General Disclaimer

One or more of the Following Statements may affect this Document

- This document has been reproduced from the best copy furnished by the organizational source. It is being released in the interest of making available as much information as possible.

- This document may contain data, which exceeds the sheet parameters. It was furnished in this condition by the organizational source and is the best copy available.

- This document may contain tone-on-tone or color graphs, charts and/or pictures, which have been reproduced in black and white.

- This document is paginated as submitted by the original source.

- Portions of this document are not fully legible due to the historical nature of some of the material. However, it is the best reproduction available from the original submission.

OLD DOMINION UNIVERSITY RESEARCH FOUNDATION

DEPARTMENT OF MECHANICAL ENGINEERING AND MECHANICS
SCHOOL OF ENGINEERING
OLD DOMINION UNIVERSITY
NORFOLK, VIRGINIA

GRADUATE ENGINEERING RESEARCH PARTICIPATION IN AERONAUTICS

By

A. Sidney Roberts, Jr., Principal Investigator

Annual Progress Report
For the period September 1, 1983 to August 31, 1984

Prepared for the
National Aeronautics and Space Administration
Langley Research Center
Hampton, Virginia 23665

Under
Research Grant NGR 47-003-052
Dr. Sam E. Massenberg, Technical Monitor
Office of University Affairs

August 1984

DEPARTMENT OF MECHANICAL ENGINEERING AND MECHANICS
SCHOOL OF ENGINEERING
OLD DOMINION UNIVERSITY
NORFOLK, VIRGINIA

GRADUATE ENGINEERING RESEARCH PARTICIPATION IN AERONAUTICS

By

A. Sidney Roberts, Jr., Principal Investigator

Annual Progress Report
For the period September 1, 1983 to August 31, 1984

Prepared for the
National Aeronautics and Space Administration
Langley Research Center
Hampton, Virginia 23665

Under
Research Grant NGR 47-003-052
Dr. Sam E. Massenberg, Technical Monitor
Office of University Affairs

Submitted by the
Old Dominion University Research Foundation
P.O. Box 6369
Norfolk, Virginia 23508-0369

August 1984

GRADUATE ENGINEERING RESEARCH PARTICIPATION IN AERONAUTICS

By

A. Sidney Roberts, Jr.*

INTRODUCTION

Early in the year, two new students embarked on the two-year study/research program, two students phased off the stipend program (one completing a masters thesis), and research tasks were advanced. Mr. Ajit Kelkar completed a two-year term in the program; he continues orderly progress toward his Ph.D. degree with an expected completion date in 1984-85. A winter solicitation was conducted, to engineering departments across the country, which was producing students who could qualify for the graduate research program in Aeronautics. Seven (7) bona fide applications were received; however, in March 1984, word was received from NASA/LRC that in all likelihood no supplementary funding for the program would be available in fiscal year 1985; as a consequence no full-time research participants were added after Spring, 1984. The graduate student compliment in the full-time program stood at four (4) during the report period.

In the following sections of this report research summaries are made. These include the four full-time projects, a completed masters thesis, and the part-time research tasks. A final section outlines plans for the termination of the grant program.

SYNOPSIS OF RESEARCH

The four full-time graduate research participants are performing tasks associated with composite material failure and testing (2), rigid body

*Professor, Department of Mechanical Engineering and Mechanics, Old Dominion University, Norfolk, Virginia 23508

dynamics (1), and fluid mechanics (1). The status of their research is reported below along with a description of a completed masters thesis and the work of part-time students. Progress on the four main research projects was reported by the graduate research participants during the Annual Graduate Student Workshop held at NASA/LRC, June 22, 1984.

Current Projects

Summaries by research participants are presented in this section. The lead task is doctoral level work and the remaining three are at the masters level.

FAILURE MODES FOR MECHANICALLY FASTENED JOINTS IN COMPOSITE MATERIALS

By

Rajiv Naik

ODU Advisor: Dr. R. Prabhakaran, NASA Advisor: Dr. J. H. Crews

The objective of the present study is to analyse and compare laminate failures in bolted joint configurations. Toward this end, tests were conducted to measure damage onset, ultimate strength, hole elongation, as well as failure energy for specimens subjected to bolt-bearing loads. Specimens consisted of 16-ply quasi-isotropic T300/5208 graphite/epoxy. They had a range of configurations that produced different failure modes. Throughout each test, bolt hole elongation was used as the servocontrol variable. Dye-penetrant-enhanced radiographs were used to observe the local damage.

The failure mode for damage onset and ultimate strength was found to be influenced by the width to diameter ratio and the edge distance to diameter ratio. Bolt clampup also influenced the failure mode. The failure energies associated with the bearing-dominant

failures were about five times as large as those measured for the shearout and tensile failures. This suggests that as new tougher composites are developed, their relative bearing and net-tensile strengths as well as the corresponding fracture energies should be measured. Such measurements would provide a basis for joint designs that consider strength as well as fracture energy.

A finite-element stress analysis was conducted for each specimen configuration. The clearance between the bolt and the hole was accounted for, but friction between bolt and hole was neglected. The non-linear contact problem for clearance-fit joints was solved by an inverse technique. The computed stresses near the hole were used with several different failure criteria to predict trends in the test data. These predictions showed which local stresses influenced the failure modes and strengths.

Further work plans include the installation of a new test set-up to test specimens in combined bearing and by-pass loading. A more sophisticated analysis which includes both clearance and friction at the joint is also in the plans. A new finite element program which can handle the non-linearities due to clearance and friction will be developed for a better understanding of the stress state near the hole, and its influence on the damage onset and failure modes.

THE DYNAMIC STABILITY OF AN EARTH ORBITING SATELLITE DEPLOYING HINGED APPENDAGES

By

Kevin Oakes

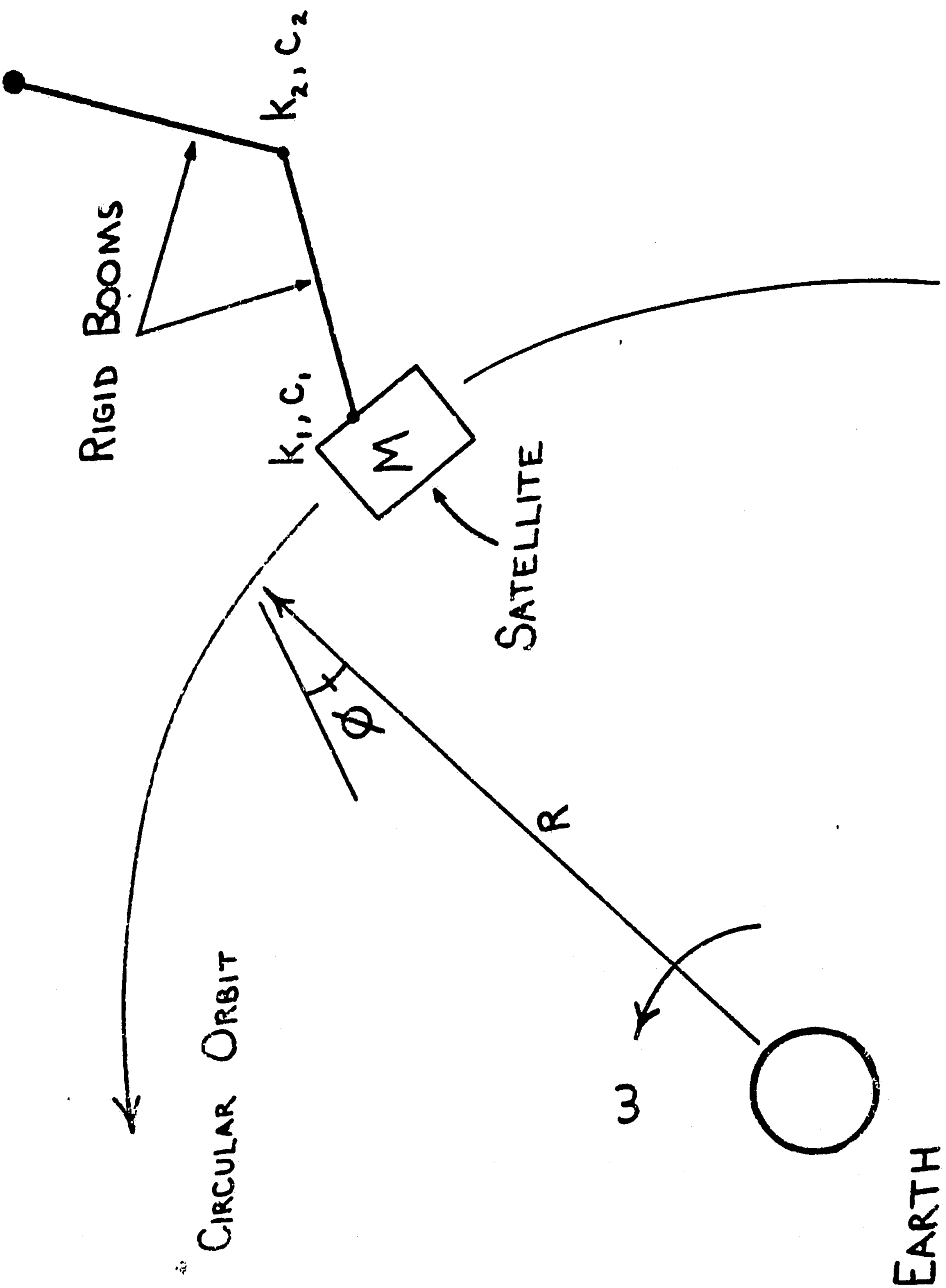
ODU Advisor: Dr. Chuh Mei, NASA Advisor: Dr. Jerrold Housner

Commencing January 1, 1984, a research problem has been defined as shown in the figure on the following page. The stability of a satellite deploying rigid booms is to be studied under the influence of a gravity gradient in a near-earth, circular orbit. The stability is defined in terms of the libration angle ϕ. More specifically, the objectives of my study are as follows:

1) develop a set of governing equations which describe the motion of the satellite during deployment of the booms. The Lagrangian method will be utilized;
2) obtain solutions to the governing equations for both the linearized and non-linear cases. This will be achieved either analytically or numerically;
3) perform various parameter studies to obtain some concluding results. If time permits, the problem will be solved for flexible booms also.

Thus far, the equations of motion for this problem have been developed for circular motion about a fixed point on earth. The governing equations account for the deployment mechanism consisting of two rotational viscous dampers and two torsional springs. Currently, the orbital effects are being added to these equations separately. These consist of: (1) orbital rate, ω, (2) gravity gradient effects, and (3) Coriolis forces. The completed equations of motion are expected to be derived by the end of August 1984.

Upon reaching this point, the equations of motion will be solved for a simple linearized case and a more difficult nonlinear case. The solutions will reflect the stability of the satellite in



terms of the libration angle, ϕ. Various parameter studies will then follow to determine the effects upon the obtained solutions.

Finally, if time allows, the problem will be solved for the deployment of flexible booms. This case will be more representative of an actual application in orbit.

ANALYSIS OF THE IOSIPESCU SHEAR TEST FOR COMPOSITE MATERIALS

By

Barry Spigel

ODU Advisor: Dr. R. Prabhakaran, NASA Advisor: Mr. Wallace C. Sawyer

For the research and development engineer, the determination of the shear properties of composite materials with a simple, reliable test has proved to be an elusive goal. The ideal shear test should be mechanically simple, use small specimens with a simple geometry and produce an unambiguous state of pure shear. Yet, one or more of these requirements is lacking in current shear test methods.

The Iosipescu Shear Test holds much promise in meeting the standards listed above. Originally developed in the early 1960's for determining shear properties of metals, the Iosipescu Shear Test has only recently been studied for use with composite materials. Though some theoretical analyses have been conducted, little experimental work has been performed. It has been the purpose of the current work to examine experimentally the Iosipescu Shear specimen and various load introduction fixtures, and to expand upon the analytical work that has been conducted.

An extensive experimental investigation was performed during

the last year. Two fixtures with different load introduction schemes were analyzed and modifications were made to better induce a pure shear state in the specimens. Various specimen geometries were also tested. The typical specimen is a double V-notched rectangle. Such parameters as notch angle and notch radius were examined to determine which specimen configuration resulted in a state of pure shear at the notches. Only twenty specimens remain to be tested out of the one-hundred tests that were planned.

The two load fixtures were also analyzed using finite element techniques. The specimens were studied to see how variations in the loading affected the state of stress in the notched area as well as throughout the entire body. Various degrees of orthotropy were examined to insure that a load introduction scheme and specimen configuration were applicable to all materials. Completion of the computer analysis is expected by the end of April 1984.

Preliminary results indicate that it will be possible to state which load fixture and which specimen geometry will produce a state of pure, uniform shear between the notches. Since both shear modulus and shear strength can be determined from one simple experiment, the Iosipescu Shear Test may be ideally suited for determining the shear properties of composite materials.

THE EFFECT OF BOUNDARY LAYER STRUCTURE ON WING TIP VORTEX FORMATION AND DECAY

By

Dan Stead

ODU Advisor: Dr. J. Kuhlman, NASA Advisor: Mr. Dennis Bushnell

Originally the objective of this research was to study the

merger of a trailing wing tip vortex with horseshoe vortices, vortex streets, and longitudinal vortices. A survey of the literature has prompted a change in this objective, due to the number of previous investigations into vortex merger. The intent now is to study the effect of boundary layer structure and turbulence on wing tip vortex formation and decay. Research has shown that the vorticity in the trailing vortex is contained in the boundary layer, and that the structure of the trailing vortex is effected by boundary layer separation and transition. These observations have provided the incentive to investigate the effect of the boundary layer structure on the trailing vortex. The structure will be changed experimentally through the addition of small longitudinal and transverse vortices, by premature transition to turbulence by the break-up of large eddies, and by using laminar, and standard airfoils. Hydrodynamic stability studies have shown that vortices are stable under axisymmetric disturbances, but are unstable to asymmetric disturbances. Small vortex streets and longitudinal vortices will be placed in and around the main vortex to observe their effect on the vortex formation, and to observe if the instabilities can be excited. Finally, free stream turbulance is a known cause of vortex meander, but it's effect on formation is not known. This effect will be investigated as will be the effect of free stream turbulance on the performance of the previously described disturbances.

The research is experimental. Velocity and pressure data will be collected by means of a small, seven-hole probe. Flow visualization will be used to observe the effects of the disturbances, including the seven-hole probe. Tests are scheduled to begin in January 1985.

Completed Project

Raymond H. Wall, working with Drs. Bob Ash (ODU) and Ping Tcheng (NASA), successfully defended his thesis in the Spring, 1984. The thesis abstract entitled, "The Development of a Microprocessor Controlled Linearly Actuated Valve Assembly," describes the work and is designated as Appendix A of this report. Mr. Wall's name is added to the cumulative list of graduate theses which have been produced under this grant program. See Table 1.

Part-Time Research Tasks

A limited amount of money had been budgeted for the report period as seed money to start-up research projects or to augment on-going projects using part-time student assistants. The following task was supported:

"Transient Heat Load Analysis for Habitable Structures."

Work on a one-dimensional, lumped parameter model, which simulated a structure receiving and losing sensible and latent heat to an ambient environment, was completed. An effort was started to compare the results with those obtained using a new "canned" computer program, ASEAM (working for Dr. Roberts; Hung Hu, $1275, Spring and Summer; Tom McNamara, $675, summer).

TERMINATION OF PROGRAM

Financial contingencies and changes in policies influencing NASA support of graduate engineering programs have apparently precipitated the decision to discontinue the Graduate Engineering Research Participation In Aeronautics at ODU. Plans continue to be made to provide for an orderly closure. Immediate steps during the report period included a moratorium on selection of new research participants and a reassessment of the 1984-85 budget which had been attached to Grant NGR 47-003-052 Supplement No. 13,

authorized on August 29, 1983. The essential guiding principle was to provide the promised stipends and tuition for the four graduate students who are the current program participants. Remaining grant monies were allocated to meet the student needs, basic administrative costs, and indirect costs.

A budget projection is attached to this report (Appendix B) which spreads the remaining grant monies over a period of time sufficient to see the current students through their two-year program commitments, viz., June 1, 1984 to May 31, 1986. The budget projection lists the direct costs items. It is anticipated that this budget projection will guide the principal investigator's expenditures especially through the next academic year.

Name	Undergraduate College	Acad. Yr. of Compl.	Department	Degree	Thesis Title
John E. Carr	ODU	1971-72	Electrical	ME*	None
Joan P. Gosink	MIT	1972-73	Mech. Eng. & Mechanics	ME	Numerical Study of the Turbulent Boundary Layer in a Hypersonic Nozzle
Joanne L. Walsh	ODU	1973-74	Mech. Eng. & Mechanics	ME	Computer-Aided Design of Light Aircraft to Meet Certain Aerodynamic and Structural Requirements
Leroy F. Albang	Iowa State	1974-75	Mech. Eng. & Mechanics	ME	Analysis of Spread Multi-Jet VTOL Aircraft in Hover
Garla Arjuna	Anantapur, India	1974-75	Mech. Eng. & Mechanics	ME	The Effect of Unreinforced Cutouts on the Buckling of Thin Conical Shells Loaded by Central Axial Compression
Michael H. Berger	ODU	1974-75	Mech. Eng. & Mechanics	ME	Application of Boundary Layer Theory to Suction Through Streamwise Slots in Wind Tunnel Walls
J. Phillip Drummond	UVA	1974-75	Mech. Eng. & Mechanics	ME	A Method for Improving the Accuracy in Phase Change Heat Transfer Data Through Increased Precision in Thermophysical Property Determination.

(cont'd)

Name	Undergraduate College	Acad. Yr. of Compl.	Department	Degree	Thesis Title
Joseph T. Fuss	Rose-Hulman	1974-75	Mech. Eng. & Mechanics	ME	Dynamics of Explosion Remnants in Earth Orbits
Raymond S. Chapman	ODU	1976-77	Civil	ME	A Model to Investigate the Influence of Suspended Sediment on the Mass Transport of a Pollutant in Open Channel Flow
Richard C. Haut, II	Rose-Hulman	1976-77	Mech. Eng. & Mechanics	Ph.D.	Evaluation of Hydrogen as a Cryogenic Wind Tunnel Test Gas
S.V.S. Manian	Madras Eng. College, India	1976-77	Mech. Eng. & Mechanics	ME	Evaluation of Upwelling Infrared Radiance in a Non-homogeneous Nonequilibrium Atmosphere
Mark D. Pardue	ODU	1976-77	Electrical	ME	Automatic Stabilization of Helicopter Sling Loads by Reaction Jets
Charles C. Marshall	ODU	1977-78	Electrical	ME	A Comparison of Digital Computers in Implementing Avionic Control Laws
Arun A. Nadkarni	Bangalore Univ., India	1977-78	Mech. Eng. & Mechanics	Ph.D.	Optimal Control of a Large Space Telescope Using an Annular Momentum Control Device

(cont'd)

Name	Undergraduate College	Acad. Yr. of Compl.	Department	Degree	Thesis Title
Paul A. Nystrom	Rose-Hulman	1977-78	Mech. Eng. & Mechanics	ME	Static Temperature Measurements in Supersonic Flow Using Laser Raman Spectroscopy
Sophia K. Ashley	NE Louisiana State Univ.	1978-79	Mech. Eng. & Mechanics	ME	Inviscid Two-Dimensional Vortex-Panel Method for Calculating the Pressure Distribution Over Non-circular Cylinders at Various Flow-Incident Angles
David L. Livingston	ODU	1978-79	Electrical	ME	A High-Speed Algorithmic Signal Processor
Phiilip S. Mastic	Kent State	1978-79	Electrical	ME	Second Order Open Loop Omega Phase Detector: Microprocessor-Based
Woodrow W. Wagner	VPI & SU	1978-79	Mech. Eng. & Mechanics	ME	Temperature and Time Dependent Viscosity of Elastomer Modified Epoxy Resin
Stephen P. Wilkinson	ODU	1978-79	Mech. Eng. & Mechanics	ME	An Experimental Investigation of a Turbulent Boundary Layer with Suction Through Closely Spaced Streamwise Slots

(cont'd)

Name	Undergraduate College	Acad. Yr. of Compl.	Department	Degree	Thesis Title
Louis A. Roussos	ODU	1979-80	Mech. Eng. & Mechanics	ME	Finite Element Model of a Timoshenko Beam with Structural Damping
Tommy T. Augustsson	U. of Florida	1980-81	Mech. Eng. & Mechanics	Ph.D.	Effects of Multiple Scattering and Surface Albedo on the Photochemistry of the Troposphere
Thomas D. Johnson, Jr.	Air Force Inst. of Tech.	1980-81	Mech. Eng. & Mechanics	ME	Experimental Study of Delta Wing Leading-Edge Devices for Drag Reduction at High Lift
Michael P. Lazar	Penn. State	1980-81	Mech. Eng. & Mechanics	ME	Low Speed Handling Characteristics of a Supersonic Transport by Eigenstructure Assignment
Gilbert O. Kraemer	ODU	1982-83	Mech. Eng. & Mechanics	ME	Interaction of a Two-Dimensional Transverse Jet in a Supersonic Mainstream
Ime I. Akpan	Boston Univ.	1982-83	Mech. Eng. & Mechanics	ME	An Approach for Including Reliability in Control System Designs
Raymond H. Wall	ODU	1983-84	Mech. Eng.	ME	The Development of a Micro-Processor Controlled Linearly Actuated Valve Assembly

*ME - "Master of Engineering" in respective department.

APPENDIX A

ABSTRACT

THE DEVELOPMENT OF A MICROPROCESSOR CONTROLLED LINEARLY ACTUATED VALVE ASSEMBLY

Raymond H. Wall
Old Dominion University, 1984
Director: Dr. Ping Tcheng with
Dr. Robert L. Ash

The development of a proportional fluid control valve/assembly is presented. This electro-mechanical system is needed for space applications to replace the current proportional flow controllers that use bulky hydraulic or pneumatic actuation systems. The flow is controlled by a microprocessor system that monitors the control parameters of upstream pressure and requested volumetric flow rate. The microprocessor achieves the proper valve stem displacement by means of a digital linear actuator. A linear displacement sensor is used to measure the valve stem position. This distance is monitored by the microprocessor system as a feedback signal to make the control closed-loop. With an upstream pressure between 15-47 psig, the developed system operates between 779 standard cm^3/sec (SCCS) and 1543 SCCS. The delivered volumetric flow rates were within 5% of the requested values. A statement on the system stability is included as an appendix. Recommendations made for future work on the design include further modification to the bellows spring and the possibility of a mass flow rate controller.

APPENDIX B

Budget Projection

June 1, 1984 to May 31, 1986

I. Unobligated Balance, 6/1/84		$46,119
II. Direct Costs		
A. Salaries		
PI		
AY 1984-85, 15%	$ 5,775	
Sum. '85, 24%	3,000	
Part-time students	1,175	
Secretary	5,574	
B. Fringe Benefits		
PI 25% of AY	1,448	
Other	720	
C. Research Participants		
Spigel}		
} already encumbered		
Naik }		
Stead		
Oakes	7,700	
	7,700	
Carryovers (for students not completing degrees in 2 years)	4,907	
D. Travel to technical meetings	1,400	
E. Reports/photocopying	300	
F. Computer Costs	520	
G. Expendable supplies	300	
H. Tuition	5,600	
I. Estimated direct costs	$46,119	
J. Balance as of 5/31/86		0