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NASA AERONAUTICS
MULTIDISCIPLINARY ANALYSIS AND DESIGN
FELLOWSHIP PROGRAM

Final Report

January 1998

Virginia Tech

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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.

Virginia Tech

MAD Center

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

→ MAD Center

Board of Directors:

B. Grossman	Va Tech	AOE	CFD Optim.
Z. Gürdal	Va Tech	AOE/ESM	Struct. Optim.
R. Haftka	U. Fl.	AMES	Struct. Optim.
R. Kapania	Va Tech	AOE	Aeroelasticity
W. Mason	Va Tech	AOE	Aero. Des.
J. Schetz	Va Tech	AOE	Aero./Manuf.

Faculty Members:

M. Anderson	AOE	Control Des.	
E. Cliff	AOE	Optim. Control	
O. Hughes	AOE	Ship Des.	
E. Nikolaides	AOE	Probabil. Des.	
D. Mook	ESM	Aero/Controls	
J. Burns	Math	Optim. Control	
M. Gunzberger	Math	Shape Optim.	
L. Watson	CS	Parallel Comp.	
R. Landgraf	ESM	Auto. Struct.	
L. Librescu	ESM	Aeroelasticity	
A. Loos	ESM	Compos. Manuf.	
A. Nayfeh	ESM	Nonlinear Dyn.	
J. H. Bohn	ME	Rapid Prototyp.	
W. O'Brien	ME	Propulsion	
M. Diesenroth	ISE	Manufacturing	
J. Nachlas	ISE	Operations Res.	

Industrial Advisory Board

MAD Center

- 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

→ MAD Center

Aerosoft	Dr. R. W. Walters
Aurora Flight Sciences	Dr. M. Hutchison
Boeing - Philadelphia	Mr. H. Rosenstein
	Mr. M. Sheffler
Boeing - St. Louis	Mr. R. Yurkovich
Boeing - Long Beach	Mr. J. Geising
Cessna	Dr. T. Seitz
Ford	Dr. Richard DeVries
General Electric	Dr. V. Kumar
Lockheed Martin	Dr. Y. Tassa
Microcraft	Dr. J. Benek
Northrop Grumman	Dr. R. P. Ley
Phoenix Integration	Dr. B. Malone
Proteus Engineering	Mr. Tobin McNatt
Sikorsky Aircraft	Mr. Christos Kassapoglou
NASA Ames	Mr. P. Gelhausen
NASA Ames	Dr. G. Guruswamy
NASA Langley	Mr. P. Coen
NASA Langley	Dr. J. Sobieski
NASA Lewis	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.
- NASA AMDAF Fellowship Program awards announced Sept. 1994.
  - 5 Awards, $200K/year, 3years
  - Virginia Tech, Georgia Tech, BYU, Cal Poly, Clemson
- Funding
  - 11/94–11/96, $216K, NASA Hqtrs.
  - 11/96–11/97, $176K, NASA Langley, MDO Branch.
- Industrial Advisory Board established Sept. 1994
  - Meetings: 10/94, 8/95, 8/96, (11/97 scheduled).
- 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

→ MAD Center

○ *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:

- ISE: Industrial Automation, Manufact. Sys. Eng., Manufact. Costs & Prod. Econ., Digital Computers in Manufact. Sys. Control
- ESM: Composite Manufacturing
- AOE: Aerospace Manufacturing

Systems Engineering Courses:

- ENGR: The Systems Eng. Process, Applied Systems Eng.
- 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	
David Cohen	Kapania / Walters	McDonnell Douglas - West
Joel Grasmeyer	Mason / Grossman	
Brian Owen	Gürdal	Sikorsky
Scott Ragon	Gürdal / Haftka	McDonnell Douglas - West
Jonathan Rich	Gürdal/Kapania	Northrop Grumman
Robert Soper	Mook	Cessna
Jason Tyll	Schetz / Diesenroth	Lockheed Martin

Related MAD Center support:

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

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

✈ MAD Center

INDUSTRY		FACULTY	STUDENTS
Matthew Hutchison	Aurora Flight Sciences	Bernard Grossman	Vladimir Balabanov
Marc Sheffler	Boeing Helicopters	Raphael Haftka	Manoj Bhardwaj
Harold Rosenstein	Boeing Helicopters	Rakesh Kapania	David Cohen
John Axtel	Cessna	William Mason	Mark Eaglesham
Terry Denardo	Hughes Space & Comm.	Zafer Gürdal	Anthony Giunta
Alex Benoliel	Hughes Space & Comm.	Eugene Cliff	Oleg Golovidov
Rudy Yurkovich	McDonnell Douglas -East	Joseph Schetz	Satish Haryadi
Joseph Giesing	McDonnell Douglas - West	Michael Deisenroth	Scott Ragon
George Tzong	McDonnell Douglas - West	James Marchman	Johnathan Rich
John Benek	Micro Craft		Ajit Shenoy
Stephen Brown	Northrop Grumman		Grant Soremekun
Valentin Gushchin	Russian Academy of Sciences		Jason Tyll

GOVERNMENT	
Gerald Seidel	NASA Hqtrs.
Guru Guruswamy	NASA Ames
Thomas Zang	NASA Langley
Jaroslaw Sobieski	NASA Langley
Christos Chamis	NASA Lewis
William Lewis	Army Aviation & Troop Com.

6th Symposium on Multidisciplinary Analysis & Optimization

✈ MAD Center

* *students*

MAD Center papers:

1. Balabanov*, Kaufman*, Knill*, Giunta*, Haftka, Grossman, Mason, Watson, "Dependence of Optimal Structural Weight on Aerodynamic Shape for a High Speed Civil Transport."

2. Chai* and Mason, "Landing Gear Integration in Aircraft Conceptual Design."

3. Cliff, Heinkenschloss and Shenoy*, "An Optimal Design Problem Governed by the 1-D Euler Equations."

4. Giunta*, Balabanov*, Kaufman*, Grossman, Mason, Watson and Haftka, "Wing Design for a High-Speed Civil Transport Using a Design of Experiments Methodology."

5. Henderson*, Gürdal and Loos, "Combined Struct. and Manufact. Optim. of Stiffened Composite Panels."

6. Issac* and Kapania, "Aeroelastic Sensitivity Analysis of Wings Using Automatic Differentiation."

7. Kapania, Bhardwaj*, Reichenback and Guruswamy, "Aeroelastic Analysis of Modern Complex Wings."

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

9. Soremekun*, Gürdal, Haftka and Watson, "Improving Genetic Algorithm Efficiency and Reliability in the Design and Optimization of Composite Structures."

10. Tyll*, Eaglesham*, Schetz and Deisenroth, "An MDO Design Methodology for the Concurrent Aerodynamic/Cost Design of MagLev Vehicles."

11. Anderson and Mason, "An MDO Approach to Control-Configured-Vehicle Design."