Final Report

January 1998

Principal Investigators:

Department of Aerospace and Ocean Engineering
Virginia Polytechnic Institute and State University
Blacksburg, VA 24061
The subject grant NGT-10025 was in effect from 10/1/93 until 10/31/96. The remaining two years of funding for this effort was transferred from NASA Headquarters to NASA Langley and a new grant NGT-1-52155 was issued covering the period 11/1/96 to 11/30/98. This report serves as the final report of NGT-10025. The efforts described herein continue under NGT-1-52155.

For a number of years, Virginia Tech had been on the forefront of research in the area of multidisciplinary analysis and design. In June of 1994, faculty members from aerospace and ocean engineering, engineering science and mechanics, mechanical engineering, industrial engineering, mathematics and computer sciences, at Virginia Tech joined together to form the Multidisciplinary Analysis and Design (MAD) Center for Advanced Vehicles. The center was established with the single goal: to perform research that is relevant to the needs of the US industry and to foster collaboration between the university, government and industry. In October of 1994, the center was chosen by NASA headquarters as one of the five university centers to establish a fellowship program to develop a graduate program in multidisciplinary analysis and design. The fellowship program provides full stipend and tuition support for seven U. S. students per year during their graduate studies.

To advise us regarding the problems faced by the industry, an industrial advisory board has been formed consisting of representatives from industry as well as government laboratories. The present membership includes major aerospace companies: Aurora Flight Sciences, Boeing Helicopter Division, Cessna, Ford, General Electric, Hughes, Lockheed, McDonnell Douglas, Northrop, Sikorsky, smaller, aerospace software companies: Aerosoft, Phoenix Integration and Proteus Engineering, along with representatives from government agencies, including: NASA Ames, Langley and Lewis.

The function of the advisory board is to channel information from its member companies to faculty members concerning problems that need research attention in the general area of multidisciplinary design optimization (MDO). The faculty and their graduate students make proposals to the board on how to address these problems. At the annual board meeting in Blacksburg, the board discusses the proposals and suggests which students get funded under the NASA fellowship program. All students participating in the program are required to spend 3–6 months in industry working on their research projects.

We are completing the third year of the fellowship program and have had three advisory board meetings in Blacksburg. Eight students have spent the three month periods in industry and two students are spending this current semester in industry. In addition to the research element of the MAD Center efforts we also have an academic component. We have developed a menu of design-related graduate courses and two new courses: one in Aerospace Manufacturing and another in MDO. Some of the MAD Center activities are described on the world-wide web at http://www.aoe.vt.edu/mads.html. The MAD Center represents an innovative approach for joint Industry-Government-University cooperation in the development of a comprehensive program in engineering education which addresses the design needs of industry.

The following charts list details of the grant: mission of the MAD Center, faculty members, purpose of the industrial advisory board, board members, summary of the graduate and undergrad-
uate program, history of the fellowship program, mission of the fellowship program, requirements of MAD fellows, course requirements, students supported, advisory board meeting participation, MAD Center research papers.
Multidisciplinary Analysis and Design Center for Advanced Vehicles

- Faculty members with a common interest in MDO applied to advanced vehicles including aircraft, spacecraft, ships, submarines, high-speed trains and automobiles.

- Research to answer industrial needs in the multidisciplinary design area.

- Provide the graduate students opportunities for research collaboration with industry.
# MAD Center Faculty Members

**Board of Directors:**

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<th>Name</th>
<th>Institution</th>
<th>Department</th>
<th>Research Area</th>
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<td>R. Kapania</td>
<td>Va Tech</td>
<td>AOE</td>
<td>Aeroelasticity</td>
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<td>J. Schetz</td>
<td>Va Tech</td>
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**Faculty Members:**

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<td>M. Anderson</td>
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<td>D. Mook</td>
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<td>J. Burns</td>
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<td>M. Gunzberger</td>
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<td>L. Watson</td>
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<td>R. Landgraf</td>
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<td>L. Librescu</td>
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<td>A. Nayfeh</td>
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<td>J. H. Bohn</td>
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<td>W. O'Brien</td>
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<td>M. Diesenroth</td>
<td>ISE</td>
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Industrial Advisory Board

- Board to provide center members with descriptions of industrial needs in the area of MDO.

- Board to review proposals by faculty member/graduate student teams for student support for the research work

- Board will make recommendations for funding with NASA Fellowship program funds.

- Will solicit from industry commitments for supporting graduate students working on these projects for at least one semester in industry.
  - Match industrial groups with present federal and state research projects.
  - Set up university-industry research teams for future funding opportunities.
Industrial Advisory Board Members

Aerosoft
Aurora Flight Sciences
Boeing - Philadelphia

Boeing - St. Louis
Boeing - Long Beach
Cessna
Ford
General Electric
Lockheed Martin
Microcraft
Northrop Grumman
Phoenix Integration
Proteus Engineering
Sikorsky Aircraft

NASA Ames
NASA Ames
NASA Langley
NASA Langley
NASA Lewis

Dr. R. W. Walters
Dr. M. Hutchison
Mr. H. Rosenstein
Mr. M. Sheffler
Mr. R. Yurkovich
Mr. J. Geising
Dr. T. Seitz
Dr. Richard DeVries
Dr. V. Kumar
Dr. Y. Tassa
Dr. J. Benek
Dr. R. P. Ley
Dr. B. Malone
Mr. Tobin McNatt
Mr. Christos Kassapoglou

Mr. P. Gelhausen
Dr. G. Guruswamy
Mr. P. Coen
Dr. J. Sobieski
Dr. C. Chamis
Student Curriculum and Research

Virginia Tech design education:

- Graduate Program in MDO.
  - Students must spend at least one semester in industry.
  - Disciplinary degree with specialization in design.
  - Selected "core" courses.
  - New Aerospace Manufacturing and MDO Courses.
  - Practice-Oriented Master's Degree.

- Improved design in Under-Graduate Program.
  - Optimization in 2nd year with Mathematica/Matlab.
  - Mini-design optimization projects in 2nd & 3rd years.
  - Senior/Graduate Aerospace Manufacturing and MDO Courses.
  - Senior capstone design involving several departments with international participation.
NASA Multidisciplinary Design and Analysis Fellowship Program

- MAD Center established June 1994.
  
  5 Awards, $200K/year, 3 years
  
  Virginia Tech, Georgia Tech, BYU, Cal Poly, Clemson

- Funding
  
  

- Industrial Advisory Board established Sept. 1994
  

- New graduate program in design being developed.
  
  MDO Course: Fall 1995
  
  Aerospace Manufacturing Course: Spring 1996

- Joint industry-university research activities underway.

- 7 graduate students per year supported on MAD projects.
NASA Multidisciplinary Design and Analysis Fellowship Program

- Innovative approach for joint Industry-Government-University cooperation in the development of a comprehensive program in engineering education which addresses the design needs of industry.

- Industry-sponsored research is more likely to be useful when the industrial sponsor teams up with the faculty and students to perform joint work.

- Joint industry-university-government projects will make the program self sustaining.
Requirements for MAD Fellows

MAD Fellows:

○ Graduate students enrolled in the MAD center certificate program.
○ Satisfy the requirements for a degree in one of the disciplinary programs, e.g., Aerospace Eng., Eng. Mechanics.

Additional requirements:

• Perform thesis research in multidisciplinary analysis and design of advanced vehicles.
• Spend an internship period of 3–6 months in industry working on a MAD project.
• Complete MAD related course work in two (M.S.) or three (Ph.D) of the following areas:
  Optimization Methods
  Manufacturing Engineering
  System Engineering & Economic Analysis
  Computer-Aided Design
Course Requirements for MAD Fellows

**Optimization Methods Courses:**
- AOE/ESM: Eng. Design Optimization, Structural Optimization
- AOE: Optimization Techniques
- ISE: Optimization I,II
- MSCI: Management Science, Advanced Management Science

**Manufacturing Engineering Courses:**
- ESM: Composite Manufacturing
- AOE: Aerospace Manufacturing

**Systems Engineering Courses:**
- ISE: Advanced Engineering Economy

**Computer Aided Design Courses:**
- ME: Computer-Aided Design I,II
- AOE: Computer-Aided Design of Vehicle Structures
- ESM: Scientific Visual Analysis with Multimedia
Students Supported By MAD Center

MAD Fellowship program support:

Chuck Baker       Grossman / Mason       McDonnell Douglas - West
David Cohen       Kapania / Walters
Joel Grasmeyer    Mason / Grossman
Brian Owen        Gürdal
Scott Ragon       Gürdal / Haftka
Jonathan Rich     Gürdal / Kapania
Robert Soper      Mook
Jason Tyll        Schetz / Diesenroth

Related MAD Center support:

Vladimir Balabanov Haftka       Boeing Commercial
Manoj Bhardwaj     Kapania        McDonnell Douglas
Oleg Golividov     Mason / Grossman
Tony Giunta        Grossman / Haftka
Duane Knill        Grossman / Mason
P. Mohan           Kapania
Ajit Shenoy        Cliff
Grant Soremekun     Gürdal        Sikorski
                        
                        

# MAD Industrial Advisory Board Meeting, 8/2-3/1996

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<th>Bernard Grossman</th>
<th>Raphael Haftka</th>
<th>Rakesh Kapania</th>
<th>William Mason</th>
<th>Zafer Gürdal</th>
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<th>Jason Tyll</th>
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6th Symposium on Multidisciplinary Analysis & Optimization

MAD Center papers:

8. Mohan*, Kapania and Jakubowski, “Control of Thermal Deformations of a Spherical Mirror Segment.”