 4024 Introduction to the Finite Element Method
AOE 4054 Stability of Structures
AOE 5024 Vehicle Structures
AOE 5034 Vehicle Structural Dynamics

AOE 5044 Dynamic Stability of Structures
AOE 5064 Structural Optimization
AOE 5074 Computer Aided Design of Structures

Aerodynamics/Propulsion:
AOE 4114 Applied Computational Aerodynamics
AOE 4984 Configuration Aerodynamics (to offered for the first time in Spring 1997)
AOE 5104 Advanced Aero and Hydrodynamics
AOE 5114 High Speed Aerodynamics
AOE 5135 Vehicle Propulsion
AOE 5144 Boundary Layer and Heat Transfer

Flight Mechanics and Control:
AOE 4004 Computer-Aided Control System Design
AOE 4144 Aircraft Automatic Flight Control
AOE 5124 Aircraft Dynamics and Control
AOE 5224 Linear Optimal Control Systems
AOE 5234 Orbital Mechanics
AOE 5244 Optimization Techniques

Ocean Engineering
AOE 4274 Computer Based Design of Ocean Structures
AOE 4754 Naval Architecture
AOE 5084 Submarine Design
AOE 5304 Advanced Naval Architecture
AOE 5305 Marine Engineering
AOE 5314 Advanced Ship Dynamics

AOE Design
AOE 4404 Applied Numerical Methods
AOE 4984 Aerospace Manufacturing
AOE/ENGR 5004 Systems Engineering
ME 5604 Computer-Aided Design I
ME 6604 Computer-Aided Design II

The Project

Teams of students will do an engineering project in the summer to complete the degree. Each project team will include members from a variety of majors, and be advised by faculty members from several disciplines. The projects will be developed jointly with an industry sponsor during the year, and the summer project will carry out the plan developed during the spring semester. This experience will be the intensive, team-oriented activity that industry wants. The final design will be presented to the entire faculty, students and industry. A team final report will also be produced to document the project.

Summary

This paper has described a new practice-oriented Aerospace Engineering Master's degree program at Virginia Tech. It is part of a program by five departments in the college of engineering to be offered for the first time in the Fall of 1996, with a small group of students. Initially, students from the five different engineering departments will be participating. It is truly multidisciplinary. Students from the different departments will work together in common core classes and on a team project. The core courses will be team taught by faculty from the different departments. We envision expanding the program to all the departments in the college, and beyond the college of engineering to include other colleges at the university. Our web page will always contain the latest details: **http://www.aoe.vt.edu/**, including a link to the POMD page: **http://www.eng.vt.edu/POMD**. General Virginia Tech information is available at **http://www.vt.edu/.**

Acknowledgments

The program described in this paper was the result of a team effort by the Practice-oriented Master's Degree Working Group. All the members are responsible for this program and we acknowledge their contributions. The working group members are, in Engineering Science & Mechanics: R. W. Landgraf, in Industrial and Systems Engineering: W. G. Sullivan, in Materials Science & Engineering: R. W. Hendricks, in Mechanical Engineering: M. Ahmadian, J. H. Bohn, E. F. Brown, H.H. Cudney, and N. S. Eiss, and, finally, in Aerospace and Ocean Engineering: B. Grossman and W. H. Mason. The effort to improve the design program in the AOE Department has included all the faculty and members of the MAD Center at Virginia Tech. We also acknowledge the contribution of Mike Deisenroth, ISE, for the new Aerospace Manufacturing Course.

References

1. Committee on Engineering Design Theory and Methodology, *Improving Engineering Design: Designing for Competitive Advantage*, National Academy Press, 1991.

2. John H. McMasters and Steve D. Ford, "The [Airplane] Design Professor as Sheepherder," AIAA Paper-90-3259, AIAA/AHS/ASEE Aircraft Design and Operations Meeting, Dayton, Ohio, Sept. 17-19, 1990.

3. Leland M. Nicolai, "Designing a better engineer," *Aerospace America*, April 1992, pp. 30-33, 46

4. James D. Lang and Paul B. Hugge, "Product and Process Design for the "New Aerospace Enterprise," 1995 ASEE Annual Conference and Exposition, Anaheim, CA, June 25-28, 1995.

5. Nancy Fitzgerald, "Mastering Engineering," ASEE PRISM, Jan. 1996, pp. 25-28.

6. E.F. Crawley, E.M. Greitzer, S.E. Widnall, S.R. Hall, H. L. McManus, J.R. Hansman, J.F. Shea and M. Landahl, "Reform of the Aeronautics and Astronautics Curriculum at MIT," AIAA Paper 93-0325, Jan. 1993.

7. W.H. Mason, "Aircraft Design at Virginia Tech: Experience in Developing an Integrated Program," AIAA Paper 95-3894, 1st AIAA Aircraft Engineering, Technology, and Operations Conference, Los Angeles, CA, Sept. 19-21, 1995 Html version: **http://www.aoe.vt.edu/aoe/faculty/Mason_f/ACDesP/ACDesPgmVPI.html**

8. J. F. Marchman, II and W.H. Mason, “Freshman/Senior Design Education,” AIAA Paper 94-0857, Jan. 1994.

9. Mark Gordon, Dan Schrage, Joel Greenstein, Jack Hebrank, Doug Hirt, Bill Mason, Tom Miller, and Jim Nau, “Early Design: Lessons and Strategies from SUCCEED”, Session 3225, 1996 ASEE Annual Conference and Exposition, Washington, DC, June 23-26, 1996. Html version: **http://succeed.ee.vt.edu/edm/begin.html**

10. B. Grossman, Director, MAD Center, see **http://www.aoe.vt.edu/mad/mads.html**

11. Michael P. Deisenroth and William H. Mason, “Curriculum Development in Aerospace Manufacturing” Session 0402, 1996 ASEE Annual Conference and Exposition, Washington, DC, June 23-26, 1996

12. W.H. Mason, Zafer Gürdal and R.T. Haftka, “Experience in Multidisciplinary Design Education,” ASEE Annual Conference, Monday, June 26, 1995, Anaheim, CA (Conrad Newberry, session chairman: Multidisciplinary Design). Postscript file available at: **http://www.aoe.vt.edu/mad/postscripts/MDOExp.html**

Biographical Information

WILLIAM H. MASON is a Professor in the Aerospace and Ocean Engineering Department at Virginia Tech. He teaches several design courses and Applied Computational Aerodynamics. Prior to coming to Virginia Tech he spent 15 years in industry at the Grumman Aerospace Corporation. His research is in multidisciplinary design, vehicle technology integration and applied aerodynamics.
http://www.aoe.vt.edu/aoe/faculty/masfac.html

BERNARD GROSSMAN is a Professor and Department Head of Aerospace and Ocean Engineering. He also serves as the Director of the Multidisciplinary Analysis and Design (MAD) Center for Advanced Vehicles. He teaches courses in fluid dynamics and his research fields include computational fluid dynamics and multidisciplinary analysis and design. He spent 12 years in industry at the Grumman Aerospace Corporation.
http://www.aoe.vt.edu/aoe/faculty/bgfac.html