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NASA/AMERICAN SOCIETY FOR ENGINEERING EDUCATION (ASEE) SUMMER FACULTY FELLOWSHIP PROGRAM 1990

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Hampton, Virginia

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SECTION I

ORGANIZATION AND MANAGEMENT

The 1990 Hampton University (HU)-NASA-Langley Research Center (LaRC) Summer Faculty Fellowship Research Program, the twenty-seventh such institute to be held at LaRC was planned by a committee consisting of the University Co-Director, LaRC staff members from the research divisions and the Office of University Affairs. It was conducted under the auspices of the Langley Research Center's Chief Scientist, Dr. Richard W. Barnwell.

Each individual applying for the program was provided a listing of research problems available to the LaRC Fellows. Each individual was requested to indicate his or her problem preference by letter to the University Co-Director. The desire to provide each Fellow with a research project to his or her liking was given serious consideration.

An initial assessment of the applicant's credentials was made by the NASA-LaRC University Affairs Officer and the University Co-Director. The purpose of this assessment was to ascertain to which divisions the applicant's credentials should be circulated for review. Each application was then annotated reflecting the division to which the applications should be circulated. After the applications had been reviewed by the various divisions, a committee consisting of staff members from the various divisions, the University Affairs Officer and the University Co-Director met. At this meeting the representatives from the various divisions indicated those individuals selected by the divisions.

The University Co-Director then contacted each selected Fellow by phone extending the individual the appointment. The University Co-Director also forwarded each selected Fellow a formal letter of appointment confirming the phone call. Individuals were given ten days to respond in writing to the appointment. As letters of acceptance were received, contact was made with each Division Coordinator advising them of their Fellows for the summer program.

Each Fellow accepting the appointment was provided material relevant to housing, travel, payroll distribution and a listing of all NASA-LaRC Research Fellows. Each Fellow, in advance of commencing the program, was contacted by his or her Research Associate or a representative of the branch.

At the assembly meeting, Dr. Samuel E. Massenberg, the NASA-LaRC University Affairs Officer introduced, Mr. Paul F. Holloway, Deputy Director of the Langley Research Center, who formally welcomed the summer Fellows. for the first time, an orientation video entitled "An overview of Langley Research Center, was presented. Miss Carolyn Floyd from the Technical Library Branch briefed the Fellows on the use of the library. Mr. Richard Weeks, manager of the LaRC cafeteria, briefed the Fellows relevant to the cafeteria policies, hours, etc. Mr. James Harris of the Computer Management Branch briefed the Fellows on the Computational Facilities. The subject of security at LaRC was discussed by O. J. Cole from the Security Branch. Safety procedures were discussed by Vernon Wessel from the Safety Branch. Patricia Gates presented programs and activities sponsored by the Activities Center. Peter Edgette discussed the Occupational Health Services available through the clinic. Further instructions were given and information disseminated by Dr. Samuel E. Massenberg and Mr. John H. Spencer, Co-Director, ASEE program.

Throughout the program the University Co-Director served as the principal liaison person and had frequent contacts with the Fellows. The University Co-Director also served as the principal administrative officer. At the conclusion of the program, each Fellow submitted an abstract describing his/her accomplishments. Each Fellow gave a talk on his/her research within the division. The Research Associate then forwarded to the Co-Director the name of the person recommended by the division for the final presentation. Eleven excellent papers were presented to the Fellows, Research Associates, and invited guests.

Each Fellow and Research Associate was asked to complete a questionnaire provided for the purpose of evaluation of the summer program.

An unusual situation arose when a Fellow arrived the beginning of May without requesting an early start date. The person then left on June 1 to attend a conference in Colorado. This was not cleared with the Co-Director. When contacted by phone, the Fellow stated that he was using the computer facilities at the University of Colorado, Boulder to conduct his research and would return in late July (after an absence of eight weeks). Since we could not agree on a more satisfactory solution, the appointment was terminated and the Fellow was given a credit for four weeks participation.

SECTION II

RECRUITMENT AND SELECTION OF FELLOWS

RETURNING FELLOWS

An invitation to apply and participate in the Hampton University (HU)-Langley Research Center (LaRC) Program was extended to those individuals who held 1989 LaRC Fellow appointments. Twenty-eight individuals responded to the invitation, however, only sixteen were selected. Twenty-seven applications were received from Fellows from previous years or from other programs. Ten were selected.

NEW FELLOWS

Although ASEE distributed a combined brochure of the summer programs, many personal letters were mailed to deans and department heads of various engineering schools in the East, South and Midwest, by Professor John Spencer of Hampton University (HU) and Dr. Surendra Tiwari of Old Dominion University (ODU), requesting their assistance in bringing to the attention of their faculties the HU/ODU-LaRC program. In addition, to the above, a number of departments of chemistry, physics, computer science and mathematics at colleges (including community colleges) and universities in the State of Virginia as well as neighboring states were contacted regarding this program. Although minority schools in Virginia and neighboring states were included in the mailing, the Co-Director from HU made site visits to minority schools soliciting applicants, and sent over three hundred letters to deans and department heads. These efforts resulted in a total of one-hundred thirteen formal applications, all indicating the HU/ODU-LaRC Program as their first choice and a total of thirty-one indicating the HU/ODU-LaRC Program as their second choice. The total number of applications received came to one hundred forty-four (Table 1).

Thirty-nine applicants formally accepted the invitation to participate in the program. Eight applicants declined the invitation. Several Fellows delayed their decision while waiting for acceptance from other programs. The top researchers seem to apply to more than one program and will make their selection based on research interest and stipend. Twenty-six positions were initially budgeted by NASA. Thirteen positions were funded by the LaRC divisions.

The average age of the participants was 42.

TABLE I

FIRST CHOICE APPLICATIONS

Total	Females		Males		Minority Schools Represented
	Black	NonBlack	Black	NonBlack	
113	1	5	8	100	9*

SECOND CHOICE APPLICATIONS

Total	Females		Males		Minority Schools Represented
	Black	NonBlack	Black	NonBlack	
31	0	0	0	31	0

NASA-LaRC PARTICIPANTS

Total	Females		Males		Minority Schools Represented
	Black	NonBlack	Black	NonBlack	
39	0	4	4	32	3*

First Year Fellows	Returnees	Number Declined
13	26	8

Positions Funded by NASA	Local Purchases
26	13

***24 applications from nine schools - There was an increase in the number of applications received from minority schools, but a decrease in the number of schools represented under the participants heading.**

SECTION III

STIPEND AND TRAVEL

A ten week stipend of $9,000 was awarded to each Fellow. Although this stipend has improved over previous years, it still falls short (for the majority of Fellows) of matching what they could have earned based on their university academic salaries. This decision to participate in the summer faculty research program does clearly reflect the willingness of the Fellow to make some financial sacrifice in order to participate in the summer program.

Travel expenses incurred by the Fellows from their homes to Hampton, Virginia, and return were reimbursed in accordance with current HU regulations. A relocation allowance of $1,000.00 was provided for the Fellows traveling a distance of 50 miles or more.

SECTION IV

LECTURE SERIES, PICNIC AND DINNER

LECTURE SERIES

In response to statements made by the Fellows, the Lecture Series was again arranged around research being done at LaRC and the speakers were LaRC research scientists.

Appendix III contains the agenda for the special ASEE Summer Lecture Series for 1990.

PICNIC AND DINNER

A picnic for the Fellows, their families, and guests was held on June 15, 1990. A seminar/dinner was held on August 1, 1990.

SECTION V

RESEARCH PARTICIPATION

The 1990 HU-LaRC Research Program, as in the past years, placed greatest emphasis on the research aspects of the program. Included in this report are abstracts from the Fellows showing their accomplishments during the summer. These abstracts, together with the comments of the LaRC Research Associates with whom the Fellows worked, provide convincing evidence of the continued success of this part of the program. The Fellow's comments during the evaluation of the program indicated their satisfaction with their research projects as well as with the facilities available to them.

The research projects undertaken by the Fellows were greatly diversified as is reflected in their summer research assignments. Their assignments were as follows:

Number of Fellows Assigned	Division
2	Applied Aerodynamics Division
1	Analysis and Computational Division
1	Acoustics Division
1	Atmospheric Sciences Division
2	Office of the Chief Scientist
2	Flight Applications Division
4	Flight Electronics Division
1	Facilities Engineering Division
4	Fluid Mechanics Division
2	Flight Management Division
3	Guidance and Control Division
2	Instrument Research Division
1	Interdisciplinary Research Office
2	Information Systems Division
5	Materials Division
2	Structural Dynamics Division
1	Systems Engineering Division
2	Structural Mechanics Division
1	Space Systems Division

Thirty-seven (95%) of the participants were holders of the doctorate degree. Two (5%) held the masters degree. The group was a highly diversified one with respect to background. Areas in which the last degree was earned:

Number	Last Degree
1	Aeronautics/Astronautics
4	Aerospace Engineering
1	Ceramic Engineering
1	Chemical Engineering
2	Chemistry
1	Civil Engineering
1	Composite Structures
1	Computational/Applied Mathematics
2	Computer Science
1	Control Theory
3	Electrical Engineering
1	Engineering Management'
1	Engineering Psychology
1	Engineering Science
1	Fluid Dynamics
1	Human Resources/Organ. Behavior
1	Industrial/Organ. Psychology
2	Mathematics
2	Materials Science & Engineering
2	Mechanical Engineering
1	Mechanics
1	Nuclear Chemistry
1	Occupational Education Admin.
1	Operations Research
1	Physical Chemistry
3	Physics
1	Structural Optimization

EXTENSIONS

A portion of the funds remaining in the travel budget was used to grant extensions to eleven Fellows in the program. To be considered for the extension, the Fellow submitted a statement of justification which was supported by the Research Associate. The requests were reviewed by the University Co-Director and the University Affairs Officer. The following individuals were granted extensions:

Louis Gratzer	2 weeks
Joseph Hafele	1 week
Stephen Hodge	1 week
John Hurley	2 weeks
Marvin Klutz	1 week
Robert McIntyre	2 weeks
Rishi Raj	1 week

EXTENSIONS CONTINUED

Carl Russell	1 week
Paavo Sepri	1 week
Paul Wang	2 weeks
Fuh-Gwo Yuan	2 weeks

ATTENDANCE AT SHORT COURSES, SEMINARS, AND CONFERENCES

During the course of the summer there were a number of short courses, seminars, and conferences, the subject matter of which had relevance to the Fellows research projects. A number of Fellows requested approval to attend one or more of these conferences as it was their considered opinion that the knowledge gained by their attendance would be of value to their research projects. Those Fellows who did attend had the approval of both the Research Associate and the University Co-Director. The following is a listing of those Fellows attending either a short course, seminar or conference:

Suresh Chandra attended three seminars: (1) by S. Girimaja on PDF Methods in Combustion, (2) by D. Wilcox on K-W Models, and (3) by R. Gaffney on Compressible Flow Modeling.

Peyman Givi attended the JANNAF Workshop on Scramjet Modeling in Orlando, Florida. He also participated in several coursed offered by the NASA Langley Learning Center.

Joseph Hafele attended a meeting with Dr. G. M. R. Winkler, Director - Time Service Division, U. S. Naval Observatory, Washington, DC.

Johnny Houston attended a short course on the GRID Generation - Eagle, by Jomshid A. Abolhassanni.

Jeng-Nan Juang attemded a seminar on Aerobrake Plasmadynamics: Macroscopic Effects.

Moira LeMay attended two seminars: (1) Research with Topographic EEG by E. Bogart, and (2) Human Factors in International Business by B. Kantowitz.

Eleanor Prochaska attended two seminars: (1) Langley Colloquia - Digital Avionics - A Cornerstone of Aviation by Cary R. Spitzer, and (2) Mission Hightlights - STS 32: Retrieval of LDEF by Bonnie J. Dunbar.

Rishi Raj attended the ASME Gas Turbine Conference.

Asit K. Ray attended a seminar entitled Progess Report of Research on High Tech Composites by Dr. Jeff Hinkley.
Craig S. Sims attended the 7th International Conference on Systems Engineering.

Resit Unal attended a short course on the Quality Engineering Using Robust Design.

In addition to the above there was attendance and participation in conferences, seminars, and short courses held at LaRC.

PAPERS PRESENTED

"Effects of Compressibility and Heat Release in a High Speed Reacting Mixing Layer", "Heat Release and Compressibility in a Hight Speed Reacting Mixing Layer" - Peyman Givi.

"Local Delaminations of (0/15/-15)s Graphite Epoxy Laminates Under Tensile Loads" - Salpekar, S. A., O'Brien, T. K., and **Hooper, Steven J**.

"Studies on the Durability of Kevlar and Nomex in the Presence of Atomic Oxygen and Ultraviolet Radiation" - S. Powell, **R. Kiefer**, P. L. Pate, **R. Orwoll**, and S. Long.

"Parallel-Vector Computation for CSI-DESIGN Code" - Duc T. Nguyen.

"A Rate Equation Approach to Gain Saturation Effects in Laser Mode Calculation" - Lila F. Roberts.

ANTICIPATED PAPERS

"Mutual Coupling Between Two Circular Horns in a Dielectrically-Covered Plane" - Christos Christodoulou.

"Computing Waves Using Incompressible Solutions" - Steve Hodge.
"A Study of the Applicability of SiC and GaAs as Aerospace Sensor Materials", "The Effect of Crystal Growth Irregularities on the I-V Characteristics of Double Barrier Resonant Tunneling Structures" - John S. Hurley.

"Plastic Deformation Mechanisms In Polyimide and Polyimide-based Semi-IPN", "Toughening Mechanism-Morphology Relationships In Polyimide-based Semi-IPNs" - Bor Zeng B. Jang.

"Radiometer System Requirements for Microwave Remote Sensing from Satellites" - Jeng-Nan Juang.

"Minimizing Distortion in Truss Structures via Simulated Annealing" - Rex Kincaid.
"User's Guide for LASGRF Laser Graphing Programs" - Glenn Klutz.

"An Empirically Derived Figure of Merit for the Quality of Overall Pilot Performance" - **M. LeMay** and R. Comstock.

"A Future Perspective on Technological Obsolescence at Langley" - Robert M. McIntyre.

"The Semidiscrete Galerkin Finite Element Modeling of Compressible Viscous Flow Past an Airfoil" - Andrew J. Meade, Jr.

"Rotor Impedance Sensitivity Analysis", "Harmonic Balance Formulation of the Rotor-Fuselage EQNS" - Kip P. Nygren.

"An Injection-Seeded Titanium Sapphire Laser for Differential Absorption Lidar" - Larry Petway.

"Analysis of Pressure Broadened Ozone Spectra in the 3µm Region" - Eleanor Prochaska.

"Effect of Rotation on Isotropic Turbulence and Homogeneous Shear" - Rishi Raj.

"Reduced Order Filters for Flexible Space Structures", The Design of Insensitive Filters" - Craig Sims.

"A Theory of Checking Software Input" - Mark Staknis.

"International Society of Parametric Analysts" - Resit Unal.

"Analysis of Composite Cylindrical Shells Under Internal Pressure" - Fuh-Gwo Yuan.

Other Fellows are planning publications based on their research but have not solidified their plans at this time.

ANTICIPATED RESEARCH PROPOSALS

Turbulence Modeling for High Speed Compressible Flows - submitted to NASA Langley Research Center - Suresh Chandra.

Response to Disturbances in a Laminar Boundary Layer - NASA Langley Research Center - Louis Gratzer.

Realistic Law of Gravity - submitted to Australian National University, Mount Stromlo and Siding Spring Observatories, Canberrra, Australia - Joseph Hafele.

Fundamental Investigation of C.F.D. Techniques in Aeroacoustics - Steve Hodge.

A Study of Applicability of SiC and GaAs as Aerospace Sensor Materials, and A Study of the Applicability of Smart Materials as Aerospace Sensor Materials - submitted to NASA Langley Research Center - John S. Hurley.

Processing-Structure-Property Relationships in High Performance Interpenetrating Networks - to be submitted to NASA Langley Research Center - Bor Zeng B. Jang.

Quantitative Analysis of Ice Films by NEAR Infrared Spectroscopy - NASA Langley Research Center - Joe Keiser.

A Proposed Study of the Relationship Between Workload and Overall Task Performance - to be submitted to NASA Langley Research Center - Moira LeMay.

A Data Base of Future Knowledge and Skills Required in Aerospace Industry, and High Tech Industries and Future Technological Obsolescence - to be submitted to NASA Langley Research Center - Robert M. McIntyre.

The Semidiscrete Galerkin Finite Element Modeling of Compressible Three-Dimensional Viscous Flow - NASA Langley Research Center - Andrew J. Meade, Jr.

Doppler Global Velocimeter Studies and Evaluations - to be submitted to NASA Langley Research Center - Leonard S. Miller.

Compressible Flow Turbulence Dissipation Equation, and Rotating Flow Homogeneous Turbulent Shear Flow - NASA Langley Research Center - Rishi Raj.

Using Laser Rate Equations to Study Saturation Effects in Laser Systems - to be submitted to NASA Langley Research Center - Lila F. Roberts.

Facilitating Researcher Use of Flight Simulators - NASA Langley Research Center - C. Ray Russell.

Turbulence Modeling for Flow in Propulsive Transition Ducts - to be submitted to NASA Langley Research Center - Paavo Sepri.

Reduced-Order Filtering and Control for Flexible Space Structures - NASA Langley Research Center - Craig Sims.

FUNDED RESEARCH PROPOSALS

Large Eddy Simulation and a Direct Numerical Simulation of High Speed Reacting Flows - NASA Langley Research Center - Peyman Givi.

The Effect of Crystal Growth Irregularities on the I-V Characteristic of DBRT Structures - National Security Agency - John S. Hurley.

The Effects of the Interaction of Polymeric Materials with the Space Environment - NASA Langley Research Center - Richard L. Kiefer.

Effects of the Space Environment on Polymeric Materials - NASA Cooperative Agreement - Robert A. Orwoll.

SECTION VI

SUMMARY OF PROGRAM EVALUATION

A program evaluation questionnaire was given to each Fellow and to each Research Associate involved with the program. A sample of each questionnaire is in Appendix V of this report. The questions and the results are given beginning on the next page.

A. Program Objectives

1. Are you thoroughly familiar with the research objectives of the research (laboratory) division you worked with this summer?

   Very much so 23 (64%)
   Somewhat 13 (36%)
   Minimally 0

2. Do you feel that you were engaged in research of importance to your Center and to NASA?

   Very much so 29 (81%)
   Somewhat 6 (16%)
   Minimally 1 (3%)

3. Is it probable that you will have a continuing research relationship with the research (laboratory) division that you worked with is summer?

   Very much so 24 (67%)
   Somewhat 10 (27%)
   Minimally 2 (6%)

4. My research colleague and I have discussed follow-up work including preparation of a proposal to support future studies at my home institution, or at a NASA laboratory.

   Yes 24 (69%) No 11 (31%)

5. What is the level of your personal interest in maintaining a continuing research relationship with the research (laboratory) division that you worked with this summer?

   Very much so 31 (86%)
   Somewhat 3 (8%)
   Minimally 2 (6%)

B.	Personal Professional Development

1. To what extent do you think your research interests and capabilities have been affected by this summer's experience? You may check more than one.

   Reinvigorated 11 (31%)
   Redirected 7 (19%)
   Advanced 27 (75%)
   Just maintained 1 (3%)
   Unaffected 1 (3%)

2. How strongly would you recommend this program to your faculty colleagues as a favorable means of advancing their personal professional development as researchers and teachers.

   With enthusiasm 23 (74%)
   Positively 8 (26%)
   Without enthusiasm 0
   Not at all 0

3. How will this experience affect your teaching in ways that will be valuable to your students? (you may check more than one)

   By integrating new information into courses 28 (78%)
   By starting new courses 7 (19%)
   By sharing research experience 31 (86%)
   By revealing opportunities for future employment in government agencies 20 (55%)
   By depending your own grasp and enthusiasm 5 (14%)
   Will affect my teaching little, if at all 1 (3%)

4. Do you have reason to believe that those in your institution who make decisions on promotion and tenure will give you credit for selection and participation in this highly competitive national program?

   Yes 21 (64%)   No 12 (36%)

C. Administration

1. How did you learn about the Program? (Please check appropriate response)

(53%) __19__ Received announcement in the mail.

(3%) __2__ Read about in a professional publication.

(44%) __16__ Heard about it from a colleague.

(11%) __4__ Other (explain). ____________________

2. Did you also apply to other summer faculty programs?

Yes __11__ (31%) No __24__ (69%)

_____ DOE

__5__ Another NASA Center

__4__ Air Force

__3__ Army

__3__ Navy

3. Did you receive an additional offer of appointment from one or more of the above? If so, please indicate from which. No __27__ Yes __3__

AIR FORCE (2) ARMY (1)

4. Did you develop new areas of research interest as a result of your interaction with your Center and laboratory colleagues?

Many __10__ (29%)
A few __24__ (68%)
None __1__ (3%)

5. Would the amount of the stipend ($900 per week) be a factor in your returning as an ASEE Fellow next summer?

Yes 21 (64%)
No 12 (36%)
If not, why My main reason for coming to Langley was to do research, not to make money. Research is the most important factor. Nine hundred per week seems reasonable.

6. Did you receive any informal or formal instructions about submission of research proposals to continue your research at your home institution?

Yes 27 (77%) No 8 (23%)

7. Was the housing and programmatic information supplied prior to the start of this summer's program adequate for your needs?

Yes 27 (84%) No 5 (16%)

8. Was the contact was your research colleague prior to the start of the program adequate?

Yes 28 (85%) No 5 (15%)

9. How do you rate the seminar program?
Excellent 10 (28%)
Very good 15 (42%)
Good 6 (16%)
Fair 5 (14%)
Poor 0

10. In terms of the activities that were related to your research assignment, how would you describe them on the following scale?

Check one per activity	Time Was			
Activity	Adequate	Too Brief	Excessive	Ideal
Research	18	7		9
Lectures	21	1	2	11
Tours	17	8		6
Social/Recreational	23	1		10
Meetings	25	2		8

11. What is your overall evaluation of the program?

Excellent 23 (66%)
Very good 12 (34%)
Good ____
Fair ____
Poor ____

12. If you can, please identify one or two significant steps to improve the program.

See Fellow's Comments and Recommendations

13. For second-year Fellows only. Please use this space for suggestions no improving the second year.

D. Stipend

1. To assist us in planning for appropriate stipends in the future would you indicate your salary at your home institution.

   SALARY MEDIAN WAS FOR THE ACADEMIC YEAR

   $ ____________ per Academic year____ or Full year ____. (check one)

2. Is the amount of the stipend the primary motivator to your participation in the ASEE Summer Faculty Fellowship Program?

   Yes 4 (12%) No 17 (50%) In part 13 (38%)

3. What, in your opinion, is an adequate stipend for the ten-week program during the summer of 1991?

   $ 9,000-7 (21%) 10,000-16(49%) 11,000-2 (6%) 12,000-7 (21%) 15,000-1 (3%)

E. American Society for Engineering Education (ASEE) Membership Information

1. Are you currently a member of the American Society for Engineering Education?

   Yes 7 (19%) No 29 (81%)

2. Would you like to receive information pertaining to membership in the ASEE?

   Yes 21 (66%) No 11 (34%)

Percentages have been rounded off to next whole number.

Percentage figures are based on the number of responses to the specific question.

Eighty-one percent of the Fellows responding felt that their research was of importance to the center (LaRC) and to NASA. Note that this is a drop from ninety-seven percent in 1989.

Eighty-six percent of the Fellows responding indicated a high level of personal interest in maintaining a continuing research relationship with the Lab/Division where they worked this summer. This figure is down from ninety-seven percent in 1989.

Seventy-five percent of the Fellows responding felt their research capabilities have been advanced as a result of the summer experience. Thirty-one percent were reinvigorated and nineteen percent redirected.

One hundred percent of those responding would give a strong positive recommendation for the program to faculty colleagues.

Thirty-two percent of the Fellows responding indicated that salary (stipend) was not the primary motivation to participation in the program.

One hundred percent of the Fellows gave a program evaluation from very good (34%) to excellent (66%).

Twenty-one percent indicated a stipend range of $9,000 for the ten weeks as satisfactory.

Forty-nine percent indicated a stipend range of $10,000 for the ten weeks as satisfactory.

Twenty-one percent indicated a stipend range of $12,000 for the ten weeks as satisfactory.

Eighty-one percent of the Fellows responding indicated that they **are not** currently members of the American Society for Engineering Education.

FELLOW'S COMMENTS

The comments were as follows: The ASEE program at Langley provided an excellent opportunity for university faculty, and I will strongly recommend this program to my colleagues. Ten weeks is a very short period of time to accomplish a research task. It is not productive to fragment this time by attending lectures, meetings and tours which are of a general nature. What I gain from my contacts cannot be evaluated in dollar amounts. Really enjoyed it, and learned a lot - relevant to classes as well as research. Physical facilities could be improved (eg. desk space, etc.). Should not be expected to attend lectures outside the area of interest. Lecture topics were about subjects that can be read in magazines or newspapers. Reserved tables for lunch after lectures - great idea, gave opportunity for interaction. The stipend is less than the university pays. This makes it difficult to select NASA (despite potential for great research) over other summer opportunities. I'm not sure that a research group should take on an ASEE Fellow for the ten weeks when there is very little going on in their lab, at least without making some effort to show the Fellow other groups that are currently productive.

FELLOW'S RECOMMENDATIONS

Recommendations included the following: Find out Fellow's personal computer requirements before the summer begins and arrange for their availability at the start. Integrate first and second year projects to make a whole, larger project. More evenings during week for Fellows to meet and discuss their research and progress. Need more contact/coordination with research associate. There should be a way to expedite the procurement of supplies and equipment or provide a way of ordering the material before coming on site. More access to PC's. Keep the Grants Seminar. More specialized short courses and seminars. Have lecturers give general and more informative talks. Lectures should be geared towards Fellows area of interest.

RESEARCH ASSOCIATES' SURVEY

Ninety-seven percent of the responses indicated that the Fellows were adequately prepared for their research assignments. Several of the Fellows brought an advanced level of knowledge to the project and were already well known for research on the research topic. The one negative response was due to a lack of definition of the research problem by the Research Associate.

All of the Research Associates responding indicated satisfaction with the diligence, interest, and enthusiasm of the Research Fellow.

Ninety-seven percent of the Associates responding expressed an interest in serving in the program again.

Ninety-three percent of the Research Associates responding expressed an interest in having the Fellow, if eligible, return for a second year.

RESEARCH ASSOCIATES' COMMENTS

"This summer research has been stimulating for me. The most rewarding aspect of all is perhaps that I have learned new concepts and been exposed to new areas of research which will enhance my research programs and expand my research interests."

"......Diligence, interest and enthusiasm are an inspiration to me in my work. His ability to go to the heart of an issue has been invaluable as an aid to my own thinking."

"This is a good program and in the past has been the vehicle for establishing long term grant relationships with certain Fellows. I would like to see the program continue."

"Superconductivity is an area of research that has unlimited potential and has a definite place as an expertise needed by NASA LaRC...The ASEE program has allowed for some very good work on superconductivity in addition to an excellent interchange between NASA and Academia."

RESEARCH ASSOCIATES' RECOMMENDATIONS

Make the appointment a two year assignment if the Fellow and Associate agree.

Please give more notice to Associates regarding ASEE Fellows' schedule - i.e. seminars, deadlines for abstracts, etc. Perhaps you can set this all down in an "orientation" letter about two weeks before the program begins.

Extend the program to twelve weeks.

SECTION VII

CONCLUSIONS AND RECOMMENDATION

CONCLUSIONS

Comments from the Research Fellows and the Research Associates indicates a very high level of satisfaction with the program. The Fellows feel their research activities to be important to them in terms of professional growth, and important to the Center and NASA. The Associates indicated the importance of the research to the Center and a few commented on how rewarding the experience was to them at a personal level.

The Research Fellows all stated that they would strongly recommend the program to faculty colleagues.

There is still a need for improved communications between the Fellow and the Associate prior to arrival. It was also noted that communications between the Fellow, the Associate and others working within the Division could be improved.

There were several statements early in the program about the lack of work space (desk, chair, etc.).

There is an indication of a need for greater access to computers (more PCs).

Although the stipend is not the primary motivator towards participation in the program, there is an indication that a larger stipend is needed.

There is a need for more informal communications between the Research Fellows - An opportunity to discuss research along with the recreational activities.

While there are some small frustrating items, the kind that go with any large and complicated operation, it can be stated that the overall indication from Research Fellows and Research Associates is that the program is highly successful and certainly achieves the goal of facilitating research interest between NASA and university faculty.

RECOMMENDATIONS

Continue to urge increased contact by the Research Associate prior to arrival. Suggest that the Research Fellow contact the Research Associate for information.

Urge greater communications between Research Associate and Research Fellow during the ten week research period. Broaden the communications base to include other persons and activities within the Division.
Establish work area and office equipment prior to arrival of Research Fellow. Arrange for required computer access by Research Fellow.

Urge increase in stipend to a minimum of $10,000.00 for the ten week period.

APPENDIX I

PARTICIPANTS - ASEE/NASA LANGLEY

SUMMER FACULTY RESEARCH PROGRAM

RETURNEES

1990 NASA-ASEE-HU FELLOWS

RETURNEES

FELLOWS	AGE	ASSIGNED TO	RESEARCH ASSOCIATE
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APPENDIX II

PARTICIPANTS - ASEE/NASA LANGLEY

SUMMER FACULTY RESEARCH PROGRAM

FIRST YEAR

1990 NASA-ASEE-HU FELLOWS

FIRST YEAR

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APPENDIX III

LECTURE SERIES

PRESENTATIONS BY RESEARCH FELLOWS

1990
ASEE/NASA
Hampton University - Langley Research Center

LECTURE SERIES

Location: Activities Center Auditorium, Bldg. 1222
Time: 10:00 a.m. to 11:15 a.m.

DATE	TOPIC	SPEAKER
June 12	Flight Tests Validated Knowledge-Based Systems Concept for Primary Flight Display	Wendell Ricks Flight Systems/Flight Management Division
June 19	Overview of Work with CEBAF	Dr. Warren Buck Hampton University
June 26	Effects of Biomass Burning Emissions on the Ozone Budget Over the Amazon	Jennifer Richardson Space/Atmospheric Sciences Division
July 3	Integrated Controls-Structures Optimization for a Large Space Structure	Sharon Padula Structures/Interdisciplinary Research Division
July 10	Review of Research in Nondestructive Measurement Science	Dr. Joseph Heyman Electronics/Instrument Research Division
July 17	High Speed Civil Transport	Dr. Vicki Johnson National Research Council (Formerly of NASA LaRC)
Aug. 7	Global Atmospheric Change: An Uncontrolled Experiment	Dr. Joel Levine Atmospheric Sciences Division Fluid Mechanics Division

Schedule of Final Presentations by Faculty Fellows
Location: **Building 1212, Room 200**
Date: **August 9, 1990**
Time: **8:30 a.m. - 4:00 p.m.**

Name/Division/Branch	Topic
Dr. Stephen Hodge AcoD/AB	Computing Waves Using Incompressible Solutions
Dr. Lila Roberts SSD/HESB	A Rate Equation Approach to Gain Saturation Effects in Laser Mode Calculations
Dr. Scott Miller FAD/FRB	Aerodynamic support of Research Instrument Development
Dr. Andrew Meade AAD/TAB	The Semi-Discreet Galerkin Finite Element Modeling of Compressible Viscous Flow Past An Airfoil
Dr. Eleanor Prochaska ASB/CDB	Analysis of Pressure-Broadened Ozone Spectra in the 3-μm Region
Dr. C. Ray Russell FltMD/CVIRB	Facilitating Researcher Use of Flight Simulators
Dr. Duc Nguyen GCD/CAB	Parallel-Vector Computation for CSI-Design Code
Dr. Asit Ray FEngD/FSB	Fine-Tuning of Process Conditions to Improve Product Uniformity of Polystyrene Particles Used for Wind Tunnel Laser Velocitometry
Dr. Paavo Sepri AAD/PAB	Computational Analysis of Flow in Propulsive Transition Ducts
Dr. Byung-Lip Lee MD/PMB	MicroCracking Mechanisms and Interface Toughening of Semi-Interpenetrating Network Matrix Composites
Dr. Joseph Keiser IRD/GRIB	Quantitative Analysis of Ice Films by NIR Spectroscopy
Dr. Resit Unal SEngD/CEO	Robust Design
Dr. Joseph Hafele FED/EB	Noise in Laser Oscillator Systems
Dr. Rex Kincaid IRO	Minimizing Distortion in a Tetrahedral Truss Structure: Simulated Annealing Versus Tabu Search

APPENDIX IV

ABSTRACTS

RESEARCH FELLOWS

N91-13310

TURBULENCE MODELING FOR HIGH SPEED COMPRESSIBLE FLOWS

by

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There is an enormous need in aeronautics and other fields for the capability of calculating two- and three-dimensional compressible turbulent flows. Turbulence models are necessary in numerical simulations because of the impracticality of computing all scales of turbulent motion. Since these scales compose a range many orders in magnitude, the computer storage required to resolve all scales is much larger than the storage capacity currently available on the most powerful computers. Even if computers did exist with the required capacity, the computational speed of current computers is too slow to handle all but the simplest of problems. Thus, approximate methods, or models of turbulence, are introduced to simplify and make the computations practical.

There are several approaches to turbulence modeling, depending on how many of the turbulent scales are included in the modeling process. A rigorous approach is to use subgrid-scale modeling (also known as large eddy simulation) in which only turbulent eddies equal to or smaller than the numerical grid sizes are modeled. In this case, the largest eddies are computed, and because they move and deform in time, the calculations are necessarily unsteady. This results in relatively large computer times and restricts the applicability of subgrid modeling to fundamental studies.

A more practical approach is to model all the scales of turbulent motion. The equations solved in this case are the Reynolds-averaged Navier-Stokes equations, and the numerical solutions, which represent long time averages of the flow variables, are usually steady in time.

Numerous eddy viscosity and Reynolds stress turbulence closure models have been developed in recent years. Computations of supersonic and hypersonic flows obtained by using several of these models are also available in the turbulent flow literature. In many instances, computations based on turbulence models are compared with available experimental data. Specific examples include attached boundary layer flows, shock wave-boundary layer interactions, and compressible shear layers. In all situations, the effort is directed at seeking models which have reasonable accuracy over a limited range of flow conditions.

The status of turbulence modeling for hypersonic flow is still far from complete. More experimental data and computational comparisons will be necessary to verify and establish compressibility corrections made to date. In addition, more experimental and computational work will be needed, especially at low Reynolds numbers because of the frequent prevalance of this regime at hypersonic speeds. Also, more research work will be necessary before the compressible mixing layer problem (e.g. in two-stream supersonic mixing) can be considered solved. In this area, current modeling modifications are, to a considerable extent, ad hoc and have not been verified for a wide range of cases. Furthermore, they are not based on an understanding of the physical mechanisms involved. Research is underway at several NASA centers to use full simulations of compressible shear layers using the time-dependent Navier-Stokes equations to provide more complete information on the mixing phenomena. This research should lead to improved modeling of compressible shear flows and will be invaluable in numerous cases such as the effort currently underway at LaRC to develop a hydrogen-fueled supersonic combustion ramjet (scramjet) engine capable of propelling a vehicle at hypersonic speeds in the atmosphere.

Work to date includes the following aspects of the computational fluid dynamics research:

1. An understanding of the SPARK code with finite-volume methods, using compact high-order and Runge-Kutta time-stepping schemes for numerical solutions of Euler equations.

2. An understanding of the SPARK code using finite-difference MacCormack schemes.
3. Application of (2) to incorporate a two-equation turbulence model and a study of the extension of the K-E model for use in compressible flows involving high speed mixing layers.
4. An understanding of the use of wall functions as boundary conditions for two-dimensional compressible flows.

References

1. Narayan, J. R. and Sekar, B., "Computation of Turbulent High Speed Mixing Layers Using a Two-Equation Turbulence Model," CFD Symposium on Aeropropulsion, NASA Lewis Research Center, April 1990.
2. Sarkar, S. and Balakrishnan, L., "Application of a Reynolds Stress Turbulence Model to the Compressible Shear Layer," ICASE Report 90-18, NASA Langley Research Center, 1990.
3. Papamoschou, D. and Roshko, A., "The Compressible Turbulent Shear Layer: An Experimental Study," J. Fluid Mechanics, vol. 197 pp. 453-477, 1988.
4. Viegas, J. R., Rubesin, M. W., and Horstman, C. C., "On the Use of Wall Functions as Conditions for Two-Dimensional Separated Compressible Flows, AIAA Paper 85-0180, 1985.

N91-13311

Mutual Coupling between Circular Apertures on an Infinite Conducting Ground Plane and Radiating into a Finite Width Slab

by
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The problem of electromagnetic coupling between two horns is of interest for the Microwave Reflectometer Ionization Sensor (MRIS) that will be used in the Aeroassist Flight Experiment (AFE). Laboratory measurements of mutual coupling between conical horns (using a flat metallic reflector to simulate a critically dense plasma outside) have shown a strong dependence on the finite dimesnions of the shuttle tile over the apertures. Since both, the dielectric tile and the plasma outside the tile reflect microwaves, a study should be done to isolate the two mechanisms so that the MRIS reentry flight data can be interpreted correctly. Once the coupling due to the tile itself is determined then the location of the critical electron number density layers can be determined.

As a first attempt to tackle this problem the *Geometrical Theory of Diffraction* was used to "modify " the existing solution [1] to mutual coupling between apertures with infinite dielectric sheets. Figure 1 depicts the main rays that contibure to coupling between the two horns.

The mutual admittance for two apertures in a infinte ground plane and radiating into a finite width dielectric slab can be written as [2]:

$$Y_{12} = Y_{12}^{o} + \sum_{n=1}^{N} Y_{12}^{n} \tag{1}$$

where Y_{12}^{o} = mutual inductance for apertures in ground plane , N = the number of reflected rays, and

$$Y_{12}^{n} = \frac{1}{V_1 V_2} \int_0^{2\pi} \int_0^{a} \left[E_\rho^1(\rho,\phi)\, H_\phi^{r,d}(\rho,\phi) - E_\phi^1(\rho,\phi)\, H_\rho^{r,d}(\rho,\phi) \right] \rho d\rho d\phi \tag{2}$$

By using the equivalent current method, aperture theory to determine the radiated fields inside the dielectric tile, and ray tracing the following contributions to mutual coupling were determined :

Coupling due to Reflection

$$\begin{aligned} Y_{12}^{n} = & \Big[\frac{j(2/\pi)\, R1\, k_d a\, cos^2\theta_0}{J_1^2(x_{11})\,(x_{11}^2 - 1)\, Z_d\, s_{01}} \, \frac{J_1'(k_d a\, sin\theta_0)}{[1 - (\frac{k_d a\, sin\theta_0}{x_{11}})^2]} \\ & \sqrt{\frac{s_{01}}{s_{02}(s_{02}+s_{01})}} \, \sqrt{\frac{s_{02}}{s_{03}(s_{03}+s_{02})}}\, e^{-jk_d(s_{01}+s_{02}+s_{03})}\Big] \\ & \int_0^{2\pi} \int_0^{a} [J_1'(x_{11}\rho/a) cos^2\phi (x_{11}/a) e^{-jk_d \rho cos\phi sin\theta_0} - \\ & \frac{J_1(x_{11}\rho/a)}{\rho}\, sin^2\phi e^{-jk_d\rho cos\phi sin\theta_0}] \rho d\rho d\phi \end{aligned} \tag{3}$$

where R1 is the reflection coefficient and a the aperture radius.

Coupling due to Diffraction from Bottom Wedges

$$Y_{12}^{n} = -(4j/Z_d)(k_d)^{1/2} D_h \frac{1}{k_d s_o} (\frac{s_o'}{s_o})^{1/2} \left(\frac{J_1^2(k_d a) sin^2(\phi_0')}{(x_{11}^2 - 1)[k_d(s_o' + s_o)]^{1/2}} \right) e^{-jk_d(s_o'+s_o)} \quad (4)$$

where D_h is the diffraction coefficient.

Coupling due to Diffraction from Top Wedges

$$\begin{aligned} Y_{12}^{n} &= B_1 \frac{2 J_1(x_{11}) J_1(k_d a sin\theta_o)}{(x_{11}/a)(k_d sin\theta_o)} \\ &+ B_3 \frac{(k_d sin\theta_0 a) J_2(x_{11}) J_1(k_d sin\theta_0 a) - x_{11} J_1(x_{11}) J_2(k_d sin\theta_0 a)}{(x_{11}/a)^2 - (k_d sin\theta_0)^2} \\ &+ B_2 \frac{(k_d sin\theta_0 a) J_0(x_{11}) J_{-1}(k_d sin\theta_0 a) - x_{11} J_{-1}(x_{11}) J_0(k_d sin\theta_0 a)}{(x_{11}/a)^2 - (k_d sin\theta_0)^2} \\ &+ .5 B_2 (cos2\phi_o - sin2\phi_o) \frac{(k_d sin\theta_0 a) J_2(x_{11}) J_1(k_d sin\theta_0 a) - x_{11} J_1(x_{11}) J_2(k_d sin\theta_0 a)}{(x_{11}/a)^2 - (k_d sin\theta_0)^2} \\ &+ .5 B_2 (cos2\phi_o + sin2\phi_o) \cdot \int_0^a J_0(x_{11}\rho/a) J_2(k_d sin\theta_0 \rho) \rho \, d\rho \quad (5) \end{aligned}$$

where B_1, B_2, B_3 are constants containing information about the incident fields and their phase.

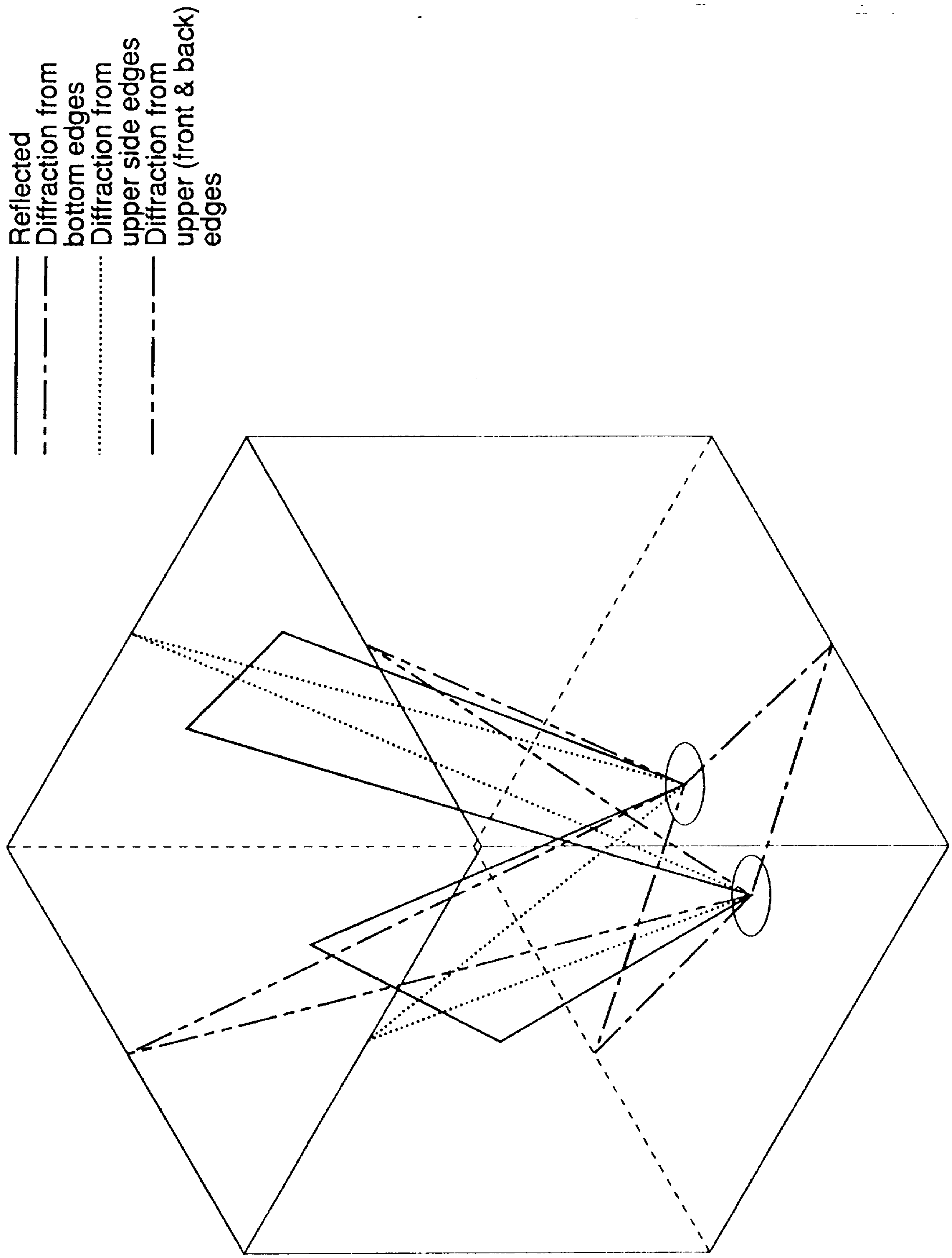
The contribution Y_{11}^{n} to the self-admittance of one aperture due to diffraction is obtained by setting $\phi_o = \pi/2$ in the above equations.

Results from two cases with different tile thicknesses have indicated that the main contribution to mutual coupling is due to diffraction from the bottom and top (back and front) wedges.

References

1. M.C. Bailey :" Near Field Coupling Between Elements of a Finite Planar Array of Circular Apertures", Ph.D. Dissertation, VPI&SU, December 1972.

2. M.C. Bailey : "Mutual Coupling Between Circular Waveguide-Fed Apertures in a Rectangular Ground Plane ", IEEE Trans. on Antennas and Propagation, July 1974, pp. 597-599.



Reflected
Diffraction from bottom edges
Diffraction from upper side edges
Diffraction from upper (front & back) edges

N91-13312

AN INVESTIGATION OF DESIGN OPTIMIZATION USING A 2-D VISCOUS FLOW CODE WITH MULTIGRID

by

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Computational fluid dynamics (CFD) codes have advanced to the point where they are effective analytical tools for solving flow fields around complex geometries. There is also a need for their use as a design tool to find optimum aerodynamic shapes. In the area of design, however, a difficulty arises due to the large amount of computer resources required by these codes. To carry out a design optimization involving multiple parameters and constraints would most likely lead to a prohibitively large drain on computer resources. It is desired to streamline the design process so that a large number of design options and constraints can be investigated without overloading the system. There are several techniques which have been proposed to help streamline the design process. My work this summer involves an investigation of the feasibility of one of these techniques.

The technique under consideration is the interaction of the geometry change with the flow calculation. Consider the problem of finding the value of camber which maximizes the ratio of lift over drag for a particular airfoil. This is an optimization problem involving one parameter. A starightforward approach to this problem would be to carry out a number of solutions to a flow code for different values of camber over a range of cambers. At each value of camber, the flow code would have to be carried out a sufficient number of iterations so that the solution is fully converged. The computed lift over drag for each solution could then be plotted versus camber. Probably ten different values of camber would be sufficient to generate a curve. The optimum camber could then be found from the curve by inspection. This process requires roughly ten applications of a grid generation program and ten fully converged flow solutions.

Now consider the same problem, but this time, instead of running the flow code to complete convergence after each change in camber, we carry out only a few iterations of the flow solution so that it is only partially converged. This partially converged flow solution is then used as the starting solution for the next grid. In this way, the design process of changing the body geometry is brought inside the flow iteration loop. In the straightforward method described above, the geometric boundary change is made outside of the flow iteration loop. If the lift and drag are fairly well established after a small number of iterations, then this procedure should yield a good approximation to the optimum camber with less computational effort.

In order to test out this technique, a particular optimization problem was tried. We considered a NACA 0012 airfoil at free stream Mach number of 0.5 with a zero angle of attack. Camber was added to the mean line of the airfoil. The goal was to find the value of camber for which the ratio of lift over drag is a maximum. The flow code used was FLOMGE which is a two dimensional viscous flow solver which uses multigrid to speed up convergence. This code was developed by Charles Swanson, Eli Turkel and Antony Jameson. A hyperbolic grid generation program was used to construct the grid for each value of camber.

First the grid was generated for six values of camber betweeen 0 and 12.5 percent. The flow solution was carried out to convergence at each value of camber. The resulting plot of lift over drag vs camber showed that a maximum value of L/D of 67.5 was obtained at a camber of 9.0 percent. It was found that 50 multigrid cycles on the finest mesh were required for convergence. Next the flow solution was run with only ten multigrid cycles on the finest mesh. This solution was used as the starting solution for the next grid. This process was carried out for the same six values of camber as above. The resulting curve showed a maximum L/D of 66.1 at a camber of 9.3 percent. The total CPU time for this case including grid generation was one-third of the time required for full convergence. Thus, a good answer to the optimization problem could be found with a savings in computer effort of a factor of three. The partially converged solutions were also carried out with five and two multigrid cycles. The case with five cylces gave comparable results. The two cycle case was not close to the converged curve although it showed the right trends.

From the above results it appears that the method of incorporating the boundary geometry change into the flow iteration loop is promising and should be given further study. Another area which needs further investigation is the development of a method for moving the interior grid points when a change in boundary shape is made. In the above test case, the grid generation code was run each time a change in camber was made. This is not an efficient way to redistribute the grid points. It would be desirable to have an efficient way to move the interior grid points smoothly when a change in boundary shape is made. One method under consideration was developed by John Batina for treating unsteady flows. In this method, the grid points are considered to be a series of masses connected by springs. The stiffness of each spring is inversely proportional to the distance between points. In this model, the grid is treated as a deformable elastic truss. The method has worked well for triangular meshes. It is hoped that it will prove useful for moving meshes made up of quadrilaterals.

N91-13313

High Speed Turbulent Reacting Flows: DNS and LES

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Abstract

The objective of the research pursued during this summer was to continue our work on understanding the mechanisms of mixing and reaction in high speed turbulent reacting flows. Our efforts, in particular, were concentrated on taking advantage of modern computational methods to simulate high speed turbulent reacting flows. In doing so, we made use of two methodologies: (1) Large Eddy Simulations and (LES) and (2) Direct Numerical Simulations (DNS).

In the work related with LES our objective is to study the behavior of the probability density functions (pdf's) of scalar properties within the subgrid in reacting turbulent flows. The use of pdf methods in a stochastic description of reacting flows has proven valuable in Reynolds averaging turbulence modeling,[1] and it is expected that their implementation for subgrid closures in LES of reacting flows would also be beneficial. In our work, we used the the data base obtained by DNS for a detailed study of the pdf characteristics within the subgrid. This data base is generated by direct simulation of an initially unpremixed homogeneous turbulent flow under the influence of a chemical reaction of the type $A + B \rightarrow Products$. Simulations are performed for flows under various initializations to include the effects of compressibility on mixing and chemical reaction. As an initial effort, it is assumed that the chemistry is infinitely fast (i.e. Damkohler Number $\rightarrow \infty$); therefore a flame sheet approximation is employed. With this approximation, the transport of an inert scalar quantity is sufficient to portray the statistical behavior of the species field. Simulations are performed for both two- and three-dimensional homogeneous flows for several values of the turbulent Mach number. A spectral-collocation algorithm based on a Fourier expansion function[2] is employed in the numerical simulations.

After the generation of the data base on the fine grid, the results are statistically analyzed within an ensemble of these grids to describe the large scale conduct on the coarse grid[3,4]. The ratio of the mesh spacings (resolution) provided by the coarse and the fine grids is a measure of the size of the filter which would be used in LES. This analysis is done at intermediate computational times, at which the influence of the initial conditions (of the chemical field) is not substantial. The results indicate that the pdf of the inert scalar within the subgrid (of various filter widths) resembles that of a Gaussian distribution. This had been already surmised in incompressible flow simulations, as previous DNS results[5,6] had suggested. However, in present simulations this behavior is observed both in incompressible flows and in compressible flows dominated with shocklets. This observation is somewhat useful since it suggests that in subgrid modeling of an inert scalar property, the information on the first two moments of the variable is sufficient to parametrize the pdf within the subgrid. With the knowledge gained to date, it is anticipated that the approach based on pdf parametrization based on its first two moments may prove serviceable for turbulent combustion simulations. The approach based on the

solution of a transport equation for pdf, however, may not be practical at this stage. An estimate of computational requirements indicates that the cost associated with LES (a semi-deterministic solution of large scale with a probabilistic description of small scale by solving a pdf transport equation) is of the same order as that of DNS on the fine grids, unless the ratio of the fine to coarse grid is large. Our ongoing investigation is concerned with investigating the effects of finite Damkohler number, which is most appropriate for pdf modeling, and also on including the influence of the heat release. The statistical analyses are also being done for different flow types and for various filter widths.

In the work related with DNS, we considered a two-dimensional temporally developing high speed mixing layer under the influence of a second-order non-equilibrium chemical reaction of the type $A + B \rightarrow Products + Heat$. Simulations were performed with different magnitudes of the convective Mach numbers and with different chemical kinetic parameters for the purpose of examining the isolated effects of the compressibility and the heat released by the chemical reactions on the structure of the layer. A full compressible code is developed and utilized, so that the coupling between mixing and chemical reactions is captured in a realistic manner[7]. A computer code developed at NASA-Langley[8,9] was employed in the simulations. The results of numerical experiments indicate that at the initial stages of the layer's growth, the heat release results in an enhanced mixing, whereas at the intermediate and the final stages, it has a reverse influence. The effect of compressibility is the same in all stages of the development; increased compressibility results in a suppressed mixing and, thus, in a reduced reaction conversion rate. Mixing augmentation by heat release is due to expansion of the layer caused by the exothermicity, and mixing abation is caused by suppression of the growth of the instability modes due to increased heat release and/or compressibility.

Calculations are performed with a constant rate kinetics model and an Arrhenius prototype, and the results are shown to be sensitive to the choice of the chemistry model. In the Arrhenius kinetics calculations, the increase of the temperature due to chemical reaction is substantially higher than that of the constant rate kinetics simulation. This results in a more pronounced response of the layer in all stages of the growth, i.e., an increased mixing at the initial phase of growth, followed by subdued mixing at intermediate and final stages. Our ongoing work in this part of our research activity includes a study of the effects of harmonic forcing in mixing promotion in the case with Arrhenius kinetics and with moderate values of the heat release.

References:

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NATURAL LAMINAR FLOW APPLICATION TO TRANSPORT AIRCRAFT

by

N91-13314

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A major goal of NASA during the last 15 years has been the development of laminar flow technology for aircraft drag reduction. Of equal importance is achieving a state of readiness that will allow the successful application of this technology by industry to large, long-range aircraft. This effort gained impetus at a time when large fuel price increases and the foreseeable scarcity of petroleum products put great economic pressure on the aircraft industry and the airlines to reduce aircraft fuel consumption. Although the original focus was on subsonic aircraft, possible application to supersonic transports is now being emphasized.

Recent progress in achieving extensive laminar flow with limited suction on the Boeing 757 has raised the prospects for practical application of the hybrid laminar flow control (HLFC) concept to subsonic aircraft. Also, better understanding of phenomena affecting laminar flow stability and response to disturbances has encouraged consideration of natural laminar flow (NLF), obtained without suction or active mechanical means, for application to transport aircraft larger than previously thought feasible.

These ideas have inspired the current NASA/ASEE project with goals as follows:

1. Explore the feasibility of extensive NLF for aircraft at high Reynolds number under realistic flight conditions.

2. Determine the potential applications of NLF technology and the conditions under which they may be achieved.

3. Identify existing aircraft that could be adapted to carry out flight experiments to validate NLF technology application.

To achieve these objectives, the current study has focused on understanding the physical limits to natural laminar flow and possible ways to extend these limits. The primary factors involved are unit Reynolds number, Mach number, wing sweep, thickness and lift coefficient as well as surface pressure gradients and curvature. Based on previous and ongoing studies using laminar boundary layer stability theory, the interplay of the above factors and the corresponding transition limits have been postulated in the form shown in Figure 1.

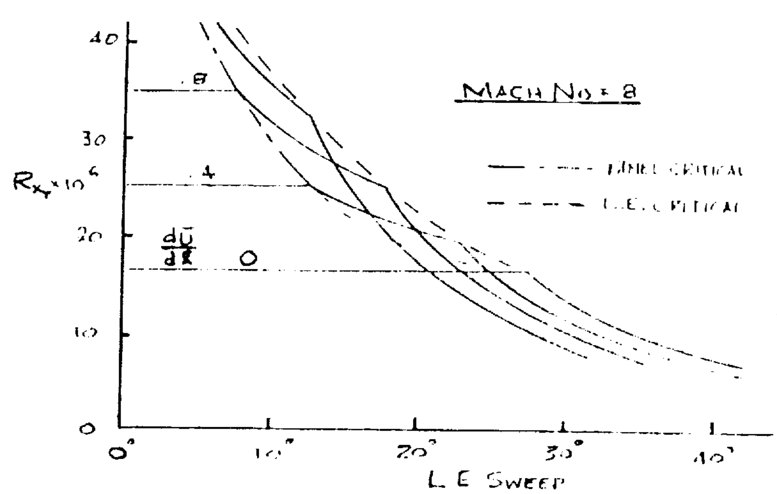

FIG. 2 TRANSITION CRITERIA FOR NLF

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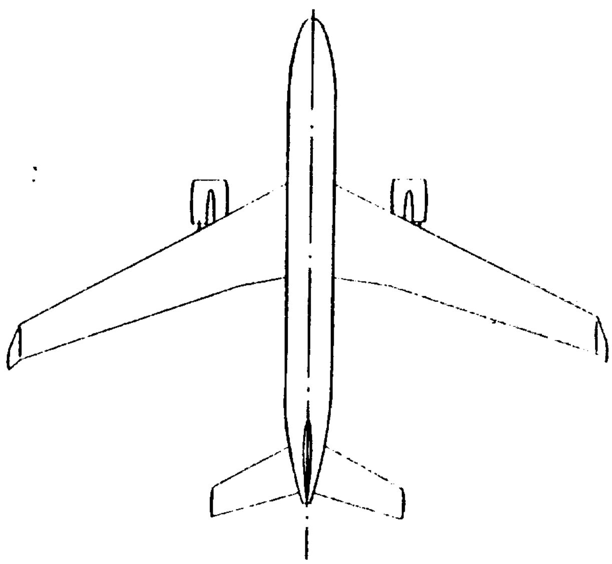
These relationships can be used as a provisional basis for identifying potential transport aircraft applications as well as to guide further theoretical studies to firmly establish NLF transition criteria. Using the above approach, several representative transport aircraft configurations have been identified as shown in Fig. 2. A comparison of lift-to-drag ratios for these types with values for comparable turbulent aircraft shows that the benefits of NLF, while diminishing with aircraft size, can still be significant for aircraft as large as the Boeing 747.



Conventional

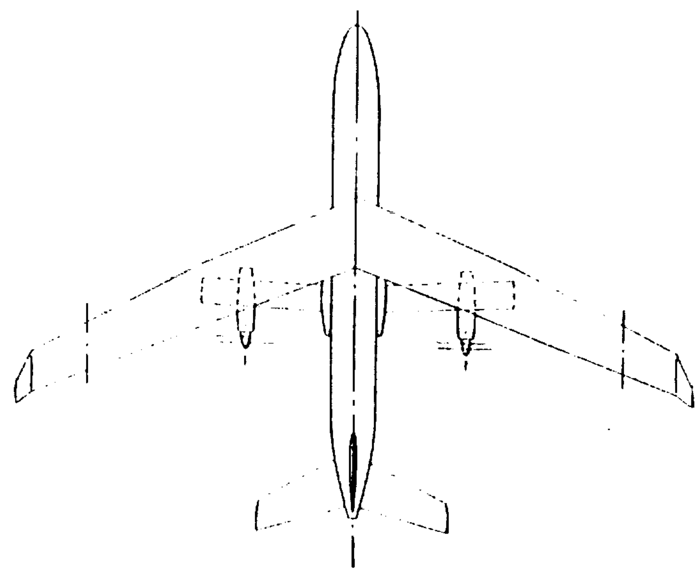


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FIG. 2 NLF CONFIGURATIONS

Based on the encouraging results of the current study, a vigorous effort to expand the NLF transition limits so as to broaden the range of potential applications is recommended. Ultimately, a flight validation phase will be required to provide full-scale data under realistic operating conditions. A preliminary assessment of aircraft that could be adapted for this purpose has indicated the following to be worthy of serious consideration. Pertinent characteristics are shown below.

AIRCRAFT	CHORD R_e	MACH NO.	L.E. SWEEP	CONFIGURATION MOD.
Lockheed P-3	29 X 10^6	.67	0°	Glove/Remove O.B. Engine
Rockwell B-1B	27 X 10^6	.80	16°	Glove/Vary Sweep
Boeing 757-200	37 X 10^6	.80	23°	Glove (Reduced Sweep)
BAC-111	26 x 10^6	.68	20°	Glove (Reduced Sweep)

Further examination of these (and perhaps other) candidates, as well as preliminary hardware studies, are needed to establish costs, schedule, and overall suitability for the flight program.

N91-13315

High Tc Superconducting Materials and Devices

by

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The high Tc (95K) $Y_1Ba_2Cu_3O_{7-x}$ ceramic materials, initially developed in 1987, are now being extensively investigated for a variety of engineering applications. These applications include such devices as conducting links, rotating and linear bearings, sensors, filters, switches, high Q cavities, magnets and motors. Some of these applications take advantage of the material's ability to lose all electrical resistance at a temperature (Tc) which is easily attainable with liquid nitrogen (77K), while others make use of the repulsion force generated between the magnetic field of a magnet and the superconductor (Meissner effect), and still others exploit the high sensitivity of the superconductive effect to magnetic fields to yield super sensitive magnetic field sensors (SQUIDS).

The superconductor applications which have presently been identified as of most interest to NASA-LaRC are (1) low-noise, low thermal conductivity grounding links for space-related detectors operating in the temperature range from 4K to 80K (SAFIRE), (2) large-area linear Meissner-effect bearings for supporting optical systems in space (IBEX) and (3) sensitive, low-noise sensors and leads for the LaRC cryogenic wind tunnel.

Devices designed for these applications require the development of a number of processing and fabrication technologies which will yield superconducting materials in both bulk and thin film forms. Included among these technologies most specific to the present needs are (1) tapecasting, (2) melt texturing, (3) magnetic field grain alignment, (4) superconductor/polymer composite fabrication, (5) thin film MOD (metal-organic decomposition) processing, (6) screen printing of thick films and (7) photolithography of thin films.

Efforts this summer have been directed toward developing some of these technologies as in-house capabilities. Accordingly, the overall objective of the program was to establish a high Tc superconductivity laboratory capability at NASA-Langley Research Center and demonstrate this capability by fabricating superconducting 123 material via bulk and thin film processes. Specific objectives included:

1. Order equipment and set up laboratory
2. Prepare 1 kg batches of 123 material via oxide raw materials
3. Construct tapecaster and tapecast 123 material
4. Fabricate 123 grounding link
5. Fabricate 123 composite for Meissner linear bearing
6. Develop 123 thin film processes (nitrates, acetates)
7. Establish Tc and Jc measurement capability
8. Set up COMMERCIAL USE OF SPACE program in superconductivity at LaRC

In general, most of the objectives of the program have been met. One-kilo batches of 123 material have been successfully prepared from in-house laboratory facilities. Powder from this oxide process was used to tapecast material which was subsequently fired, electroded, mounted on a PCB substrate and encapsulated as a superconducting grounding link. Additional powder also was used to prepare composites which were able to float a permanent magnet via the Meissner effect. Thin films prepared from nitrate and acetate precursors have been prepared using a dipping deposition process in conjunction with alumina and silver foil substrates. Thus far, the acetates appear to be the most promising. X-ray data indicate the proper crystalline structure for superconductivity, however, electrical measurements have not yet substantiated the existence of superconductivity in these films.

Finally, efforts to implement a COMMERCIAL USE OF SPACE program in superconductivity at LaRC have been completed and at least two industrial companies (AVX, Kodak) have indicated their interest in participating. This program should now move forward.

N91-13316

NOISE IN LASER OSCILLATOR SYSTEMS

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The aim of the SUNLITE program is to demonstrate the performance of ultra-stable laser systems in the environment of space. The program uses Non-Planar-Ring-Oscillators (NPRO) which have shown great promise for time and frequency standards with unprecedented resolution and stability. An immediate goal is to test NPRO oscillators in orbital "free fall" by 1994. During the past year there has been remarkable progress in the design and pre-flight testing of the SUNLITE test package. Current theoretical studies are investigating the possible effects of various noise sources on the linewidth and linecenter frequency stability of servo-controlled NPRO lasers. This work reviews the frequency control system and considers the potential impact on frequency stability of noise sources in the control system and in the environment.

The schematic diagram shows the optical system and electronic feecback control circuit for the SUNLITE test package. The frequency of the output laser beam is controlled as follows. The laser diode, Item 1, provides the pump radiation for the NPRO laser, item 2. The electro-optic modulator, item 4, FM modulates the part of the laser beam that is fed to the external reference cavity, item 7. The return signal is FM demodulated and a frequency error signal is generated by items 10, 11, 12, and 13. The error signal is fed to the piezoelectric crystal, item 3, which changes the size of the NPRO cavity and continuously adjusts the laser frequency to lock it onto a resonance frequency of the external cavity.

As can be seen in the diagram, there are numerous optical and electronic interfaces. Each interface provides a potential source of variability or noise in the laser frequency. The purpose of the theoretical work currently underway is to model the entire control system and thereby identify the sensitivities and major contributors to frequency fluctuations in the output beam.

If the laser frequency could be locked perfectly onto the external cavity, the output beam would contain only the frequency noise imposed on the reference cavity by the environment. To test the control system and check for reference cavity noise, two NPRO lasers with separate reference cavities will be compared. The goal of the '94 test is to demonstrate a linewidth $\Delta f \approx 1$ Hz, or a linewidth to linecenter ratio $\Delta f/f_o \approx 3X10^{-15}$, where $f_o \approx 3X10^{14}$ Hz, the frequency of the Nd:YAG in the NPRO laser. This goal represents an improvement by a factor of about 1000 over previous surface lab tests. Such a small linewidth ratio can be realized because of the relatively low noise expected in the microgravity environment of space.

When a physical quantity is measured repeatedly, there always will be some variation in the measured quantity. Uncontrolled changes in the frequency of a laser are caused by frequency noise. For measurement times T less than ≈ 1 sec, white phase noise contributes to the linewidth, while for measurement times T greater than ≈ 1 sec, flicker frequency noise contributes to linecenter drift.

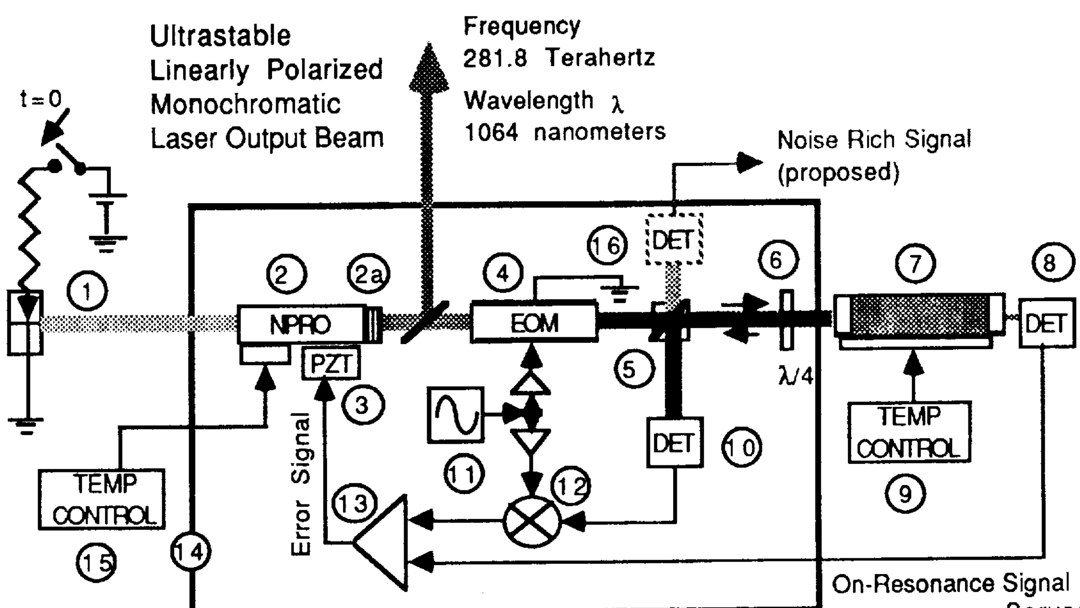
There is a theoretical relationship between the minimum observable Δf, the linecenter frequency f_o, and measurement time T. Suppose an electromagnetic wave is observed at a fixed point in space for a sample or averaging time τ, where τ is determined by a local "perfect" clock. If during the time τ, n_1 periods of the wave pass by and are counted, we say that the "sample" mean frequency $f_1(\tau) = n_1/\tau$. If this experiment is repeated successively N times for a total measurement time $T = \tau N$, the result would be a sequence of N values $\{f_1,...,f_i,...,f_N\}$. By definition from statistics, the mean frequency $f_o = \Sigma f_i/N$; the variance $\Delta f^2 \approx \Sigma(f_o - f_i)^2/N$; and the standard deviation $\Delta f = (\Delta f^2)^{1/2}$. If f_o is constant over the measurement time T, any nonzero variance Δf^2 is said to be due to "phase noise", and the linewidth ratio would decrease in inverse proportion to the square root of τ, according to the equation:

$\Delta f/f_o \approx [(\Sigma(f_o-f_i)^2)^{1/2}/\Sigma f_i](T/\tau)^{1/2}$. Thus, if there is only zero-mean phase noise on a wave, there are no fluctuations in the mean frequency f_o, and the observed linewidth Δf decreases in inverse proportion to the square root of the averaging time. In this region a log-log graph of the "Root Allan Variance" shows a steady decrease with slope -1/2.

A graph of the Root Allan Variance also indicates the time over which f_o is constant, which is called the "coherence time", τ_o. If the wave moves with the speed of light, c, the mean wavelength and mean frequency are related by $f_o\lambda_o = c$, and the coherence length $L = c\tau_o$. The point on a graph of the Root Allan Variance where the slope changes from -1/2 to zero or a positive slope is an indication that f_o is no longer constant beyond the corresponding averaging time. This point gives a measure of the coherence time. Thus, the minimum observable linewidth Δf is related approximately to the coherence time τ_o by $\Delta f \approx 1/\tau_o$.

If the linewidth of the SUNLITE laser is approximately 1 Hz, the coherence time would be $\tau o \approx 1$ sec, and the coherence length would be ≈ 1 light-second ≈ 186,000 miles ≈ 300 million meters. Such a coherence length would be very useful in long-baseline interferometry, inter-satellite communications, laser ranging to the Moon, and gravity wave antennas. We anxiously look to the future when the coherence time mignt be eventually increased to 1000 sec and the coherence length to 300 billion meters.

SUNLITE LASER OSCILLATOR SYSTEM



1 Laser Diode Pump Source
2 Nonplanar Ring Oscillator
2a Polarizer
3 Piezoelectric Crystal
4 Electro-optic Modulator
5 Polarization Sensitive Beamsplitter
6 Polarization Quarterwave Plate
7 Ultrastable Fabry-Perot Cavity
8 On-Resonance Photodiode Detector
9 Temperature Controller
10 Return-beam Photodiode Detector
11 10MHz RF Oscillator
12 FM Demodulator
13 Servocontroller Feedback Error Signal Amplifier
14 Laser Frequency Control Servosystem
15 NPRO Heat/Cool Temperature Controller
16 Noise Signal Photodiode Detector

JCHafele
Aug1990

N91-13317

Acoustic Waves Superimposed on Incompressible Flows

by
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Introducton. The use of incompressible approximations in deriving solutions to the Lighthill wave equation was investigated for problems where an analytical solution could be found. A particular model problem involves the determination of the sound field of a sphereical oscillating bubble in an ideal fluid. It is found that use of incompressible boundary conditions leads to good approximations in the important region of high acoustic wave number.

Background. The Navier Stokes equations that govern the motion of Newtonian fluids also govern the propagation of acoustic waves. In tailoring the Navier Stokes equations for acoustic calculations, Lighthill was able to rewrite the Navier Stokes forms of the momentum and mass conservation equations in the form of wave equations with inhomogeneous right hand sides. This was an exact result without any of the linearization that leads to the classical wave equation. In particular, the equation for the pressure is

$$\frac{\partial^2 p}{\partial t^2} - c_0^2 \nabla^2 p = \frac{\partial^2 T_{ij}}{\partial x_i \partial x_j}. \qquad (1)$$

The *Lighthill stress tensor* T_{ij} on the righthand side is a function of all the unknown flow quantities. Technically, therefore, nothing has been accomplished in garnering a solution; however, this shift of viewpoint has been enormously productive in the theoretical investigation of jet noise [Lighthill]. Especially important is the fact that the Lighthill equations are homogeneous in regions away from turbulent flow.

The assumption of incompressibility leads to the equation

$$\nabla^2 P = -\rho_0 \frac{\partial^2 U_i U_j}{\partial x_i \partial x_j}.$$

Here we capital P to denote the incompressible pressure and U the incompressible velocity. As above, little p will denote compressible (exact) pressure.

The idea is to find ϵ_p such that $P+\epsilon_p$ well approximates the compressible solution. Ideally $p = P + \epsilon_p$, (the approximation is exact!) but this would happen only with "difficult" properly juxtaposed boundary conditions and inhomogenities corresponding to the exact Lighthill equation. For the model problem we instead approximated these terms with compressible boundary conditions and inhomogenities leading to a problem where the right hand side T_{ij} of (1.1) is known.

Pulsating bubble problem. We illustrate this procedure for the boundary value problem resulting from a pulsating bubble in an ideal fluid. In this situation the Lighthill tensor T_{ij} is zero and our concern will be with approximate boundary conditions.

Consider a bubble of radius a pulsating with radial velocity $\bar{U}(a(t), t)$. This may be approximated with fixed velocity $U(t)$ at $r = a$ [Temken]. For brevity, we ignore the mathematical statements of the governing equations and all important boundary conditions and go right to the solutions.

The compressible solution (normally hard) is

$$p = \frac{\rho_0}{\rho} c_0 a[U(\bar{t}) - \frac{c_0}{a} \int_{-\infty}^{\bar{t}} U(\tau) e^{-c_0/a(\bar{t}-\tau)} d\tau.]$$

The incompressible solution (normally easier) is

$$P = P_0 + \rho_0 \dot{U} \frac{a^2}{r} - \frac{1}{2} \rho_0 U^2 \frac{a^4}{r^4}.$$

The last term is negligible for small Mach number.

The composite solution $P + \epsilon_p$ with incompressible boundary conditions is given with

$$\epsilon_p = \frac{\rho_0 a^2}{\rho} \dot{U} \left(t - \frac{(r-a)}{c} \right) - \rho_0 \dot{U}(t) \frac{a^2}{\rho}.$$

Inserting a Fourier mode $U = exp(i\omega t)$ results in a comparison of $i\omega$ with

$$\frac{-\omega k a}{1 + ika} e^{ika} e^{-i\omega/c_0}.$$

The comparisons are very favorable for $k = \omega/c_0$ large which indicates accuracy for important high frequencies. Other methods of approximation reveal different local similarities.

Continued Investigation. Other boundary value problems corresponding to dipole and quadrupole sources are now receiving attention. This should determine whether this methodology will be useful for formulating stable problems using incompressible information.

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N91-13318

EDGE DELAMINATION of COMPOSITE LAMINATES SUBJECT to COMBINED TENSION and TORSIONAL LOADING

by

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Delamination is a common failure mode of laminated composite materials. This type of failure occurs at the free edges of laminates where singular interlaminar stresses are developed due to the difference in Poisson's ratios between the adjacent plies. Typically the delaminations develop next to a 90 degree ply. Edge delamination is important since it results in reduced stiffness and strength of the laminate. The tension/torsion load condition is of particular significance to the structural integrity of composite helicopter rotor systems. Material coupons can easily be tested under this type of loading in servo-hydraulic tension/torsion test stands using techniques very similar to those used for the Edge Delamination Tensile Test (EDT) delamination specimen.

Edge delamination of specimens loaded in tension has been successfully analyzed by several investigators using both classical laminate theory and quasi-three-dimensional (Q3D) finite element techniques. The former analysis technique can be used to predict the total strain energy release rate, while the latter technique enables the calculation of the mixed-mode strain energy release rates. The Q3D analysis is very efficient since it produces a three-dimensional solution on a two-dimensional domain. Some investigators have attempted to employ this technique to analyze the torsion problem as well. Unfortunately, these formulations violate the natural boudary conditions on the free edges of the specimen, thus a full three-dimensional solution is required.

Preliminary tests indicate that delamination under pure torsion loading is associated with angle cracks in the 90 degree plies. These matrix cracks probably form due to tensile failure of the matrix material. Delaminations subsequently form due to the singularities which exist at the ends of these cracks. These delaminations then grow in both the length-wise and width-wise directions. The matrix crack/delamination geometry on one free edge is antisymmetric to the geometry on the opposite free edge. Thus a full 3-d finite element model is required analyze this specimen.

A computer program was developed which generates PATRAN commands to generate this finite element model. PATRAN is a pre- and post-processor which is commonly used with a variety of finite element programs such as MSC/NASTRAN. The program written at NASA LRC creates a sufficiently dense mesh at the delamination crack tips to support a mixed-mode fracture mechanics analysis. The program creates a coarse mesh in those regions where the gradients in the stress field are low (away from the delamination regions). A transition mesh is defined between these regions. This program is capable of generating a mesh for an arbitrarily oriented matrix crack. This program significantly reduces the modeling time required to generate these finite element meshes, thus providing a realistic tool with which to investigate the tension torsion problem.

N91-13319

A THREE-DIMENSIONAL APPLICATION WITH THE NUMERICAL GRID GENERATION CODE - EAGLE (UTILIZING AN EXTERNALLY GENERATED SURFACE)

By

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ABSTRACT

Program EAGLE (Eglin Arbitrary Geometry ImpLicit Euler) is a multiblock grid generation and steady-state flow solver system. This system combines (A), a boundary conforming surface generation scheme, (B) a composite block structure grid generation scheme, and (C) a multiblock, implicit Euler flow solver algorithm. The three codes are intended to be used sequentially from the definition of the configuration under study to the flow solution about the configuration. EAGLE has been specifically designed to aid in the analysis of both freestream and interference flow field configurations.

These configurations can be comprised of single or multiple bodies ranging from simple axisymmetric airframes to complex aircraft shapes with external weapons. Each body can be arbitrarily shaped with or without multiple lifting surfaces.

Program EAGLE is written to compile and execute efficiently on any CRAY machine with or without Solid State Disk (SSD) devices. Also, the code uses namelist inputs which are supported by all CRAY machines using the FORTRAN Compiler CFT77. The use of namelist inputs makes it easier for the user to understand the inputs and to operate Program EAGLE. Recently, the Code has been modified to operate on other computers, especially the SUN Sparc4 Workstation.

Program EAGLE was jointly developed by the Air Force Armament Laboratory's (AFATL) Aerodynamic Branch (FXA) at Eglin Air Force Base, FL, and Mississippi State University (IMSU), Department of Aerospace Engineering.

Several two-dimensional grid configurations have been completely and successfully developed at NASA LaRC in ACD/CAB, using EAGLE. Currently, the grid generation group in CAB is beginning to utilize EAGLE for three-dimension grid applications. The activities of this project involved developing with EAGLE a three-dimensional grid configuration (the volume grid) around a surface (the PLS Vehicle) that had not been developed by EAGLE.

DISCUSSION

The summer activities involved required preliminary pre-research preparation activities and the research itself. The following major tasks consisted of the pre-research preparation while working through two-dimensional applications of EAGLE:

A. Becoming more proficient with UNIX and the editors on LaRC's Super-computing Network Subsystem (SNS) consisting of a four-processor CRAY-2S computer (named Voyager, two virtual memory CONVEX 210 computers (named Eagle and Mustang), and MASSTOR, a high-capacity storage device;

B. Becoming proficient with the use of the IRIS Workstation and the graphic package PLOT3D (used to display the surface and grid configurations);

C. Learning to operate other local computer systems for making hard copy black and white grid plots from postscript files, and,

D. Understanding in details, the three volumes of documentation describing the Numerical Grid Generation Code--EAGLE.

THREE-DIMENSIONAL APPLICATION WITH EAGLE

The primary three-dimensional application initially involved accepting a surface grid, the PLS Vehicle (one- half), formatted and in PLOT3D form. First, a FORTRAN program had to be written to convert the surface to be unformatted and in EAGLE form. Additionally, the program interchanged the roles of the I's and the K's, changing a 81 x 1 x 125 surface to a 125 x 1 x 81 surface. Another step involved getting EAGLE to read the surface, store it, and print it out in a PLOT3D form, so that it could be inspected for proper orientation. The major tasks were those of developing the boundary Generation Run Stream (PLSV3d.b), executed by Surf and the Volume Grid Generation Run Stream (PLVS3d.g), executed by Grid. The former involved strategically and appropriately identifying six points, generating three-line segments, two conic sections, and properly rotating them to meet in order to form the outer boundary. The latter run stream generated the volume grid. The final product was a volume grid generated about the PLS Vehicle surface.

A second three-dimensional demonstration application was made operational using Program EAGLE.

N91-13320

A STUDY OF THE APPLICABILITY OF GALLIUM ARSENIDE AND SILICON CARBIDE AS AEROSPACE SENSOR MATERIALS.

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Most of the piezoresistive sensors, to date, are made of silicon and germanium. Unfortunately, such materials are severely restricted in high temperature environments. In this study, by comparing the effects of temperature on the impurity concentrations and piezoresistive coefficients of silicon, gallium arsenide, and silicon carbide, we seek to determine if gallium arsenide and silicon carbide are better suited materials for piezoresistive sensors in high temperature environments
(T > 1400 °C). The results show that the melting point for gallium arsenide prevents it from solely being used in high temperature situations, however, when used in the alloy $Al_xGa_{1-x}As$, one gets not only the advantage of the wider energy band gap, but also the higher desired melting temperature. Silicon carbide, with its wide energy band gap and higher melting temperature suggests promise as a high temperature piezoresistive sensor.

MATERIALS	MELTING POINT (°C)	ENERGY GAP (eV) (Room Temperature)
Silicon (Si)	1412	1.12
Silicon Carbide (SiC)	2830	2.86
Gallium Arsenide (GaAs)	1240	1.424
Aluminum Gallium Arsenide ($Al_xGa_{1-x}As$) (x is alloy composition)	$1511-58x+560x^2$ (solidus curve) $1511+1082x-580x^2$ (liquidus curve)	$1.424+1.247x$ ($x<0.45$) ($1.9+0.125x+0.143x^2$) ($0.45<x<1.0$)

N91-13321

PLASTIC DEFORMATION MECHANISMS IN POLYIMIDE RESINS AND THEIR SEMI-INTERPENETRATING NETWORKS

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PROJECT SUMMARY

High-performance thermoset resins and composites are critical to the future growth of space, aircraft, and defense industries in the U.S.A. However, the processing-structure-property relationships in these materials remain poorly understood. In the present ASEE/NASA Summer Research Program, the plastic deformation modes and toughening mechanisms in single-phase and multiphase thermoset resins were investigated. Both thermoplastic and thermoset polyimide resins and their interpenetrating networks (IPNs and semi-IPNs) were included in the present study. The fundamental tendency to undergo strain localization (crazing and shear banding) as opposed to a more diffuse (or homogeneous) deformation in these polymers were evaluated. Other possible toughening mechanisms in multiphase thermoset resins were also examined. The unique topological features of network chain configuration/conformation and the multiplicity of phase morphology in IPNs and semi-IPNs provide unprecedented opportunities for studying the toughening mechanisms in multiphase thermoset polymers and their fiber composites.

High performance semi-IPNs were prepared by combining a polyamic acid (a precursor to LaRC-TPI thermoplastic polyimide available from NASA LaRC or Mitsui Toatsu, or NR150B2 from Du Pont) with PMR-15 molding powder through solution mixing. PMR-15, one of the NASA-developed thermoset polyimide resins, possesses a good thermal stability but very poor toughness. The concept of high performance interpenetrating networks (IPNs) combines an easy-to-process but brittle thermoset with a tough but difficult-to-process thermoplastic polymer. This combination has led to the development of numerous high temperature semi-IPNs that could be processed like a thermoset and possess good toughness like a thermoplastic. Our first achievement in this Summer Research Program was to successfully cast thin films of PMR-15 from a solution state, which was considered to be extremely difficult if not impossible. For the first time, thin films of NR-150B2 thermoplastic polyimide and several series of NR-150B2- and LaRC-TPI-based semi-IPNs were obtained by solvent casting.

Thin films of various compositions were cut into rectangular specimens for in-situ polarizing light microscopic observation of crack-tip deformation mechanisms with a miniature tensioning device attached onto the microscope stage. Mechanisms near, ahead of, and in the wake of a crack tip were examined in-situ at various stages of loading. LaRC TPI was found to exhibit combined shear yielding and crazing under plane-stress loading conditions. In response to tensile loading, the single-edge-notched TPI specimen appeared to show some initial diffuse shear yielding, which was quickly turned into a more localized combined shear-banding/crazing mode. Crazes appeared to grow at a slightly faster rate than shear bands and therefore always led the way in development of the deformation zone ahead of a growing crack tip. Final failure of the specimen involves the propagation of the crack through the center or along the edge of the deformation zone. Contrarily, NR-150B2 exhibited diffuse shear yielding; no shear banding or crazing was found near the crack tip.

Adding a small amount of thermoplastic component, either NR-150B2 or LaRC TPI, was found to significantly improve the fracture toughness of PMR-15 thermoset PI. PMR-15 films also showed diffuse shear yielding with a small deformation zone. This can be understood on the basis of a limited extensibility of a highly cross-linked network. Numerical calculations were performed to confirm this low value of network chain draw ratio. The dimensions of the deformation zone ahead of the crack tip was increased as a higher weight fraction of the thermoplastic component was added. On the other end of the fracture toughness spectrum, the deformation zone size of a thermoplastic matrix was found to scale down with an increasing amount of thermoset PMR-15. Deformation also became more diffuse with a higher PMR-15 content in LaRC TPI. Fracture toughness variations can be correlated with deformation mode changes in these semi-IPNs.

In the near future, various semi-IPNs with controlled phase morphologies and network structures will be fabricated by manipulating the backbone structure, component fractions and phase separation kinetics. The effects of these parameters on the mechanical behavior of these semi-IPNs will be examined. Several other approaches will also be taken to determine the dominant plastic deformation mechanisms in a semi-IPN resin or composite.

N91-13322

RADIOMETER SYSTEM REQUIREMENTS FOR MICROWAVE REMOTE SENSING FROM SATELLITES

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An area of increasing interest for the Antenna and Microwave Research Branch is the establishment of a significant research program in microwave remote sensing from satellites, particularly geosynchronous satellites. Due to the relatively small resolution cell sizes, a severe requirement is placed on the "beam efficiency" specifications for the radiometer antenna.

Geostationary satellite microwave radiometers could continuously monitor several important geophysical parameters over the world's oceans. These parameters include the columnar content of atmospheric liquid water (both cloud and rain) and water vapor, air temperature profiles, and possibly sea surface temperature.

Two principle features of performance are of concern for this study. The first is the ability of the radiometer system to resolve absolute temperatures with a very small absolute error, a capability that depends on radiometer system stability, on frequency bandwidth, and on footprint dwell time. The second is the ability of the radiometer to resolve changes in temperature from one resolution cell to the next when these temperatures are subject to wide variation over the overall field-of-view of the instrument. Both of these features are involved in the use of the radiometer data to construct high-resolution temperature maps with high absolute accuracy.

The pulsewidth or sea state (depending on which represents the larger time spread to the altimeter) determines the footprint size. This footprint acts as a spatial filter that has to be considered in detecting surface features. Its minimum radius is calculated as follows:

$$r = (hcT)^{1/2}$$

where h = satellite height, c = speed of light, T = pulsewidth.

A simple (first-order only) model of the return waveforms can be based on physical-optics scattering theory. The illuminated surface area determines the reflected radar power as the pulse impinges on the earth's spherical surface. This backscattered power (on the average) increases until the whole pulse has reached the surface.

Every object with a physical temperature above absolute zero ($0°K$ = $-273°C$) radiates energy. The amount of energy radiated is usually represented by a brightness temperature T_B and it is defined as

$$T_B(\theta,\phi) = \varepsilon(\theta,\phi)T_m = (1-|\Gamma|^2)T_m$$

where

T_B = brightness temperature (equivalent temperature; ^oK),
ε = emissivity (dimensionless),
T_m = molecular (physical) temperature (^oK),
$\Gamma(\theta,\phi)$ = reflection coefficient of the surface for the polarization of the wave.

The brightness temperature emitted by the different sources is intercepted by antennas, and it appears at their terminals as an antenna temperature. The temperature appearing at the terminal of an antenna is weighted by the gain pattern of the antenna. This can be written as

$$T_A = \frac{\int_0^{2\pi}\int_0^{\pi} T_B(\theta,\phi)G(\theta,\phi)\sin(\theta)d\theta d\phi}{\int_0^{2\pi}\int_0^{\pi} G(\theta,\phi)\sin(\theta)d\theta d\phi}$$

where

T_A = antenna temperature (effective noise temperature of the antenna radiation resistance; ^oK),
$G(\theta,\phi)$ = gain (power) pattern of the antenna.

If no mismatch losses and a lossless transmission line between the antenna and the receiver, the noise power transferred to the receiver is given by

$$P_r = KT_A\Delta f$$

where

P_r = Antenna noise power (W),
K = Boltzmann's constant (1.38 E-23 J/^oK),
T_A = antenna temperature (^oK),
Δf = bandwidth (Hz).

If the transmission line losses between the antenna and receiver must be considered, the antenna temperature T_A has to be modified to include the line losses. The effective antenna temperature at the receiver terminals is given by

$$T_a = T_A e^{-2\alpha l} + T_o(1 - e^{-2\alpha l})$$

where
T_a = antenna temperature at the receiver terminals (^oK),
T_A = antenna temperature at the antenna terminals (^oK),
α = attenuation coefficient of the transmission line (Np/m),
l = length of transmission line (m),
T_o = physical temperature of the transmission line (^oK).

The antenna noise power must has a certain noise temperature T_r (due to thermal noise in the receiver components), the system noise power at the receiver terminals is given by

$$P_s = K(T_a + T_r)\Delta f = KT_s\Delta f$$

From the receiving equipment, the antenna is a source of useful signal and also a unwanted noise caused by radioemission from the Galaxy, atmosphere, Earth, local objects, and the antenna elements themselves. The noise temperature of a network is the temperature of the output resistance that provides the same noise power which received from the network. The noise power output of an antenna can be characterized by the antenna noise temperature, T_{na}. The antenna noise temperature can be obtained from the equation as follows:

$$T_{na} = \bar{T}_m + \bar{T}_s\beta\eta + T_o(1-\eta)$$

with

$$\bar{T}_m = \frac{\int_{\Omega_m} T(\theta,\phi)F(\theta,\phi)d\Omega}{\int_{\Omega_m} F(\theta,\phi)d\Omega} \quad , \quad \bar{T}_s = \frac{\int_{\Omega_s} T(\theta,\phi)F(\theta,\phi)d\Omega}{\int_{\Omega_s} F(\theta,\phi)d\Omega}$$

where

T_m = the average background brightness temperature for the antenna main lobe,
T_s = the average background brightness temperature for the antenna side lobe,
T_o = temperature of the surrounding medium (^oK),
β = the antenna stray factor,
η = the radiation efficiency,
$F(\phi,\theta)$ = an antenna pattern function.

From the system noise power the equation becomes

$$\begin{aligned} P_s &= KT_s\Delta f = K(T_a + T_r)\Delta f \\ &= K\Delta f\left[T_A e^{-2\alpha l} + T_o(1-e^{-2\alpha l}) + T_r\right] \\ &\approx K\Delta f\, T_A e^{-2\alpha l} \end{aligned}$$

By the Fourier transforms and Bessel functions, the antenna noise temperature equation can be solved. This result can then be used to produce a computer program that can accept input "temperature-contrast" maps.

QUANTITATIVE ANALYSIS OF ICE FILMS BY NEAR-INFRARED SPECTROSCOPY

by

N91-13323

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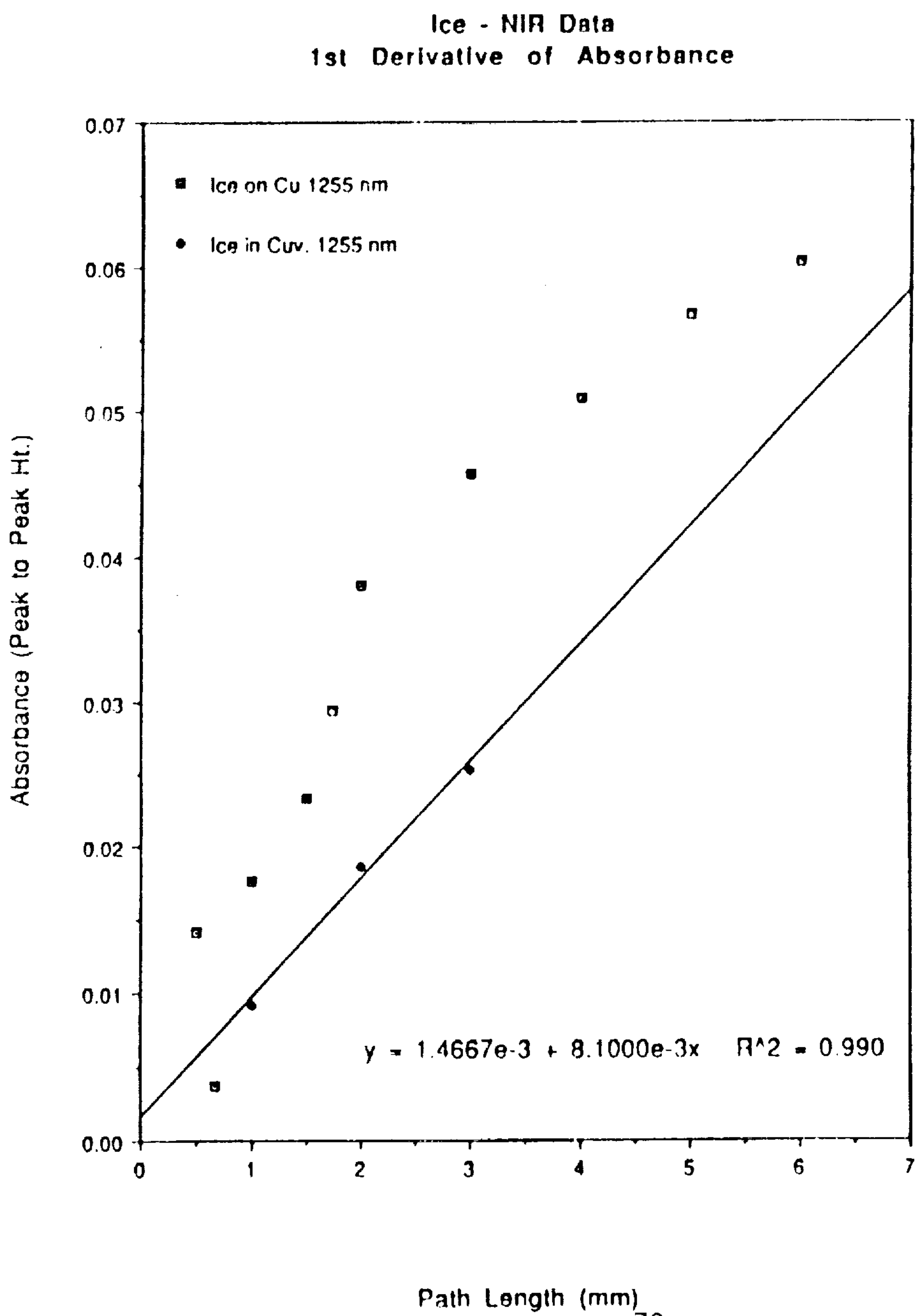
One of the outstanding problems in the Space Transportation System is the possibility of the ice buildup on the external fuel tank surface while it is mounted on the launch pad. During the T-2 hours (and holding) period, the Kennedy Space Center Ice Team is allowed to approach the external tank and monitor/measure the frost/ice thickness on it. However, after the resumption of the countdown time, the tank surface can only be monitored remotely. Currently, remote sensing is done with a TV camera coupled to a thermal imaging device. This device is capable of identifying the presence of ice, especially if it is covered with a layer of frost. However, it has difficulty identifying transparent ice, and, it is not capable of determining the thickness of ice in any case. Thus, there is a need for developing a technique for measuring the thickness of frost/ice on the tank surface during this two hour period before launch.

The external tank surface is flooded with sunlight (natural or simulated) before launch. It may be possible, therefore, to analyze the diffuse reflection of sunlight from the external tank to determine the presence and thickness of ice. The purpose of this project was to investigate the feasibility of this approach.

A near-infrared spectrophotometer was used to record spectra of ice. It was determined that the optimum frequencies for monitoring the ice films were 1.03 and 1.255 microns. These two bands have absorption cross sections appropriate for the film thicknesses of interest (0-3 mm).

A special holder for growing ice of controlled thicknesses on a copper substrate was built. This holder was used in conjunction with an integrating sphere to obtain diffuse reflectance spectra of ice films on copper. In Figure 1 a plot of Absorbance at 1255 nanometers (1.255 microns) versus path length is given. The open squares are data points from diffuse reflectance spectra in which the path length is assumed to be twice the film thickness. The solid squares with the line drawn through them were obtained from transmission spectra of ice grown in cuvettes. In this case the film thickness is equal to the path length of the cuvette. The diffuse reflectance data is reproducible although not linear. With the exception of one data point, all of the data taken in the diffuse reflectance mode had a larger absorbance than predicted from the data taken in the transmission mode. This is believed to be due to multiple scattering effects. In other words, the actual path length of an average photon is larger than twice the film thickness. Similar results were obtained from absorbance data at 1.03 microns. Currently, there is an attempt being made to fit these data to a model involving multiple scattering effects.

Additional experiments need to be conducted to investigate the effect of varying other parameters, such as the light collection angle, the distance between the detector and the surface, and the substrate.



N91-13324

THE EFFECTS OF THE SPACE ENVIRONMENT ON TWO ARAMID MATERIALS

by

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Two aramid fibers having closely related chemical structures have been chosen for important roles in the first tether to be used to connect pairs of orbiting vehicles. The protective outer jacket of the tethers will consist of woven fibers of poly(m-phenylene isophthalamide), commercially available from du Pont as Nomex. A cylindrical sheath of woven Kevlar 29, whose principal constituent is poly(p-phenylene terephthalamide), will be the load-bearing component for the tethers. The repeat units of these materials are shown in Figures 1 and 2. Both aramids have high strength-to-weight ratios, favorable thermal and chemical stabilities, and high electrical resistivities.

Orbiting tethers will be in a hostile environment in which short-wavelength electromagnetic radiation and energetic charged particles degrade exposed organic materials such as these aramid fibers[1]. At lower orbiting altitudes atomic oxygen is an especially serious hazard, since it causes rapid erosion from organic surfaces with which it comes in contact[2].

Ultraviolet radiation causes degradation of aramids through a pathway known as the Photo-Fries rearrangement in which amide linkages in the polymer backbones are broken[3]. This takes place predominately near the surface where the incident radiation has not been attenuated. Byproducts from the Photo-Fries process are uv absorbers. They form a protective skin, thus helping to reduce degradation rates. However, atomic oxygen would most likely erode this uv shield, thereby contributing to an unwanted synergism with the uv radiation.

Studies on the effects of ultraviolet radiation and atomic oxygen on fibers and films of Kevlar and Nomex are in progress. The Kevlar used in these studies is Kevlar 49, which is almost identical chemically to Kevlar 29. It was purchased in fiber form from du Pont in a spooled tow with a denier of 22,910. Type 430 Nomex, obtained from du Pont in a 1200 denier tow, was also studied. Films of both aramids were prepared.

Films of Kevlar were prepared by dissolving fibers in dimethyl sulfoxide (DMSO) containing a small amount of methanol and potassium t-butoxide. A thin layer of the solution was drawn across a glass plate, and the film formed when the plate was immersed in dichloromethane. The films were rinsed with water and air dried. Nomex films were pulled from solutions prepared by dissolving fibers in a mixture of dimethylacetamide and lithium chloride.

In an experiment to simulate the effects of atomic oxygen in space, small tows of Kevlar and Nomex were mounted in a commercial ashing device filled with oxygen at low pressure. An rf discharge in the instrument dissociated the molecular oxygen producing a strongly oxidizing atmosphere containing O(3P)[4]. Erosion was measured in terms of mass loss. The square root of the fraction of the original mass remaining after the sample had been eroded for a period of time, t, was found to decrease linearly with t, consistent with erosion from the surface of long, thin rods. These results are shown in Figure 3. After accounting for the difference in the diameters of the Kevlar and Nomex fibers, it was found that the rates of mass loss per unit surface area were the same within experimental uncertainties for the two aramids.

Kevlar films were exposed to uv radiation in an apparatus consisting of a small vacuum chamber, 23 cm in diameter, into which a mass spectrometer and a quartz window were incorporated. Samples were exposed under vacuum with a 1000 watt xenon-arc lamp. Volatile products could be monitored with the mass spectrometer during the exposures. Transmission infrared spectra were taken before and after exposure to monitor chemical changes in the films. Initial results showed small changes in the infrared spectra which are consistent with degradation through a Photo-Fries process. Emission of volatile products was too low for positive identification.

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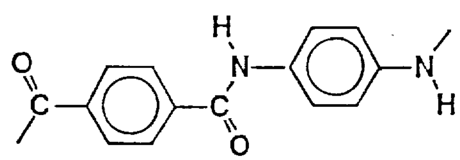

Fig. 1 The repeat unit of Kevlar

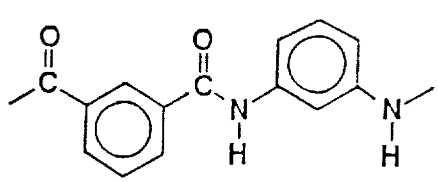

Fig. 2 The repeat unit of Nomex

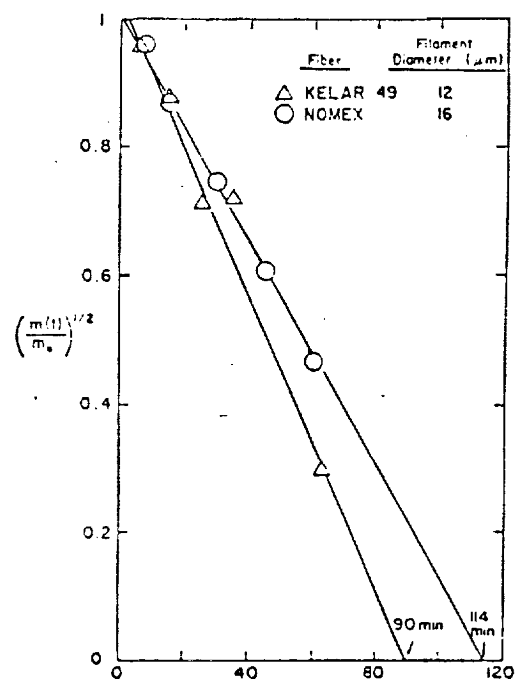

Fig. 3 Mass loss from Kevlar and Nomex fibers in an rf glow discharge chamber.

N91-13325

MINIMIZING DISTORTION IN TRUSS STRUCTURES VIA TABU SEARCH

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The shape control of large flexible space structures is of great interest to structural designers. A related problem is to seek ways to minimize the need for active controls by careful design and construction of the space structure. Consider a tetrahedral truss structure that is used to support a precision segmented reflector or antenna surface. The structure has a hexagonal platform and is characterized by the number of rings of members in the truss. For simplicity we assume that a flat truss geometry exists. Hence, all structural members and ball joints are required to have the same nominal length and diameter, respectively.

Inaccuracies in the length of member or diameters of joints may produce unacceptable levels of surface distortion and internal forces. In the case of a truss structure supporting an antenna, surface distortions may cause unacceptable gain loss or pointing errors. In this study we focus solely on surface distortion, however, internal forces may be treated in a similar manner.

One remedy is to impose stringent manufacturing tolerances on the hardware supplier, however this increases the cost of the space structure enormously. Alternatively, if the member lengths and joint diameters can be measured accurately it may be possible to configure the members and the joints so that root-mean-square (rms) surface error and/or rms member forces is minimized.

Following Greene and Haftka (1989) we assume that the member force vector f in a tetrahedral truss structure is linearly proportional to the member length errors e_M of dimension $NMEMB$ (the number of members) and ball joint diameter errors $\mathbf{e_J}$ of dimension $NJOINT$ (the number of joints), and that the displacement vector $\mathbf{d}$ is a linear function of $\mathbf{f}$. Let $NNODE$ denote the number of positions (ball joints) on the top surface of the truss where error influences are measured. Let $\mathbf{U_M}$ ($NNODE$ x $NMEMB$) and $\mathbf{U_J}$ ($NNODE$ x $NJOINT$) denote the matrices of influence coefficients. Then, $\mathbf{d} = \mathbf{U_M e_M} + \mathbf{U_J e_J}$. Concatenating $\mathbf{e_M}$ with $\mathbf{e_J}$ and $\mathbf{U_M}$ with $\mathbf{U_J}$ yields $\mathbf{d} = \mathbf{Ue}$. Thus u_{ij} is the influence of a unit displacement error in member (or joint) j on surface distortion at surface node i.

Let $\mathbf{D}$ be a positive semidefinite weighting matrix (in our computational experiments we let $\mathbf{D}$ be the idenitity matrix of appropriate dimension) denoting the relative importance of the surface nodes where distortion is measured. The mean-squared displacement error can then be written as

$$d_{rms}^2 = \mathbf{e^T U^T D U e} = \mathbf{e^T H e}$$

That is, we wish to find the permutation of the components of $\mathbf{e_M}$ and $\mathbf{e_J}$ that minimizes d_{rms}^2. Let $N = NMEMB + NJOINT$. Our combinatorial optimization problem DSQRMS, then, is

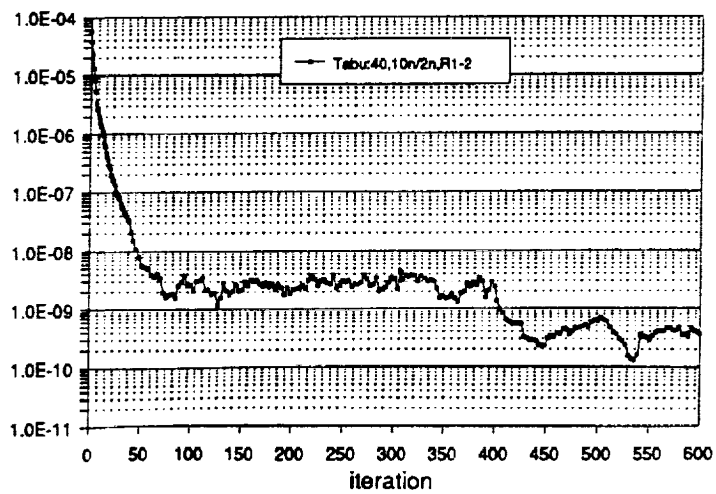
$$Min \sum_{j=1}^{N} \sum_{i=1}^{N} e_{\pi(i)} h_{ij} e_{\pi(j)}$$

over all permutations Π of {1,2,...,*NMEMB*} and {1,2, ...,*NJOINT*}. The plausibility of this technique has been its recent success on a variety of NP-Hard combinatorial problems including the quadratic assignment problem (see Skorin-Kapov (1990)).

Tabu search is a directed greedy procedure. A *move* is generated by choosing at random two members of the truss structure to exchange positions. If this move produces a decrease in the objective function value then a short term memory list of previous moves is scanned. If the current move is on this list it is disallowed, otherwise it is accepted. At each iteration of Tabu search a sampling of the space of all pairwise exchanges is made and the best accepted move in this sample space is kept. This procedure is repeated for *maxit* iterations.

To test our Tabu search code for DSQRMS we use the appropriate influence matrices for a flat, two-ring tetrahedral reflector truss generated by Greene and Haftka (1989). In this example there are 102 members (*NMEMB*) and 31 ball joints (*NJOINT*) of the same nominal length, respectively. Hence, all the members may be interchanged and all the joints may be interchanged. (This would not be the case if a parabolic reflector truss were used.) In addition, 19 positions on the surface of the truss (*NNODES*) were used to measure error influences.

After a variety of experiments a set of *good* parameters was chosen for Tabu search. The *sample size* at each iteration is 10 ∗ *NMEMB* and the short term memory size is 40. In addition four *pruning* rules were used to accelerate the search. Figure 1 displays a typical Tabu search output for this parameter set. Note that the y-axis is a log scale and that 200 of the 600 data points are displayed.



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N91-13326

A USER-FRIENDLY MENU-DRIVEN LANGUAGE-FREE LASER CHARACTERISTICS CURVES GRAPHING PROGRAM

by

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The facility for laser researchers and engineers to have available a menu-driven language-free program to be able to graph the interrelationship of the many physical parameters of laser materials is an expressed concern of the Environmental Sensors Branch of the Flight Electronics Division.

The accuracy to which atmospheric composition can be measured is in some part dependent upon the known characteristics of the measuring instruments and the recording and interpretation of the data measured. Unique demands of space-based lasers used for atmospheric remote sensing include long life; high reliability; minimal weight, physical size and electrical energy demands; narrow spectral bandwidth; high output power and temperature insensitivity. In the selection of laser materials to use as active sensors from airborne platforms it is essential that the researcher or engineer know how various factors of the specific material composition interact. Questions such as how does rod size and frequency or absorption relate and how might this be affected by temperature variations must be answered before the material is selected.

The branch has already established a facility that takes collected data and feeds this into mathematical models that generate improved data arrays by correcting for various losses, base line drift, and conversion to unity scaling. This is then stored in a data base of laser materials. The data base contains the physical parameters of laser, nonlinear, and optical materials which are used by the laser models. One section contains ASCII files of absorption spectra, emission spectra, and laser diode emission spectra. The transmission or absorption spectra are acquired on a Perkin-Elmer IR-9 spectrophotometer. The spectra are transferred from the Perkin-Elmer's host computer to an IBM PC where headers are added to the files to identify the contents of the spectra. The emission spectra are acquired on a SPEX monochrometer. The laser diode emission spectra were provided by NASA and Night Vision Labs. This data base is under continuing updating and expansion to include all available laser material regardless of source.

The tabulated section of the data base is divided into several parts: crystalline, optical, mechanical, and thermal properties; absorption and emission spectra information; chemical name and formulas; and miscellaneous.

This summer's project was an extensive revision of the program developed during the 1989 summer fellowship. At that time a menu-driven language-free graphing program was developed that would reduce and or remove the requirement that all users become competent FORTRAN programmers and concomitant requirement that they also spend several days to a few weeks becoming conversant with the GEOGRAF library and sequence of calls and the continual refreshers of both. It was, and still is, the consensus within the Branch that their time is more important in their specific research specialties.

The work during the 1989 summer included becoming thoroughly conversant or at least very familiar, in the FORTRAN language mode, with the GEOCOMP Corporation's GEOGRAF. GEOGRAF is a FORTRAN callable graphics library that helps plot to screen, printer, or plotter during execution or to a disk file during execution for actual plotting at a later time. In GEOGRAF the programmer instructs the plotter, be it screen, printer, or plotter, with FORTRAN call statements rather than through the symbolic language required by the graphics device. Learning the FORTRAN language, how to actually run each of the subroutines in the GEOGRAF library, and sequence of calls in actually setting up to graph a new set of data would require a large block of time. The 1989 development involved trial runs of the various callable library routines on dummy data then with actual data base files and some additional data from current research that was not in the data base but currently needed graphs. These actual runs provided the knowledge as to which actual subroutines would need to be included in the menu-driven program to provide for graphing all files from the data base. The result was a menu-driven language-free implementation of a program which would require that the user only know how to use microcomputers in order to graph a two dimensional array of data. The user would simply be responding to items displayed on the video screen.

Talking with various researchers, and making special runs on data they had collected directly, it became evident that methods would need to be provided for them graph more than one graph-line on the same chart, to generate a paralleling array of data to serve as the other axis when their data collection system had provided for only one array of data, and to plot parametric data in a meaningful manner. This was all accomplished during the summer of 1990.

The program is now generic in that it will take any data file whether in the data base or not and plot it for the user with him/her responding to a few simple yes/no or provide a selection or number questions. The program generates the format for the data read statement if it is not contained in the file header and the user who do not know how to write them.

There are several areas that need additional investigation. One includes the possibility of plotting only segments of the data file when the users sees need for an enlargement of specific areas such as emission and absorption spectra. A second would be plotting from two or more files on the same plot. And a third would be to investigate the possibility of loading these onto a host computer for the Division or even Center wide use.

N91-13327

MICROCRACKING MECHANISMS AND INTERFACE TOUGHENING OF SEMI-IPN POLYIMIDE MATRIX COMPOSITES

by

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(In Collaboration with *Dr. R. Pater, Senior Polymer Scientist, MD/PMB*)

One of the most critical issues for structural durability of fiber-reinforced composites with normally brittle *thermoset resin* matrix has been the occurrence of *localized micro-scale damage* (often called *crazing* or *microcracking*) in the form of either *resin fracture* near the fiber-matrix interface or *fiber-matrix debonding*. Localized micro-damage occurs at a relatively low level of applied strain (less than 0.3 to 0.5% in static tension) under both *mechanical* and *thermal* loading. For the composites with high degree of differential shrinkage of matrix and fibers in cooling, the micro-damage can be induced by *residual stresses* even in the absence of external loading. Once initiated, microscale damage of matrix/interface develops into *matrix-dependent macroscopic failure* modes such as interfiber splitting, constrained ply cracking (first ply failure) and delamination.

As a means of increasing the resistance of fiber composites against *matrix damage accumulation*, particularly *delamination growth*, past empirical efforts of toughening brittle thermoset resins with the inclusion of *elastomer particles* or *ductile thermoplastic domain* were successful to various extents. In fact, the use of elastomer-toughened epoxy resin matrix became an almost standard practice of composite prepreg industry. In the case of brittle thermoset polyimide matrix composites, one promising approach of increasing matrix toughness with minimal change of modulus and temperature resistance has been the addition of secondary domains of ductile thermoplastic polyimide to the base resins, which results in *semi-interpenetrating network* (semi-IPN) type polymer alloys .

In contrast to the success in reducing damage accumulation of composites, toughening of resin matrix was <u>not</u> successful in raising the resistance of composites against *damage initiation* under *cyclic loading*. Fiber-reinforced resin composites in general do not exhibit clear-cut *fatigue endurance limit* (threshold cyclic stress for infinite fatigue life) which indicates the *onset of critical micro-damage or cracks* in other structural materials. However, as Owen pointed out in his earlier work, all S-N curves of composite systems with thermoset resin matrices of varied toughness or flexibility tend to <u>converge</u> at low levels of stress amplitude such as *10^7 cycle fatigue endurance strength*. In other words, the effects of matrix toughening on fatigie lifetime of composites become less and less noticeable in longer term loading. This fact suggests that the *fatigue damage intiation resistance* of composites is not governed by fracture toughness of resin matrix and instead may be more dependent on the *resistance to interfacial debonding*.

In controlling the *resistance to interfacial debonding* of fiber-resin composites, as Plueddemann pointed out, we have to consider the following two requirements of contradictory nature. Firstly, optimum stress transfer between a high modulus fiber reinforcement and a lower modulus resin matrix requires an *interphase region of intermediate modulus* (which leads to so-called *restrained layer theory* in surface science). Secondly, the toughness of composites and the ability of interface region to withstand differential shrinkage between matrix and reinforcement (i.e. residual stresses) require a *flexible interphase region* to relieve local stresses (*deformable layer theory*). The latter requirement was examined in epoxy resin matrix composites by adding flexible or ductile interlayer between the fiber and matrix. Although the approach was shown to increase impact fracture energy of composites, enough data were not available on its effects on fatigue damage resistance of composites

In view of the facts discussed so far, a new research program has been initiated with the 1990 Summer Faculty Research Project (SFRP) as a preliminary phase. The following three objectives are being pursued for the overall program: (a) to elucidate the mechanisms of microcracking for graphite fiber-reinforced semi-IPN polyimide matrix composites under mechanical and thermal cyclic loading, (b) to devise material engineering solutions for possible *improvement of fatigue damage resistance* (or the increase of fatigue endurance strength) of semi-IPN matrix composites by *tailoring of modulus and toughness of fiber-resin interface region*, (c) to assess processing characteristics of the composites and their roles in controlling the resistance of composites to microcracking and the effectiveness of interface toughening.

In the 1990 SFRP, main emphasis was placed upon the initial screening of material systems and optimization of processing conditions for semi-IPN matrix composites with *tailored interface*. As a first set of control material systems to study, the composites were prepared with unsized Celion 6000 graphite fiber reinforcement and the following resin matrices of varied fracture toughness: (a) PMR-15 thermoset polyimide, (b) semi-IPN of PMR-15 thermoset polymide and NR150B2 thermoplastic polyimide in 75/25 ratio, (c) semi-IPN of PMR-15 and NR150B2 in 50/50 ratio. The measurement of rheological behavior of composite prepreg in squeeze flow condition indicated progressive lowering of resin flowability with increasing content of NR150B2 thermoplastic polyimide in semi-IPN. Confirming the rheological property measurement, curing of semi-IPN matrix composites required higher molding pressure to obtain adequate flow.

For the composites with the resin matrix of semi-IPN in 75/25 ratio, interface tailoring was attempted by using graphite fibers coated with the resins of systematically varied *fracture toughness*. Our initial trial was limited to sizing of graphite fibers with a dilute solution of either brittle PMR15 or ductile NR150B2 resin. In both cases, relatively uniform coating of fibers was obtained. The PMR15-sized fibers were B-staged prior to their use in prepreg. In our continuing work, a broad range of interlayer toughness will be achieved by coating the fibers with the reactants of semi-IPN having lower or higher content of thermoplastic constituent in comparison with the composition of surrounding resin matrix.

In pursuing the objectives of overall research program, we intend to define the respective roles and interaction of critical parameters such as *modulus transition* at the fiber-resin interface, *residual stresses* due to cooling, fracture *toughness* of interlayer, *flow* characteristics of resin matrix, and fiber *wetting* behavior. The assessment of damage initiation and accumulation of composites under mechanical cyclic loading will be based on the S-N (strss amplitude vs fatigue lifetime) data, the measurement of dynamic creep rate, and microscopic examination of fracture modes. In thermal cyclic loading, similar approaches will be taken to assess the occurrence and extent of local damage with the data of temperature range vs strength/stiffness retention, thermal strain for full strength retention and thermal strain for full stiffness retention replacing S-N curve, fatigue endurance strength and dynamic creep rate respectively.

N91-13328

OPERATIONAL TESTING OF A FIGURE OF MERIT FOR OVERALL TASK PERFORMANCE

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An overall indicator, or figure of merit (FOM), for the quality of pilot performance is needed to define "optimal" workload levels, predict system failure, measure the impact of new automation in the cockpit, and define the relative contributions of subtasks to overall task performance. A normative FOM has been developed (ref. 1) based on the calculation of a standard score for each component of a complex task. It reflected some effects, detailed in an earlier study (ref. 2), of the introduction of new data link technology into the cockpit. Since the technique showed promise, further testing was done this summer.

A new set of data was obtained using the recently developed Multi-Attribute Task Battery (ref. 3). This is a complex battery consisting of four tasks which can be varied in task demand, and on which performance measures can be obtained. It is illustrated in Table 1.

Table 1. Tasks in the Multi-Attribute Task Battery, with methods of controlling task demand and performance measures.

Task	Description	Demand Control	Performance measure
Monitoring	changes in lights and dials	events per minute	response time to event onset
Tracking	2-dimensional, first order compensatory task	frequency of generating function	RMS error
Communications	responses to verbal messages	events per minute	response time to event onset
Resource Management	adjusting fuel level in 6 tanks with 8 pumps	ratio of pump flow rates	RMS error from 2500 gals

This battery was presented to 12 subjects in a 20 minute trial at each of three levels of workload or task demand, and performance measures collected on all four tasks. The NASA-TLX workload rating scale was presented at minutes 6, 12, and 18 of each trial. A figure of merit was then obtained for each run of the battery by calculating a mean, SD, and standard score (number of SD units away from the mean) for each task. This procedure, with its rationale, is described in more detail in reference 1.

The resulting figure of merit increased significantly with increasing workload and was also positively correlated with error rate in the monitoring task, so that, when the FOM indicated poorer performance, missed signals were also more likely.

Each task contributed its own proportion to the overall FOM, and relative contributions changed with increasing workload. Figure 1 shows decreases in performance on tracking and resource management, but not on communications and monitoring, when workload increases. Figure 2 shows the increase in resources that had to be devoted to communications and monitoring in order to maintain that constant performance, and that this was at the expense of performance on tracking and resource management. Thus, the FOM shows the effect of task changes, not only on the individual task that is changed (e.g. obviated by automation or greatly increased by a near accident), but also on the performance of other tasks and of the whole task. The cost to other tasks of maintaining constant performance on an individual task can be quantified.

The ratings collected later in the task got lower under low workload and higher under high workload, i.e., easy tasks got easier with time, while hard tasks got harder.

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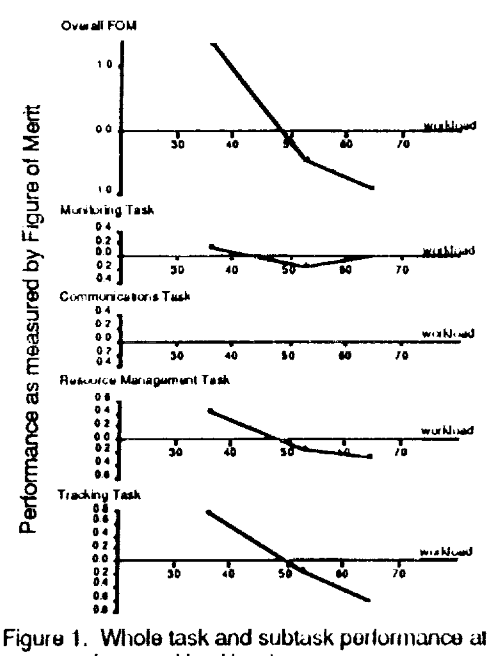

Figure 1. Whole task and subtask performance at three workload levels

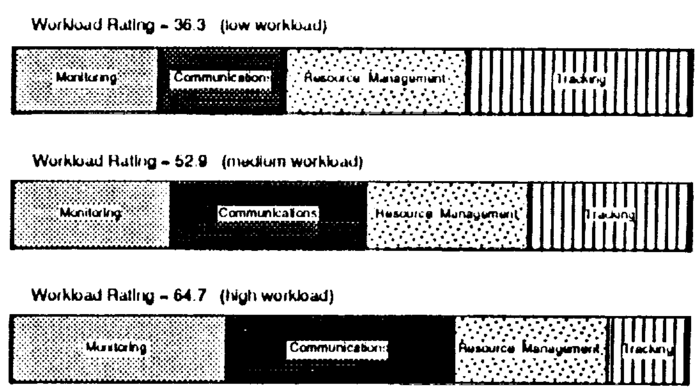

Figure 2. Proportion of cognitive resources used by four time-shared tasks under three workload levels

SURVEY OF LANGLEY AEROSPACE RESEARCH SUMMER SCHOLARS (LARSS)

by

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Abstract

While Director of the 1990 LARSS program, I designed a Survey for Langley Aerospace Summer Scholars. The main purposes of the survey were to track those students who participated in LARSS. The objectives included tracking those continuing their education, and those permanently employed in industry, government, and higher education, and creating a database for future tracking.

One of the most significant results is that there are currently 26 past LARSS graduates currently employed by NASA or NASA Contractors.

Of the responses, 62% indicate that they are continuing their education with 65% enrolled in graduate programs and 35% enrolled in undergraduate programs. Of these, 22% are pursuing doctoral degrees, 43% are pursuing masters, and 35% are bachelor level students.

It is also significant that 49% of those permanently employed are working for the government or a federal research laboratory; 47% are working in industry, and 5% are working in higher education. Eighty-one per cent of those working for the government are NASA employees or NASA Contractor employees.

The following is a synopsis of the data obtained from the responses:

Topic	# Responses	Percentage
Surveys Sent	197	
Surveys Returned	134	68%
Graduates Continuing Education	83	62%
Bachelor Level Students	29	35%
Master Level Students	36	43%
Doctoral Level Students	18	22%

Graduates Employed Full Time:	66	49%
Government Employees	32	49%
Industry Employees	31	47%
Higher Education Employees	3	4%
NASA Employees or NASA Contractors	26	78%

NASA employment opportunities:

Graduates Interested	102	76%

Income Versus Degree (Median Range):

NASA/NASA Contractors

Bachelor's Degree	$25,001-$30,000
Master's Degree	$30,001-$35,000

Industry, Government, Higher Education Employees
(NOT NASA/NASA Contractors)

Bachelor's Degree	$30,001-$35,000
Master's Degree	$35,001-$40,000

This analysis reflects the growth in the quality of the Langley Aerospace Summer Scholars Program. The program continues to expand and these students are providing an excellent pool of qualified candidates for NASA recruitment. Seventy-six percent of the respondents indicated they were interested in learning more about career opportunities at NASA.

References: Dr. Samuel E. Massenberg, University Affairs Officer
Sherry Sullivan, NASA Langley Personnel Division
Past LARSS Graduate Rosters

SURVEY OF LANGLEY AEROSPACE RESEARCH SUMMER SCHOLARS

(Please print or type)

1. NAME ______________________________ 2. LARSS 1986 1987 1988 1989 1990 (circle)

Cross Reference: Maiden name or former name legally changed ______________________

3. Permanent Address: ______________________________

4. Mailing Address______________________________

5. Daytime Phone Number: ( )__________ 6. Birthdate: __________________ Mo/Day/Year

7. Social Security Nunber: ______ - ____ - ______ 8. Sex: [] F [] M

9. Marital Status: [] Married [] Single (including divorced, widowed)

10. Ethnic Background:

[] Native American [] Caucasian [] Hispanic

[] African American [] Asian [] Other

EDUCATION

11. University or College Currently Attending:

Institution	Grade Point Average	Completion Date	Degree/Program

12. Status: [] Undergraduate [] Graduate [] Postgraduate

13. Attending: [] Day [] Evening [] Full time [] Part time

14. Highest Degree Earned:

Institution	Grade Point Average	Completion Date	Degree/Program

EMPLOYMENT

15. Current Status:

[] Am presently employed by______________________________ Position______________

Organization /Address

[] Have signed contract or made a commitment with______________________________

[] Am seeking employment

[] Am negotiating with one or more specific organizations

[] Other (specify) ______________________

16. Current Annual Income:

[] $20,000 or less [] $35,001 - $40,000

[] $20,001 - $25,000 [] $40,001 - $45,000

[] $25,001 - $30,000 [] $45,001 - $50,000

[] $30,001 - $35,000 [] $50,000 or more

17. Are you interested in learning more about career opportunities with NASA? [] Yes [] No

18. Other noteworthy achievements you would like to include: ______________________

____

19. How did the LARSS experience influence you? ______________________

____

Signature ______________________________ Date ______________

N91-13329

A Future Perspective On Technological Obsolescence At Langley Research Center

by

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The present research effort was the first phase of a study to forecast whether technological obsolescence will be a problem for the engineers, scientists, and technicians at NASA Langley Research Center (LaRC). There were four goals of the research: (1) To review the literature on technological obsolescence; (2) To determine through interviews of Division Chiefs and Branch Heads Langley's perspective on future technological obsolescence; (3) To begin making contacts with outside industries to find out how they view the possibility of technological obsolescence; and (4) To make preliminary recommendations for dealing with the problem.

Selected Results of the Study

A complete description of the findings of this research can be reviewed in a technical report in preparation. The following are a small subset of the key findings of the study:

1. NASA's centers and divisions vary in their missions and, because of this, in their capability to control obsolescence.

2. Research-oriented organizations within NASA are believed by respondents to keep up to date more than the project-oriented organizations.

3. Asked what are the signs of a professional's technological obsolescence, respondents had a variety of responses. Here are some of the most common responses: (a) The obsolescent professional uses out-dated methods and tools to carry out research. (b) The obsolescent professional is one whose opinion is no longer sought by his or her peers. (c) The obsolescent professional is one who continues to carry out essentially the same research for long periods of time without change or development.

4. Top performing scientists were viewed as "continuous learners," keeping up to date by a variety of means. The most commonly mentioned were the following: (a) Taking advanced degrees; (b) Writing and presenting research

papers; (c) Interacting with their peers both inside and outside of NASA.

5. When asked what incentives were available to aerospace technologists for keeping up to date, respondents specified a number of ideas. The majority emphasized personal pride, self-motivation, and achievement of research career goals.

6. Respondents identified many obstacles to professionals' keeping up to date in the future. Among them were the following: (a) Demands on professionals' time due to paper work and non-research-related activities; (b) Lack of interdisciplinary collaboration and cooperation; (c) The possibility that NASA's mission will change from carrying out state-of-the-art research on the frontiers of technology to carrying out research with near-term, applied payoff; (d) The sheer rate of change in the various fields, particularly the computer software and hardware fields.

7. Most respondents expressed some concern for the future of the professionals at NASA vis a vis the issue of professional obsolescence. Those who showed the least concern were involved in the "basic research" areas. They indicated that in order for the research work within their division or branch to be funded and accepted in publication form by technical journals, it will have to be innovative and will, therefore, "force" professionals to keep up to date.

Recommendations

Several preliminary recommendations can be made at this time. These are subject to change as more data are collected

1. In an effort to emphasize the importance of "continuous learning," NASA should continue to formally incorporate professional development into its human resource development efforts.

2. NASA cannot depend on an influx of new technical professionals in the future to "absorb the shock" of developing technology. Projections indicate that this influx will not take place. Therefore, management needs to continue maintain and step up its vigilance concerning the possibility of technological obsolescence.

3. Research on the topic of professional obsolescence and strategic planning for professional technical development within aerospace-related industries should be carried out. This research would provide NASA as well as industry in general with valuable information for strategic planning and development.

N91-13330

The Semidiscrete Galerkin Finite Element Modeling of Compressible Viscous Flow Past an Airfoil

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Abstract

During the ASEE summer tenure at NASA Langley I participated in two projects that were of mutual interest to myself and the staff of the Transonic Aerodynamics Branch. The primary project was the numerical simulation, by a finite element/finite difference method, of the viscous flow about an airfoil. This project was a natural outgrowth of my Ph.D dissertation[1]. The secondary project involved the numerical simulation of the three-dimensional separated and vortex-dominated flow about a hemispherically capped cylinder in the transonic regime. This was a logical continuation of the experimental high-alpha study of the hemisphere – cylinder[2] at NASA Ames. Dr. Veer Vasta, of the Computational Aerodynamics Branch, and I have started preliminary calculations[3] for the hemisphere-cylinder at 0° and 5° angle of attack. It was thought that in view of the limited time given, a majority of my efforts would be best applied to the primary project. It was agreed that the secondary project should be handled as a long term task.

An appreciable amount of work done by the Transonic Aerodynamics Branch's (TAB) Applied Aerodynamics Group, is in the design of airfoils and wings in the transonic regime. The solution of the flowfield about these bodies is required to determine the important parameters of lift, moment, and drag. Viscous effects must be accounted for if the drag is to be accurately calculated. At present there are basically two approaches to the numerical simulation of the flowfield, the use of fully viscous models and the inviscid/viscous models.

The fully viscous models require the solution of an approximation of the Navier-Stokes equations and therefore should simulate most of the physical mechanisms. However, in all cases the fully viscous models require relatively large amounts of computer time and storage. Because of their relative speed and simplicity the inviscid/viscous models are still in wide use in design and theoretical investigations. The inviscid/viscous models assume that most of the flowfield can be considered inviscid and that the viscous effects about a body can be approximated by experiments or theoretical means. The most familiar theoretical method of accounting for the viscous effects, is the solution of Prandtl's boundary layer approximations.

A fast, accurate, and computationally efficient inviscid flow solver has recently been developed by Hartwich[4] of the TAB. It is thought that Hartwich's program coupled to a fast, accurate, and computationally efficient boundary layer code, will make an excellent tool for airfoil design. The purpose of the primary project was to develop a compressible boundary layer code using the semidiscrete Galerkin finite element method.

The numerical scheme employed used the combination of a Dorodnitsyn formulation of the boundary layer equations[5], with a finite difference/finite element procedure (semidiscrete Galerkin method[6,7]), in the solution of the compressible two-dimensional boundary layer equations.

Linear elements were chosen for computational efficiency while also providing adequate accuracy. The finite element discretization yielded a system of first order ordinary differential equations in the streamwise direction. The streamwise derivatives were solved by an implicit and noniterative finite difference marching scheme.

A laminar compressible boundary layer code has been developed and has been tested for a NACA 0012 airfoil at a Mach number of 0.5, a Reynolds number of 5000, and zero angle of attack (Fig. 1). At present the boundary layer program solves up to, but not beyond, separation. Also it does not, at present, interact with the inviscid flow solver. However, the code gives good results on the NACA 0012 airfoil, even for the very crudest grid of three nodes. Figure 1b, using seventeen nodes, gives the proper peak coefficient of friction, but separates too early[8]. The NACA 0012 test case is considered a preliminary and encouraging result. It it is believed that the early separation problem is a result of the lack of interaction between the inviscid and boundary layer codes.

Work will continue on the boundary layer program to impliment a turbulence model, extend calculation beyond flow separation, and to incorporate an inviscid code/boundary layer code interation model.

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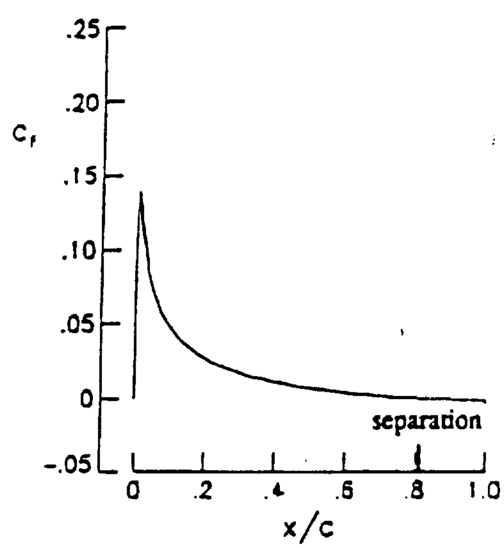

Fig. 1 a. R. Radespiel NASA TM 101557, 1989.

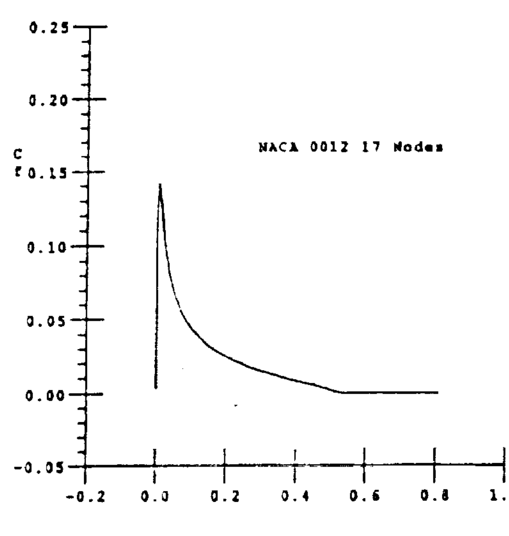

Fig. 1 b. S.D.G. Method

N91-13331

AERODYNAMICS SUPPORT OF RESEARCH INSTRUMENT DEVELOPMENT

by

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Development of new research instrumentation is typically a long and difficult process requiring contributions from a range of scientific and engineering disciplines. Aerodynamic velocimetry systems are no exception to this thesis. Physicists, Chemists, Electrical Engineers, and Aerospace Engineers are now commonly involved in aerodynamic instrumentation development. The Aerospace Engineer's role is, typically, to evaluate system performance and define measurement applications.

A new velocimetry system, originally conceived by Northrop Research and Technology Center, is currently being developed at the NASA LaRC. The device, known as a Doppler Global Velocimeter (DGV), can record three velocity components within a plane simultaneously and in near real time. Current velocimetry methods, such as the Laser Velocimeter, provide only point measurement of the flow behavior. Under many circumstances, an instantaneous global measurement of the flow field is preferred.

To make measurements the DGV, like a many other velocimetry systems, relies on the scattering of light from numerous small (0.5-2.0 micron diameter) particles in a flow field. The particles or seeds are illuminated by a sheet of Laser light and viewed by two CCD cameras. The scattered light from the particles will have a frequency which is a function of the source Laser light frequency, the viewing angle, and most importantly the seed velocities. One of the CCD cameras is fit with an atomic line filter which passes light as a function of frequency. The exact relationship between the transferred light intensity and frequency is easily identified through calibration. Thus by determining the scattered light intensity the velocity can be measured at all points within the light sheet simultaneously. The second camera is used to compensate for seed size and distribution uniformity problems. The complete velocimetry process is extremely quick allowing up to 30 global measurements per second.

Upon completion of DGV component construction and initial check out a series of tests in the Basic Aerodynamic Research (wind) Tunnel (BART) are scheduled to verify instrument operation and accuracy. If results are satisfactory, application of the DGV to flight measurements on the F-18 High Alpha Research Vehicle (HARV), at the NASA Ames-Dryden research center, are planned.

The DGV verification test in the BART facility will utilize a 75 degree swept delta wing model. A major task undertaken this summer included evaluation of previous results, obtained using established techniques, for this same model. Understanding this data is important since it will be utilized as a baseline for DGV evaluations. A specific series of tests matching exactly previous tests and exploring new DGV capabilities were developed and suggested. Upon completion of the BART investigation test matrix a good measure of the DGV system accuracy and ability will be established.

Another task undertaken was to study DGV system installation possibilities in the F-18 HARV aircraft. To meet projected velocity measurement requirements and to identify mounting locations for the DGV transmitting and receiving optics, in available aircraft spaces, a three dimensional assessment tool was implemented. The DGV Laser and CCD camera systems were arranged, using a Computer Aided Design (CAD) software package, at numerous locations and the measurement capabilities evaluated in three dimensions quickly and easily. A number of potential DGV installation schemes for the F-18 were established using this method.

In addition to the above work, a simple seeding system modification was "developed" and utilized to make Particle Imaging Velocimetry (PIV) measurements in the BART facility. Flow seeding may at first seem like a simple task, but unfortunately it can become a time consuming and difficult problem. The simple modification allowed for proper seeding and good measurement capability. Since the seeding requirements for the DGV are basically the same, this modification has the potential for application in the future scheduled tests.

N91-13332

PARALLEL - VECTOR COMPUTATION FOR CSI-DESIGN CODE

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NASA LaRC - ASEE Summer '90 Program
May 14 - August 10, 1990

Summary

Computational aspects of CSI (Control-Structure Interaction) DESIGN code is reviewed. Numerical intensive computation portions of CSI-DESIGN code have been identified.

Improvements in computational speed for the CSI-DESIGN code can be achieved by exploiting parallel and vector capabilities offered by modern computers, such as the ALLIANT, CONVEX, CRAY - 2 and CRAY - YMP.

Four options to generate the coefficient stiffness matrix and to solve system of linear, simultaneous equations are currently available in CSI-DESIGN code. A pre-processor to use RCM (Reverse Cuthill-Mackee) algorithm for bandwidth minimization has also been developed for CSI-DESIGN code.

Preliminary results obtained by solving a small-scale, 97 node CSI finite element model (for eigen-solution) have indicated that this new CSI-DESIGN code is 5 to 6 times faster (using 1 Alliant processor) than the old version of CSI-DESIGN code. This speed-up was achieved due to the RCM algorithm and the use of a new skyline solver.

Efforts are underway to further improve the vector speed for CSI-DESIGN code, to evaluate its performance on a larger scale CSI model (such as phase zero CSI model), to make the code running efficiently on multi-processor, parallel computer environment, and to make the code portable among different parallel computers available at NASA LaRC, such as the Alliant, Convex and Cray Computers.

N91-13333

CALCULATION OF ROTOR IMPEDANCE FOR USE IN DESIGN ANALYSIS OF HELICOPTER AIRFRAME VIBRATIONS

by

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ABSTRACT

Excessive vibration is one of the most prevalent technical obstacles encountered in the development of new rotorcraft. The majority of vibrations problems are not even identified until the flight testing phase of development. The inability to predict these vibrations is primarily due to deficiencies in analysis and simulation tools. The Langley Rotorcraft Structural Dynamics Program was instituted in 1984 to meet long term industry needs in the area of rotorcraft vibration prediction. As a part of the Langley program, this research endeavors to develop an efficient means of coupling the rotor to the airframe for preliminary design analysis of helicopter airframe vibrations.

Due to the very different dynamics and structural configurations of the rotor and fuselage, these two structures have historically been analyzed separately. The coupling of the two structures has normally been accomplished by the calculation of the forces acting on the fixed rotor hub and then the application of these fixed hub forces to the fuselage for vibration analysis. This method neglects the very important dynamic interaction between the two structures and as a result is not adequate for vibration analysis.

Two different methods are available to correctly couple the rotor and airframe in order to account for these interactions. The first method couples the rotor and airframe equations directly through constraint equations and thus creates a merged set of equations representing the combined structures. The second method, called impedance matching, equates the forces and displacements at the rotor and fuselage connection for a given frequency.

In impedance matching, the loads transmitted by the rotor hub to the airframe, F, are represented as a combination of the fixed-hub loads, F_0, and a linear correction to account for hub motions, x (eqn 1).

$$F = F_0 + [A]\, x \qquad \text{(eqn 1)}$$

The A matrix, which provides the hub forces due to hub motions, is the rotor impedance matrix. The forces due to motion of the fuselage can also be represented in terms of impedance (eqn 2), where B is the fuselage impedance matrix.

$$F = [B]\, x \qquad \text{(eqn 2)}$$

By equating the forces and displacements of the rotor and fuselage at the rotor hub, the following relation is obtained for the hub motion (eqn 3). The coupled hub forces can now be found from equation 2.

$$x = [B - A]^{-1}\, F_0 \qquad \text{(eqn 3)}$$

The great utility of this result to the airframe designer lies in the independence of the fuselage properties, represented by the B matrix, from the rotor properties. If the fuselage structure is changed, only the fuselage impedance changes and no additional rotor analysis is required.

Although the fuselage impedance, B, can be readily calculated, the rotor impedance, A, is considerably more difficult to obtain.

The main effort of this research has been to modify an existing computer program for modeling the dynamic and aerodynamic behavior of rotorcraft called DYSCO (DYnamic System COupler) to calculate the rotor impedance. DYSCO was recently developed for the U.S. Army by Kaman Aerospace Corporation and has proven to be adaptable for the inclusion of new solution methods. The solution procedure developed to use DYSCO for the calculation of rotor impedance is shown below.

1. Start with a trimmed rotor-fuselage coupled model.

2. Create a separate model from the Rotor Component only.

3. Find the Hub Fixed Forces.
   a. Run the rotor component as a separate model with only the blade degrees of freedom (DOFs), no hub DOFs, in a time history solution. This produces the motions of the blades with the hub fixed. Write the resulting rotor state vectors to a file.
   b. Create a second rotor model which includes the hub DOFs. Add to the model, the steady forces required to keep the rotor hub in equilibrium.
   d. Run this model with the Rotor Impedance Solution, SRI1. The SRI1 solution modifies blade state vectors to add elements for the hub DOFs. Each of the hub DOF elements will be zero, however, they are required to calculate the fixed hub forces. SRI1 calls the Interface Force Solution, SII3 to calculate and save the Fixed Hub Forces for future use.

4. Find the Forces due to Hub Imposed Displacement.
   a. Create a third Rotor Model by modifying the second model to increase the Hub Mass (and/or Hub Moment of Inertia) to 10^6 times the actual hub and rotor mass.
   b. Run this third model with SRI1 to obtain the state vectors of the rotor hub and blades corresponding to the harmonic displacement of the rotor hub. The model will be run for the cosine and sine displacements of each hub DOF in succession, and the resulting state vectors are saved to a file. Input the force magnitude necessary to produce the desired displacement.

5. Calculate the Impedance Matrix.
   a. Return to the second rotor model, which consists of the true representation of the rotor hub. Run SRI1 for the third time to obtain the Hub Interface Forces caused by the harmonic displacement of each of the hub DOFs from the state vectors just produced with the heavy hub model.
   b. Subtract the fixed hub forces from the hub forces due to hub motion. Perform a harmonic analysis of the resulting forces and the Fourier coefficients become one column in the impedance matrix.
   c. Form the entire matrix from the columns of Fourier coefficients obtained for each cosine and sine motion of every hub DOF.

Verification of the procedure by comparison with a known solution for a simple wind turbine model is about 75 percent completed, and initial results are encouraging. After the wind turbine impedance is confirmed, the verification effort will continue by comparison to solutions of a more sophisticated rotorcraft model. Future work includes determination of the sensitivity of the rotorcraft airframe vibrations to helicopter flight conditions and rotor modeling assumptions. When completed, this research will ascertain the feasibility and efficiency of the impedance matching method of rotor-airframe coupling for use in the analysis of airframe vibrations during the preliminary rotorcraft design process.

N91-13334

ADDITIVES TO REDUCE SUSCEPTIBILITY OF THERMOSETS AND THERMOPLASTICS TO EROSION FROM ATOMIC OXYGEN

by

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Polymeric materials have many attractive features such as light weight, high strength, and broad applicability in the form of films, fibers, and molded objects. For these reasons synthetic polymers are increasingly being incorporated on orbiting vehicles as the material of choice for thermal blankets, tethers, structural trusses, adhesives, etc. In low-earth orbit (LEO, e.g., 300-500 km) these materials, when exposed on the exterior of spacecraft, have the serious disadvantage of being susceptible to erosion by atomic oxygen (AO).

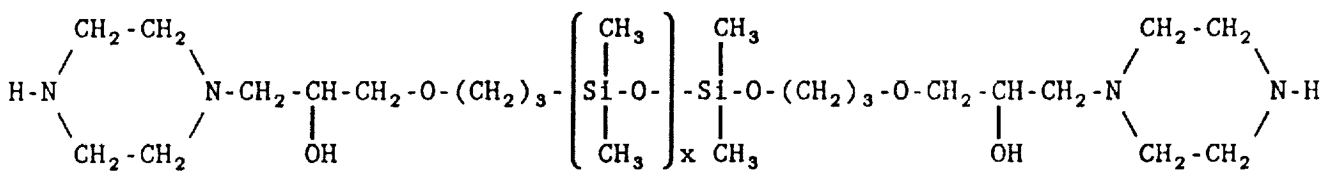
AO is the most common chemical species at LEO altitudes. At typical satellite speeds of 8 km/s, forward facing surfaces undergo 10^{14}-10^{15} collisions/s/cm^2 with AO. AO can be an extremely efficient oxidizing agent as was apparent from the extensive erosion of organic films exposed in STS missions. The mechanism for erosion involves the reaction of oxygen atoms at the surface of the substrate to form small molecular species, sometimes with scission of the polymer backbone. These volatile products escape immediately and the etching of the surface continues as long as it is exposed to AO.

The susceptibility of polymeric materials varies with their chemical composition. Polyethylene and (Mylar) polyester are among the most vulnerable polymers. Experiments in LEO revealed that, for each collision of an oxygen atom with polyethylene or polyester film, an average of 2-3 amu (atomic mass units) of film were eroded. At 10^{14} collisions/s/cm^2, this corresponds to a loss of 0.1 mm from the surface each year. On the other hand, completely fluorinated polymers (Teflon) and polymers with silicon atoms incorporated chemically in their structure are much less susceptible: less than 0.1 amu erodes per collision. The fluorinated films are resistant to AO because the carbon atoms in the macromolecules are already bonded to atoms (fluorine) that are more electronegative than oxygen. Unfortunately fluorocarbon polymers have only limited applicability in space because the carbon-fluorine bond is especially vulnerable to scission by solar UV. More relevant to this work are the silicon-containing polymers. Their resistance to AO is attributed to the formation of a protective coating of inert silicates $(SiO_2)_x$. This quasi quartz-like barrier is generated during the initial period of exposure of the polymer film to AO. Because silicates are nonvolatile, they remain behind on the surface of exposed films blocking the remainder of the material from further erosion by AO.

Films with silicon atoms incorporated in the molecular structures have large coefficients of thermal expansion. This limits their utility. In an alternative approach we have looked for additives to mix physically (as opposed to attaching chemically) that would form a similar protective oxide layer when the film is exposed to AO. A large number of organic compounds containing silicon, germanium, or tin atoms were screened. Most were found to have very limited solubility (<5% by weight) in the polyetherimide (Ultem) films that we are trying to protect from AO. However, one, bis(triphenyl tin) oxide (abbreviated BTO), is miscible in Ultem up to ca. 25%.

Films of Ultem polyimide containing up to 25 wt-% BTO were prepared by evaporation of solvent from a solution of Ultem and BTO. The effects of atomic oxygen on these films were simulated in the oxygen atmosphere of a radio-frequency glow-discharge chamber. Typical results are shown in Fig. 1. Here the degradation rates of polyetherimide with and without BTO are shown as a function of the exposure time. During the initial stage when the tin oxide film is forming, the mass loss of the doped film is considerably greater owing to the greater volatility of the oxidation products involving constituent atoms that are not connected to the long chainlike macromolecules of the Ultem. At longer times after the tin oxide has accumulated on the surface, the erosion rate has decreased to two/thirds that of the undoped polymer. The protective layer on the surface is evident in EDAX studies. Fig. 2 is an EDAX spectrum of an Ultem film containing 20% BTO, before and after a 360-min exposure in the oxygen plasma of the glow discharge chamber. It shows the surface composition changes markedly from predominantly carbon and oxygen to tin and oxygen.

In a second part of this study, we have undertaken to incorporate silicon atoms in epoxy resins by including the following compound and an analogue with



phenyl in place of the methyl substituents at the silicon atoms as part of the curing agent for the epoxy. Experiments are in progress to measure the resistance of films of the cured epoxy to AO in the discharge chamber.

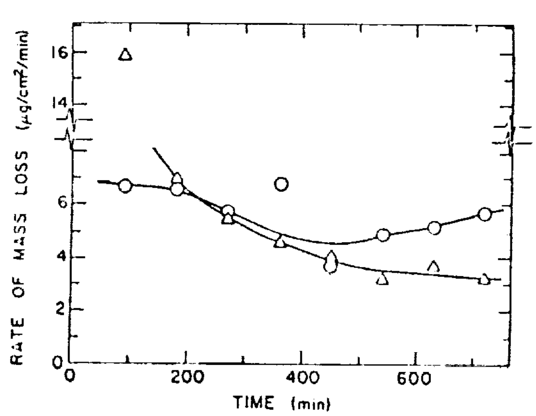


Fig. 1. Erosion rates of polyetherimide doped with 25 wt-% BTO (triangles) compared with those of undoped film (circles).

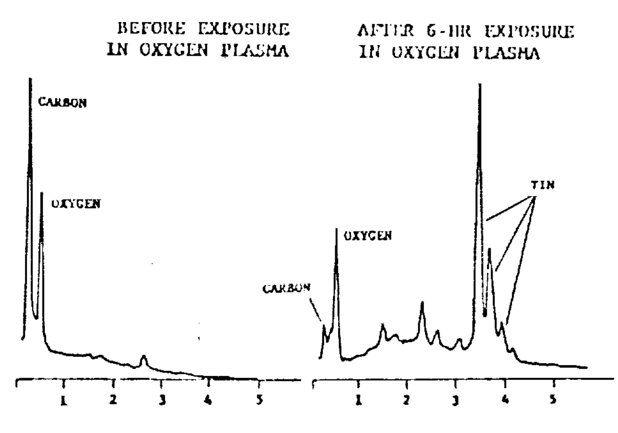


Fig. 2. EDAX spectra of a polyetherimide film with 20 wt-% BTO before and after a 6-hr exposure in the discharge chamber.

N91-13335

A Modified Pump Laser System to Pump The Titanium Sapphire Laser

by

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As a result of the wide tunability of the titanium sapphire laser NASA has sited it to be used to perform differential absorption lidar (DIAL) measurements of H_2O vapor in the upper and lower troposhere. The titanium sapphire laser can provide a spectrally narrow (.3-1.0 pm), high energy (.5-1.0 J) output at 727, 762 and 940nm which are needed in the DIAL experiments. This laser performance can be obtained by addressing the line-narrowing issues in a master oscillator and the high energy requirement in a fundamental mode oscillator (called power oscillator). By injection seeding, the single frequency property of the master oscillator can produce a line narrow high energy power oscillator.

The work performed this summer was to assist in the demonstration of a breadboard model of the titanium sapphire laser that will ultimately be used in NASA lidar atmospheric sensing experiment. The task was to identify and solve any problem that would arise in the actual laser system. One such problem was encountered in the pump laser system.

The pump laser that is designed to pump both the master oscillator and power oscillator is a Nd:YLF laser. Nd:YLF exhibits a number of properties which renders this material an attractive option to be used in the laser system. Nd:YFL crystal is effectively athermal; it produces essentially no thermal lensing and thermally induced birefringence is generally insignificant in comparison to the material birefringence resulting from the uniaxial crystal structure. However, in application repeated fracturing of these laser rods were experienced. Because Nd:YLF rods are not commercially available at the sizes needed for this application a modified pump laser system to replace the Nd:YLF laser rod was designed to include the more durable Nd:YAG laser rods. In this design, compensation for the thermal lensing effect that is introduced because of Nd:YAG laser rods is incleded.

N91-13336

Analysis of Pressure-Broadened Ozone Spectra in the 3-μm Region

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The presence of a layer of photochemically produced ozone in the stratosphere has been recognized for some time. This ozone layer is vital to life on earth, as it provides a shield from harmful ultraviolet radiation that is a normal component of sunlight. During the mid 1980's, a deficit in the ozone layer was observed over the Antarctic continent. Since that time, the need to observe and monitor the ozone content in the stratosphere has been the motivation of considerable scientific effort. More recently, the effects of increased atmospheric ozone amounts at the earth's surface have been found to be of significant environmental concern. Spectroscopic methods are the basis for remote sensing techniques to measure atmospheric content of many species, including ozone, on global and regional scales. As technology continues to improve, the understanding of the spectra of these species becomes increasingly important in allowing accurate retrieval of data obtained by remote sensing techniques.

The Molecular Spectroscopy Lab at NASA-Langley has been involved in a long term effort to carefully and fully characterize the infrared spectra of small molecules of atmospheric interest, including methane, water vapor, ozone, and their isotopic counterparts. High resolution gas phase infrared spectra are obtained using both a tunable diode laser system, and the McMath Fourier transform spectrometer at the Kitt Peak Solar Observatory. Spectra are obtained at various pressures and temperatures for pure gas samples, and for samples containing mixtures of the species of interest in nitrogen, oxygen, or air. From these spectra, using a non-linear least squares fitting technique, spectral parameters of position, intensity and half-width have been determined for varying laboratory conditions that approximate atmospheric conditions experienced in remote sensing situations. These parameters are of interest in theoretical studies of these species, as well as in allowing more accurate interpretation of remote sensing data.

The current work in the lab involves the analysis of a series of McMath FTIR spectra of ozone broadened by mixing with air, nitrogen or oxygen. Each spectrum covers the region from 2396 to 4057 cm^{-1}. Each vibrational band is analysed by first dividing its region into small (0.5 to 2.0 cm^{-1}) intervals containing a few well isolated absorption lines of reasonable intensity. Each of these small intervals is "fit" by multiple iterations of the non-linear least squares program until residuals (difference between calculated and observed spectrum, as percent of the strongest intensity in the interval) are minimized to a "reasonable" value which corresponds to the noise level of the measured spectrum. Position, intensity and half-width are recorded for later analysis. Half-widths are normalized for each pressure and a pressure broadening coefficient is determined for each absorption line.

This summer, intervals for the $3\nu_3$ ozone band in the region from 3000 to 3060 wavenumbers are being examined. In particular, analysis of the region from 3000 to 3030 wavenumbers has been completed for all ten experimental conditions, and broadening coefficients have been found for over 200 lines of the $3\nu_3$ region for the three broadening gases. The remaining 3030 to 3060 wavenumber region remains to be fitted before a final analysis of line broadening in the $3\nu_3$ ozone band can be completed.

Appendices:

1. Ozone Broadening Experimental Conditions
2. Comparison of Halfwidths for O_3 Line at 3010.9152 cm^{-1}. (comparable results have been obtained for each line that has been studied in the ozone $3\nu_3$ region)

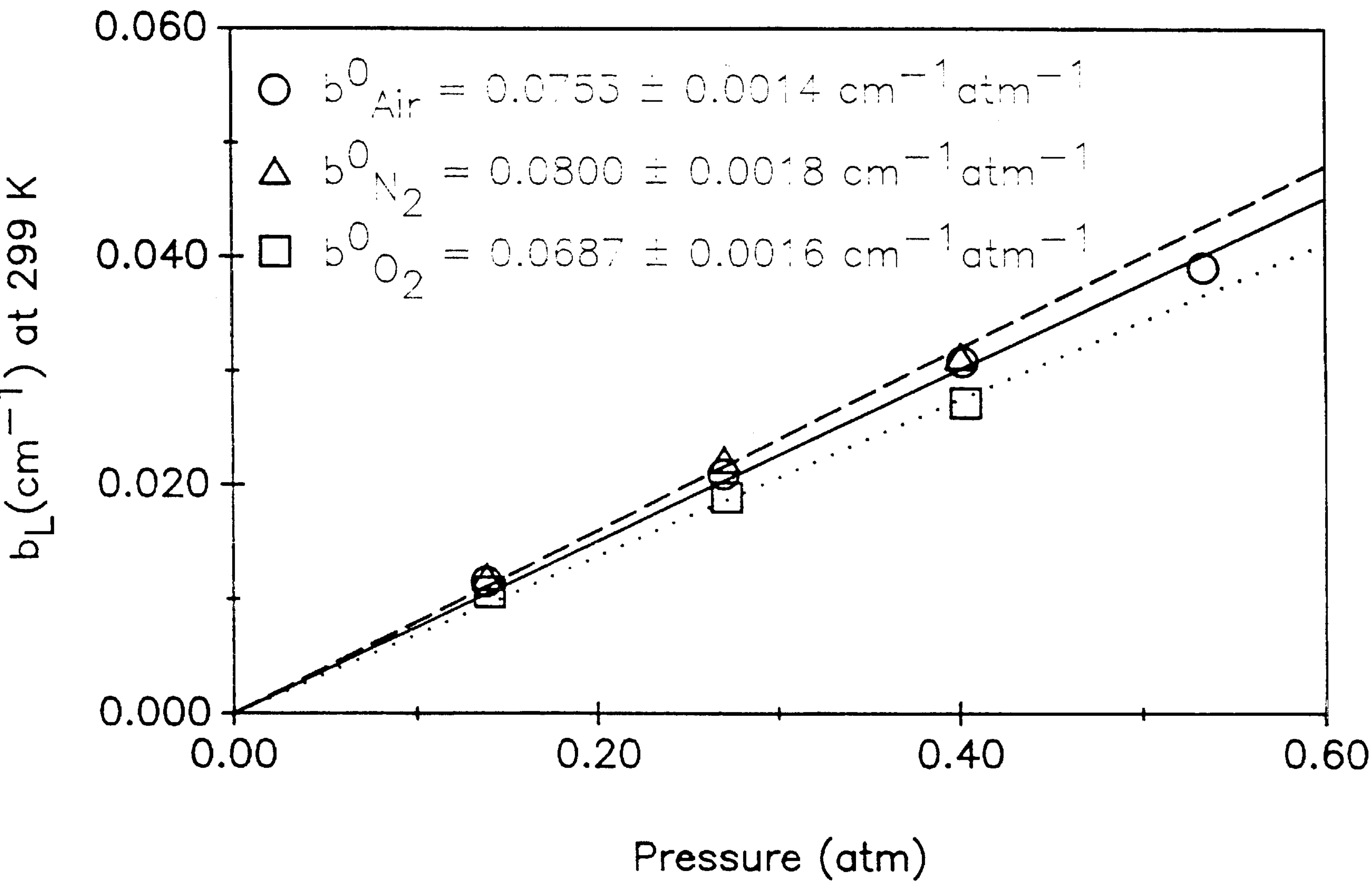
OZONE BROADENING

EXPERIMENTAL CONDITIONS

Gas Mixture	Volume Mixing Ratio	Pressure
O_3 in Air	4.16%	105.0 torr
	2.13	204.9
	1.43	305.0
	1.08	405.3
O_3 in N_2	4.54	105.1
	2.33	205.1
	1.57	304.2
O_3 in O_2	5.18	106.3
	2.67	206.2
	1.80	306.4

All spectra were recorded using a 2.39 m cell at 26 ± 1°C, and 0.01 cm^{-1} resolution.

COMPARISON OF HALFWIDTHS FOR O_3 LINE AT 3020.9152 CM^{-1}



N91-13337

SIMULATION OF ROTATION EFFECT IN TURBULENCE DISSIPATION RATE EQUATION

By
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It has been observed that the Reynolds stress transport equations using the usual isotropic dissipation rate transport equations do not accurately predict the correct evolution of the kinetic energy in both homogeneous shear and isotropic decay. This same effect carries over to more practical flows such as those with strong irrotational strains and/or adverse pressure gradients. The deficiencies in these predictions have been attributed to the need for modifications in the isotropic dissipation rate equation. Pope(1) and Hanjalic and Launder(2) have proposed modifications to this equation. These modifications have been tested in the cased of homogenous shear and iso-decay and their performance analyzed. The results are compared to the rotating flow models of Bardina(3) and Raj(4).

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N91-13338

Fine-Tuning of Process Conditions to Improve Product Uniformity of Polystyrene Particles Used for Wind Tunnel Velocimetry

by

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Background

Monodisperse polymer particles (having uniform diameter) have been used for the last two decades in physical, biological and chemical sciences. In NASA Langley Research Center monodisperse polystyrene particles are used in wind tunnel laser velocimeters. These polystyrene (P.S.) particles in latex form had been formulated at the Engineering Laboratory of the FENGD using emulsion-free emulsion polymerization. Monodisperse P.S. latices particles having different particle diameters had been formulated and useful experimental data involving effects of process conditions on particle size have been accumulated. However, similar process conditions and chemical recipes for polymerization of styrene monomer have often yielded monodisperse particles having varying diameters. The purpose of this summer research was to improve the P.S. latex product uniformity by fine-tuning of the process parameters based on knowledge of suspension and emulsion polymerization.

Present Study

A set of preliminary experimental runs based on a recommended process settings derived from previous studies made at NLRC revealed the need to: (1) monitor the temperature and PH of the reactor, agitator speed; (2) more complete cleaning of the reactor vessels to prevent seed polymerization in subsequent runs; (3) supplement the current approximate method of measuring particle size by Transmission Electron Microscopic (TEM) technique; and (4) measure the molecular weight and distribution of final particles to lend to better correlation of product properties with process parameters.

Runs made with these fine-tunings are shown on a table attached. The molecular weight data will be provided by the Polymer Laboratory at NLRC and the TEM measurements will be made by the author when he returns to his University. With the exception of four runs, the latex particle sizes of the runs can be represented as 2.0± 0.3 μm. Except for the run 294-3L the deviations of the particle size of the rest three runs can be attributed to premature stoppage of agitator due to undue build-up of polymer agglomerates and/or deviation of temperature by 2-3°C off the desired level of 65°C. Molecular weight and TEM data of the P.S. particles should shed more light on reasons for these deviations. The PH's of the latices were more or less the same.

Limited number of runs made to date at different agitator speeds (RPM) show that there is an optimum RPM range which yields particle size targeted. An agitator speed below this range causes reduced particle size and speed above this range would cause mechanical coalescence of the particles yielding large agglomerates. Further runs to investigate this is in progress.

A set of recommendations for fine tuning of the process parameters to improve P.S. latex product uniformity is transmitted to the Engineering Laboratory of FENGD.

EMULSION-FREE STYRENE POLYMERIZATION PROCESS DATA

Run No.	Temp Initial/Final °C	Agitator RPM Initial/Final	D/I Water M Ω cm	PH (Final)	% Solid	Dp (μm) (Nikon Micrograph)	Dp*** (TEM)	***MW (GPC)
290-3L	62.8/65.1	150/Stopped	10.0	-	6.0	1.7		
291-3L	64.5/65.2	150/Stopped	7.0	2.6	6.2	2.0		
292-3L	62.8/65.4	150/Stopped	7.0	2.6	6.36	2.1		
293-3L	62.5/64.7	150/120	7.0	2.6	6.3	2.3		
294-3L	62.9/64.1	150/140	18.0	2.65	6.14	1.0		
295-3L	62.5/65.8	150/150	18.0	2.60	6.45	2.1		
296-3L	63.0/64.6	150/100	18.0	2.65	6.0	2.1		
*297-3L	62.6/62.8	150/50	18.0	2.75	5.61	2.7		
**298-3L	63.0/65.3	150/120	18.0	2.60	-	2.2		
**300-3L	62.3/62.3	150/125	18.0	2.6	5.73	2.6		
**301-3L	62.3/65.2	150/Stopped	18.0		6.0	1.3		

** Reactor Heater and Agitator Motor Connected to Constant Voltage Source

* 62 ml of 1% $MgSO_4$ Used Instead of Usual 55 ml

*** To be Analyzed at LaRC Polymer Laboratory and Christian Brothers University

N91-13339

A Rate Equation Approach to Gain Saturation Effects in Laser Mode Calculations

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Abstract

Space exploration and research will require large amounts of power. Solar pumped laser systems have been shown to have potential for meeting the performance requirements necessary for power transmission in space. The successful design of laser systems for these applications will depend, in part, on having a clear understanding of the development of the dynamical processes in the laser cavity and on the effects that changes in physical and design parameters have on laser performance. In particular, it is necessary to know the amplitude and phase distributions of the laser beam at the output aperture when steady state operation is achieved in order to determine the far-field power distribution. The output from the laser will depend on the active medium, the optical environment of the active material and on the gain distribution in the active region as laser action builds up and reaches steady state.

An important component in the design process will be a realistic model of the active laser cavity. A computer model of the laser cavity, based on Huygens' principle, has been developed by M. D. Williams in the Space Systems Division/ High Energy Science Branch. The code calculates the amplitude and phase of an optical wave reflected back and forth between the mirrors of a laser cavity. The original code assumes a gain distribution which does not change with the build up of oscillations in the cavity. A step in the direction of realism is the inclusion of a saturable gain medium in the cavity. The objective of this study is to incorporate saturation effects into the existing computer model.

As an optical wave propagates back and forth between the mirrors of an optical resonator, it satisfies the Fresnel-Kirchhoff formulation of Huygens' principle which is summarized briefly below. If $U(x_1,y_1)$ is the complex amplitude field at a point (x_1,y_1) on a mirror M_1, then the field V at a point (x_2,y_2) on mirror M_2 can be determined by the following propagation equation:

$$V(x_2,y_2) = \exp(-jkD)\int_{M_1} K(x_2,y_2;x_1,y_1)U(x_1,y_1)dS \qquad (1)$$

where D is the distance between the mirrors and K is the propagation kernel which depends on the aperture and other intervening optical elements in the cavity. The integral is a surface integral which is evaluated over the aperture.

A transverse mode represents a field which reproduces its structure after a passage through the resonator and hence is an eigenfunction of the integral operator defined by (1). The method of solution of the eigenvalue problem, first described by Fox and Li in 1961, involves an iterative procedure in which the wave is propagated back and forth until a steady state is achieved.

In the case of a saturable gain medium in which the gain has variations transverse to the optical axis, the integral equation is

$$V(x_2,y_2) = \exp(-jkD)\int_{M_1} \exp(\alpha D)K(x_2,y_2;x_1,y_1)U(x_1,y_1)dS \qquad (2)$$

where α, which depends on the transverse position, is the complex amplitude gain coefficient. The gain coefficient is proportional to the population inversion density in the active material and is given by $\alpha = \sigma N/2$. The parameter σ is the stimulated emission cross section and N is the population inversion density.

The theoretical study of transient laser dynamics frequently involves the use of rate equations which describe the temporal evolution of the excited states and photon density in the laser cavity. The number and complexity of the rate equations depends primarily on the nature of the active material. In this study, an idealized four-level model was used, but the principles involved are general enough to be used for other systems. It is assumed that there are no axial variations in either the population inversion density or the photon density. For simplicity, a uniform and continuous pumping rate is assumed. In laser mode calculations, the usual approach is to assume that the active medium is concentrated into two thin sheets which are adjacent to the mirrors. The optical wave is propagated through a free space length and the population inversion density is calculated by integrating the rate equations over the time required for the optical wave to pass through the length of the cavity. Then the field is multiplied by the gain and appropriate mirror reflection coefficient .The surface integral (2) is then computed. Iteration continues until a steady state is achieved.

Steady state conditions in a laser system are reached in times on the order of microseconds, but the computer calculations are very intensive and time-consuming. Thousands of calculations are performed to compute the surface integral, and the integration of the laser rate equations, accomplished by a fixed step Runge-Kutta algorithm, requires 5 evaluations of the derivatives per time step. An obvious shortcoming to this approach is the time expense for computation.

For all calculations, physical parameters typical of solid state lasers were used and pumping rates were well above threshold. The procedure worked well for the case of plane parallel mirrors, both with rectangular and circular apertures. The steady state profiles at the output aperture of the normalized population inversion, relative intensity, and phase, respectively, for a plane parallel resonator are shown in Fig. 1. For the confocal resonator, however, very small time increments were necessary to integrate the rate equations, and the computation is very sensitive to the magnitude of the pumping rate. Work has begun to incorporate an adaptive integration algorithm which will speed up the integration and prevent numerical overflow produced by accumulated truncation error.

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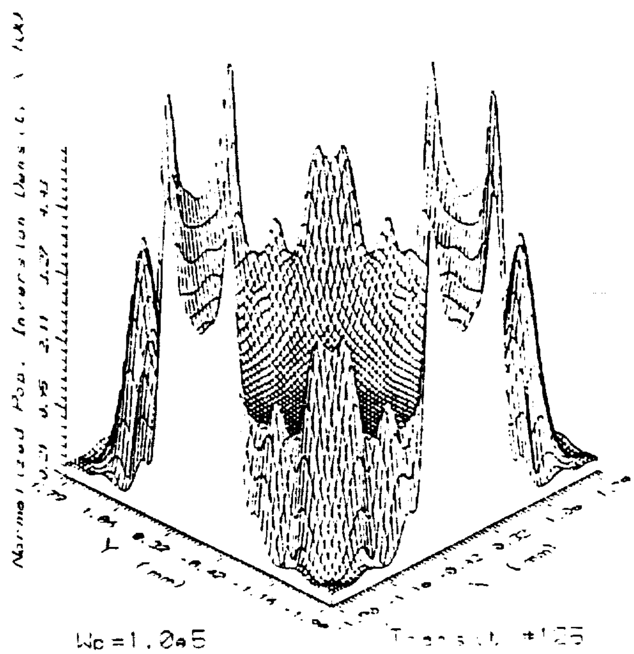
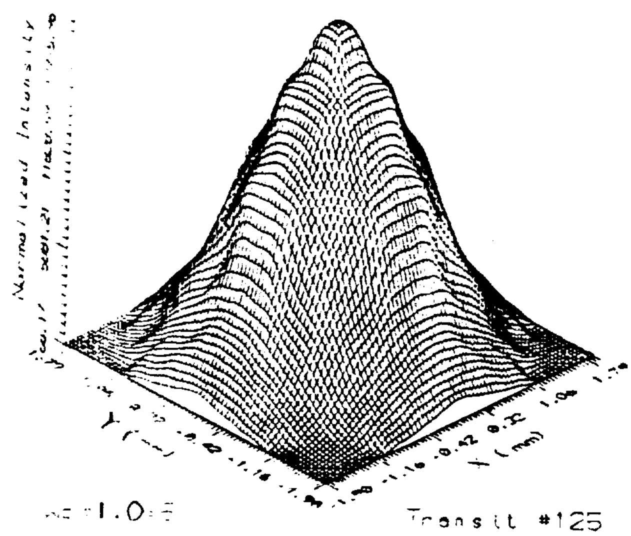
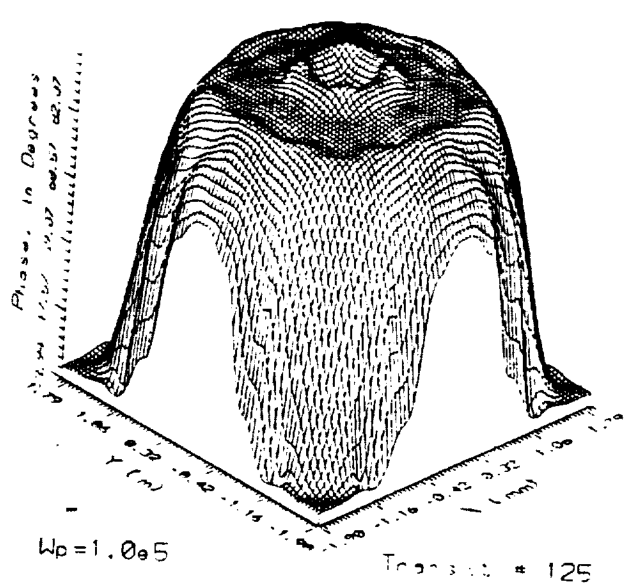


Figure 1. Population Inversion Density, Normalized Intensity, and Phase at the output mirror after 125 transits of the initial optical field through a plane-parallel resonator with circular aperture.





N91-13340

Facilitating Researcher Use of Flight Simulators

by
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INTRODUCTION

Researchers conducting experiments with flight simulators encounter numerous obstacles in bringing their ideas to the simulator. This paper reports on research into how these simulators could be used more efficiently. The study involved: (1) analyzing the Advanced Concepts Simulator software architecture, (2) analyzing of the interaction between researchers and simulation programmers, and (3) proposing a documentation tool for researchers.

DISCUSSION

I. Analysis of the Advanced Concepts Simulator Software Architecture

The Advanced Concepts Simulator (ACS) is designed to model flight station concepts for a 1995 transport aircraft. The ACS provides a platform for research into a wide variety of flight management systems technologies and pilot/cockpit interfaces. The implementation of the ACS involves about a dozen computers and nearly one million lines of software. The first use of this simulator is scheduled for 1991.

Given that the normal mode of use for a flight simulator is to change an aircraft subsystem and gather performance data from that change, it is imperative that a simulator be modifiable. The following recommendations are made for changes to the ACS software in order to accommodate modifiability: (1) in the short term, substantially reduce the number of global variables, repartition some of the software modules, and produce up-to-date system documentation, and (2) in the long term, move to modern software engineering technologies (i. e., Computer Assisted Software Engineering tools for real-time systems, object oriented approaches, etc.).

II. Analysis of the Interaction Between Researchers and Flight Simulation Systems

Researchers' interaction with simulation systems is unique. Researchers are not system "users" in the traditional sense (pilots are the "users"); researchers are not "programmers" or "analysts" (even though much of the work involves programming and systems analysis). The interaction between researcher and simulator is described in Figure 1. Analysis of this interaction revealed four problem areas:

1. Design Specifications -- Many research projects involve complex algorithms and/or pilot-cockpit interfaces. Producing specifications for the programmers is extremely complex and expensive. Researchers and programmers often engage in a protracted process of exchange and compromise before a display design is completed. Another approach has the researcher actually programming the system on a PC and the program becomes the specification to the simulator programmers.

2. Simulator Documentation -- No accurate documentation on how the simulator works is currently available. Researchers generally agree that having information about what models are used within the simulator, data flow between modules, and how modules are organized could be of great benefit.
3. Pilot Orientation -- Briefing manuals for other simulators have been developed; however, pilot orientation will be more extensive on the ACS in order for the pilot to become acquainted with the "advanced concepts".
4. Researcher Collaboration -- In conducting an experiment, a researcher produces much "informal results" for which there is no forum currently available.

III. A Proposal for a Documentation Tool for Researchers

A documentation tool which addresses the four problems listed above must have the following characteristics: accurate, easily (or automatically) updated, well organized, provide rich means for access to the information, easy to use, encompass a variety of types of information, help generate ideas, flexible/robust -- easily adapted for unplanned uses, improve with use, and encourage active participation (researchers contribute as well as receive information). Also, for such a tool to be effective researchers must be committed to contributing to the information base ("I Know" becomes "We Know").

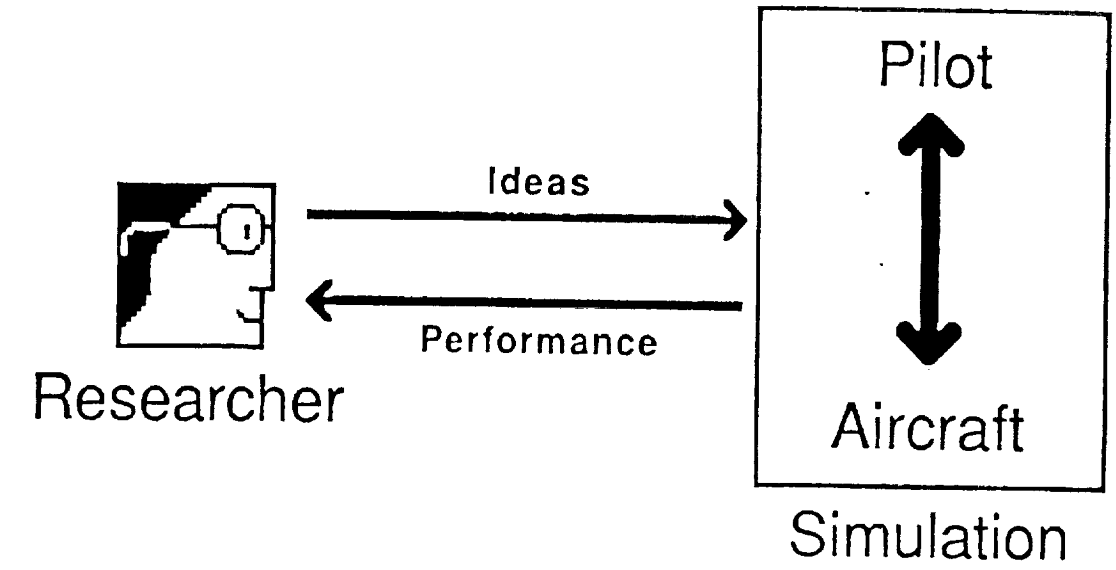
To address these required characteristics, a documentation tool has been proposed and a preliminary implementation has been performed. The documentation tool is a hypertext which contains the information about flight crew orientation, flight crew displays, data flow within the simulator, module hierarchy, what variables can be set by the researcher, what data can be automatically collected, researcher notes, simulation limitation, and planned modifications to the simulator. The tool provides for prototyping of cockpit displays which can be used as design specifications, pilot orientation materials, and description to other researchers in future experiments. Also, the tool includes management of researcher notes which can serve as a means to disseminate formal and informal results.

CONCLUSION

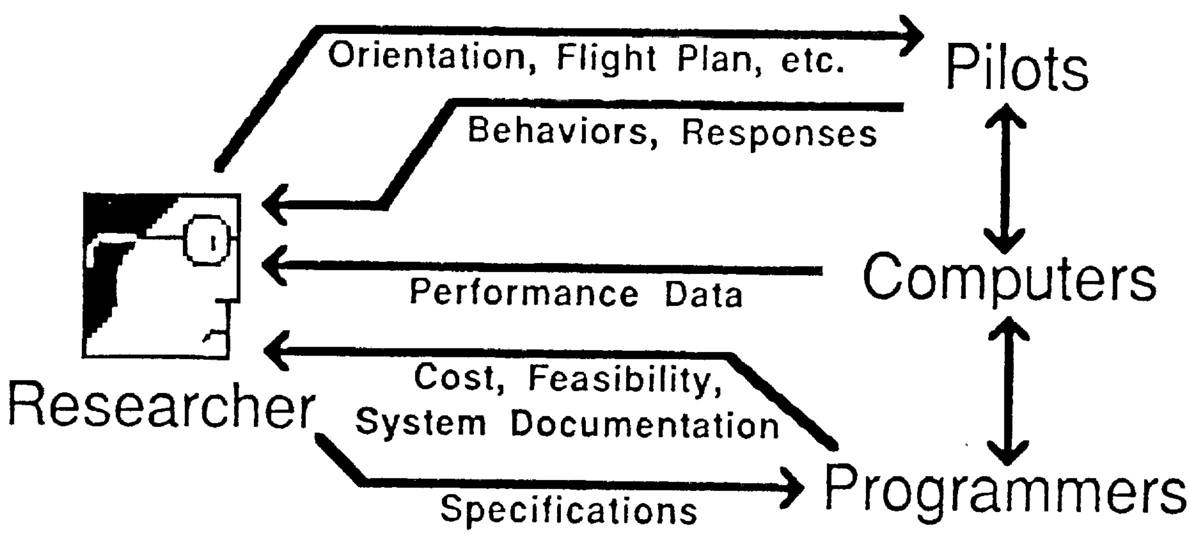
The following conclusions have been drawn from this research:

1. Effort must be devoted to "cleaning up" and documenting the ACS.
2. Communication between researchers and the simulation system is a major problem.
3. Communication among researchers of "informal results" is limited.
4. Hypertext can be used to facilitate researcher activities by providing prototyping, specification, and documentation of flight crew displays, facilitating communication among researchers, and providing access to information about how the simulator is implemented.

A plan for creating the documentation tool described here should include: formal design of the tool, implementation, and validation of the tool by using it in conjunction with a research project on the ACS.



What the Researcher wants?



(This is illustrative--not a complete description of information flow.)

What the Researcher gets?

Information Flow Between the Researcher
and the Simulation System

Figure 1

N91-13341

COMPUTATIONAL ANALYSIS OF FLOW IN 3D PROPULSIVE TRANSITION DUCTS

by

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The main focus of this investigation has been to undertake a numerical analysis of fully three dimensional, statistically steady flows in propulsive transition ducts that are being considered for use in future aircraft of higher maneuverability. The purpose of the transition duct is to convert axisymmetric flow from conventional propulsion systems to that of a rectangular geometry of high aspect ratio, so that downstream thrust deflectors may be applied to effect pitch and yaw moments. In an optimal design, the transition duct would be of minimal length in order to reduce the weight penalty, while the geometrical change would be gradual enough to avoid detrimental flow perturbations. Recent experiments conducted at the Propulsion Aerodynamics Branch [1] have indicated that thrust losses in ducts of superelliptic cross-section can be surprisingly low, even if flow separation occurs near the divergent walls. However, from a material standpoint, it may be unacceptable to accommodate the greatly increased heating which accompanies flow disturbed by separation, secondary vortices, or increased turbulence.

The present investigation has proceeded along three avenues, with a fourth component involving turbulence modeling being considered for future continuation. In order to address the objective of developing a rational design procedure for optimal transition ducts, it is necessary to have available a reliable computational tool for the analysis of flows achieved in a sequence of configurations. Current CFD efforts involving complicated geometries usually must contend with two separate but interactive aspects; namely, grid generation and flow solution. The first two avenues of the present investigation have been comprised of suitable grid generation for a class of transition ducts of superelliptic cross-section, and the subsequent application of the flow solver PAB3D to this geometry. The code, PAB3D, has been developed at the Propulsion Aerodynamics Branch as a comprehensive tool for the solution of both internal and external high speed flows. A document for its operation is currently being refined by its principal developer, K. S. Abdol-Hamid [2]. Helpful guidance in the aspects of grid generation is gratefully acknowledged by the author to S. P. Pao, who has recently reported results [3] of his adaptive grid methods jointly with K. S. Abdol-Hamid.

The third avenue of investigation has involved analytical formulations to aid in the understanding of the nature of duct flows, and also to provide a basis of comparison for subsequent numerical solutions. Attention is drawn to the fundamental analytical solution derivable for fully developed laminar duct flow of rectangular cross-section. This solution explicitly clarifies the seemingly paradoxical corner flow limit, in which a vanishing velocity with vanishing gradients still maintains a non-vanishing curvature, so that viscous retardation can indeed counterbalance an axial pressure decay. It is suggested that this physical balance may be connected with the well known appearance of corner vortices, and therefore, that numerical simulations of corner flows must adequately represent the velocity Laplacian in this neighborhood. In a parallel analytical effort, a closed form solution has been derived for the incompressible 3D Navier-Stokes equations, which are driven by a particular volumetrically distributed force field. The solution is adapted to the geometry and boundary conditions of a duct of rectangular cross-section, and it characterizes flow similar to that which has been observed experimentally. This solution provides the three benefits of aiding in the physical understanding of the role of Reynolds stresses, aiding in the correct application of boundary conditions, and aiding in the assessment of the accuracy of numerical flow solvers.

Numerical results to date include the generation of two preliminary grid systems for duct flows, and the initial application of PAB3D to the corresponding geometries, which are of the class tested experimentally. The first grid system discretizes the volume bounded by superellipses of evolving exponent described in Reference 1, and which is denoted as configuration 2 therein. The second grid system corresponds to a duct comprised of evolving rectangular cross-section, with the same height and width variation as in configuration 2. The rectangular duct has been included in the investigation for three reasons. First, the simplicity of the geometry permits a quick and unambiguous application of a computational mesh, which is easily concentrated in the wall and corner neighborhoods. Second, this duct retains all the essential flow features desired for study in the more practical configurations. Third, the rectangular duct highlights the important possibility of streamwise corner vortex generation, which could influence the design of optimal ducts. Preliminary mesh generation for the superelliptical duct has also been completed to the extent that PAB3D accepts this mesh for computation without unduly ill effects. However, refinement of the superelliptical gridwork is necessary for obtaining numerically accurate results.

At the writing of this report, only the initial computations utilizing PAB3D have been completed. These have indicated the appearance of the main flow features anticipated for such duct geometries, but it has also become apparent that the preliminary outflow boundary condition utilized must be modified for this subsonic case. Incomplete specification of such boundary conditions has been a problem recognized by various investigators. For the present study, a downstream nozzle will be added to the configuration in order to provide a supersonic exit condition, which also simulates the actual case that has been tested.

Recommendations for continued investigation fall into five categories; namely, grid refinement, boundary condition evaluation, turbulence modeling and utilization, implementation of the analytical test case, and comparison of converged solutions with the available experimental results. Some of these should be completed within the time remaining in the summer tenure, while research support will be sought for further continuation also.

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N91-13342

REDUCED-ORDER FILTERING FOR FLEXIBLE SPACE STRUCTURES

By

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There is a need for feedback control of the large flexible space structures which are going to be increasingly important in the future of the space program. These structures are very lightly damped, and vibrations may persist for a long time when the system is disturbed unless an active feedback control strategy is used to damp out the vibrations. The system is best described by a partial differential equation description, but the more common approach is to use a large set of second order differential equations, where a large number of modes must be retained if the mathematics is to provide an adequate description of the dynamical process. Sensors, such as accelerometers and rate gyros, may provide data to the feedback controller so that it may respond appropriately to control the system. The data from the sensors is not perfect, but is subject to noise, called measurement noise, and the dynamical process itself is subject to disturbances referred to as process noise. This research is concerned with filtering the sensor signals to remove the measurement noise, and using the resulting state estimates to control the system.

Since the equations are linear, and the objectives are more or less standard, it would seem that the problem mentioned above could be solved using the standard state space techniques known as Kalman Filtering and Linear Quadratic Regulator Design [1]. The two difficulties with this approach are that the system order is very high, and that some system parameters are not known with any precision. In particular, the damping terms are not well known. Furthermore, a filter and control which worked satisfactorily on earth might not work as well in space under the micro-gravity conditions. We are proposing ways of dealing with the two problems mentioned. The problem of high dimensionality leads to a Kalman filter which may be so computationally burdensome that it cannot be implemented in real time, and so is not useful for control purposes. Typically, one tries to overcome this problem by reducing the order of the model until it is possible to process the filter equations in real time. But the model may then not represent the physical system with much accuracy. Instead, our approach is to constrain the order of the filter prior to optimization, but not reduce the model order more than necessary, so that we do not introduce modeling errors beyond those which occur naturally. The filter designed is then of smaller dimension than the model, and is consequently called a reduced-order filter. But its design is based on the higher order model of the dynamical structure and the noise processes. In the course of designing these reduced-order filters, we noticed that they were sometimes very robust and insensitive to modeling errors when compared to the Kalman Filter. We were able to identify just what it was that caused this lack of sensitivity to variable parameters, and developed a procedure for designing filters which would be completely insensitive to certain system parameters such as damping coefficients.

The author and his students have worked on the design of various types of reduced order filters in the past [2,3,4,5], but never applied any of the techniques to flexible space structures. The techniques we applied during the course of the current research on structures was based on the work reported in [4] and [5] where the reduced-order filter is forced to have an observer structure [6]. The design reported in [4] and [5] had to be modified in such a way that it allowed for and took advantage of correlated process and measurement noise, a feature which resulted from the presence of accelerometer measurements. The design of the new filters was straight forward and computer code was written to demonstrate how they compared with Kalman Filters. These filters, while simpler to implement than a Kalman Filter, had performance loss relative to a Kalman Filter's performance when all model parameters were known. But when false parameters were assumed, the reduced-order filters could perform better than the Kalman Filters under some circumstances.

We found that the ability to be insensitive to certain system parameters was a property that was linked to how one made use of the accelerometer measurements, and we were able to develop a procedure for designing both full and reduced-order filters which were insensitive to parameter variations. The key to the procedure was that certain of the filter gains had to be set at specific values to achieve the insensitivity of performance desired. The remaining gains could then be optimized. The price paid was the fact that more traditional designs gave better performance when system parameters were at their nominal values. Ways of trading off robustness and peak performance are currently being investigated. Computer code was prepared to test the ideas suggested here, and it seems that the procedure of using the insensitive design might be a good idea when parameters are apt to be far from their nominal values, but there are probably better procedures when parameters are fairly close to their nominal values. One outstanding feature of the proposed filters is that Luenberger's Separation Principle [6] is always true for them regardless of how parameters may change. This makes eigenvalue analysis for the closed loop system very easy.

Other research that is under way and could be important for flexible space structure control is concerned with observer based stochastic control, and reduced-order filters that only use accelerometer data.

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N91-13343

Improving System Reliability through Formal Analysis and Use of Checks in Software

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Software is playing increasingly important roles in avionics systems. It is widely used in navigation and, in some cases, in control loops that maintain aircraft stability. To guarantee the safety of flight systems, the FAA requires that critical components have a probability of failure no greater than 10^{-9} per hour of flight. The FAA suggests that a system should continually check itself to determine whether system components have failed so that appropriate responses to failure can be made. Software is being used to diagnose system components for failure. SIFT (Software Implemented Fault Tolerance) was a computer system developed to study the use of software to check for failure and manage processor reconfiguration [Wen].

While software can play a useful role in checking the status of sensors and hardware components, critical software must itself be ultrareliable. Many approaches are currently in use to improve software reliability. They include using structured design techniques, compilers, static analysis, and designing fault tolerance into the software. Although these approaches can improve software reliability, none can guarantee with a high level of confidence that the software satisfies its specifications.

To guarantee that software satisfies its specifications, formal verification can be used. With this a program and its specification are viewed as mathematical objects, and a mathematical proof is used to show that the program and its specification are equivalent. Since its initial study in the late 1960's, great strides have been made in formal verification. Semi-automated theorem proving systems now exist that monitor and assist in software verification [Hen, Ody].

Two important caveats come with formal verification. The first is that a verified program is only as good as its specification. If the specification does not adequately reflect system needs, then its software implementation will not either. The second caveat is that a verified program will produce correct results only when the program is invoked with specified input. A program executed upon unspecified or illegal input will produce unspecified results, and in critical systems this can lead to tragedy. Even verified software must check input for legality and respond appropriately if illegal input is detected.

In previous research [Sta], a theory of checking was developed to offer assistance in analyzing specifications and designing run-time checks. The theory is well suited for integration with a formal approach to software specification and verification. In the theory, checking is considered abstractly in terms of n-ary relations much like those of relational database theory. Such relations provide an ideal representation of software specifications. Within the theory checks are categorized, checks on input and checks on results are considered, and formal attention is given to the minimization and logical combination of checks. The theory consists of a framework of definitions and theorems for reasoning about checking.

The focus of this summer's research has been upon input checks and the obstacles in checking input to critical systems. A central concern, particularly for flight-critical software, is with a property referred to as independence. The concern is with circumstances under which it is possible to apply isolated, independent checks to separate sensor inputs and be assured that all illegal input will be properly detected. The problem can be stated in terms of a group of blind men inspecting an animal. When can the blind men, each inspecting a separate part of the animal and exchanging no information, guarantee that the animal *is not* an elephant? The answer can be explained easily when specifications (of software input or of elephants) are viewed as n-ary relations. A relation can be checked by isolated checks only if it possesses the property of independence.

When possible, input should be specified to be independent so that legality can be checked easily. However, in real-time systems such as flight control systems that interact with the physical environment, dependence appears to be determined to a large extent by the environment and cannot be "specified away." As a consequence, it may be very difficult to check input for safety or legality.

Presently, we are investigating independence and checking in the context of the GCS (Guidance and Control System) [Wit]. The GCS is a simulation of the Viking Mars Lander environment. The simulator is intended for testing software that implements control laws for landing the spacecraft. The lander input comes from sensors, internal parameters, and data saved from previous frames. The large number of inputs and their complex interrelationships provide an exciting context in which to investigate independence and the difficulties of supplying input checks. At this stage we are focusing on independence of sensor input. Later we hope to study the larger problem of all system input.

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N91-13344

DESIGN OPTIMIZATION FOR COST AND QUALITY: THE ROBUST DESIGN APPROACH

by

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Designing reliable, low cost and operable space systems has become the key to future space operations. Designing high quality space systems at low cost is an economic and technological challenge to the designer. A systematic and efficient way to meet this challenge is a new method of design optimization for performance, quality and cost, called, Robust Design. Robust Design is Dr. Genichi Taguchi's approach for design optimization. It consists of:

- Making system performance insensitive to material and subsystem variation, thus allowing the use of less costly materials and components,
- Making designs less sensitive to the variation in the operating environment, thus improving reliability and reducing operating costs,
- Using a new structured development process so that engineering time is used most productively.

The objective in Robust Design is to select the best combination of controllable design parameters so that the system is most robust to uncontrollable noise factors. The robust design methodology uses a mathematical tool called an orthogonal array, from design of experiments theory, to study a large number of decision variables with a significantly small number of experiments. Robust design also uses a statistical measure of performance, called a signal-to-noise ratio, from electrical control theory, to evaluate the level of performance and the effect of noise factors.

The purpose of this research is to investigate the Robust Design methodology for improving quality and cost, demonstrate its application by the use of an example, and suggest its use as an integral part of space system design process.

The three steps of the design process are, system design, parameter design, and tolerance design. System design involves innovation and technical knowledge of the engineer to develop a design architecture that meets the functional requirements. After the system architecture is decided on, the next step is to select the optimum levels for the controllable design parameters such that the system is functional, exhibits a high level of performance under a wide range of conditions, and is robust to noise factors. Parameter design has the greatest impact on cost and quality. Studying the design variables one at a time or by trial and error is the common approach to design optimization. This leads to either a very long and expensive time span for completing the design or a premature termination of the design process such that the product design is far from optimal. As an alternative, Robust Design significantly reduces the number of experimental configurations to be studied. Thus, research and development costs are reduced due to the improved efficiency of generating information needed to design systems so that they are insensitive to operating conditions, production variation and deterioration of parts. As a result, production and operations costs are also greatly reduced.

The third step, tolerance design, is only required if robust design can not produce the required performance without costly special components or high process accuracy. It involves tightening of tolerances on parameters where their variability could have a large negative effect on the final system. Typically tightening tolerances leads to higher cost.

Robust Design methodology was applied to a Heat Exchanger Design optimization problem. The objective was to determine the the optimum combination of controllable design parameters to minimize cost considering the uncertainty due to noise factors. The steps in the Robust Design study consisted of:

1. Identify the main function,
2. Identify the noise factors and testing conditions,
3. Identify the quality characteristic to be observed and the objective function to be optimized,
4. Identify the control factors and their alternative levels,
5. Design the matrix experiment and define the data analysis procedure,
6. Conduct the matrix experiment,
7. Analyze the data, determine optimum levels for the control factors,
8. Predict the performance under these conditions.

The results of the study indicate that Robust design methodology can truly aid design engineers in designing for low cost and high quality. Principal benefits are; time and resource savings, handling of nonlinearities and interactions, quantitative measures of sensitivity of optimum results and, quantitative recommendations to which design parameters should be changed to achieve minimum cost, high quality solutions.

N91-13345

Design of QMF (Quadrature Mirror Filter) in Spatial Domain & Edge Encoding

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(Mr. Fred Huck NASA Research Principle Investigation)

SUMMARY

Simoncelli and Adelson [1] have extended the one-dimensional QMF filter to two dimensions with hexagon symmetry and three dimensional spatio-temporal extensions with rhombic - duodecahedray symmetry. Jain and Crochiere presented an excellent QMF design technique in the time domain [2]. We propose here to extend the design of a two dimensional QMF over a rectangular lattice in the spatial domain based primarily on the extension of the idea of Jain and Crochiere. In addition, the design will investigate the use of 2-D Z-transformations. The basic block diagram of a two-dimensional QMF is shown in Figure 1.

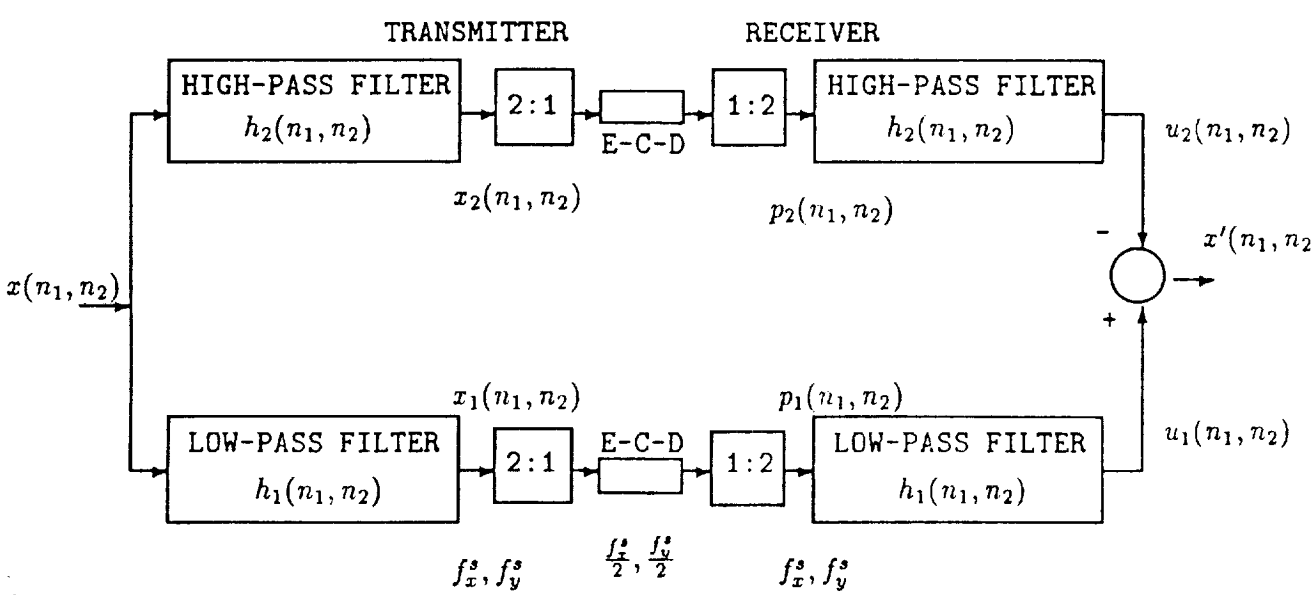

Figure 1: Two dimensional quadrature mirror filters in a two-band subband coder.

Each of the blocks E-C-D denotes the cascade of an encoder, channel and decoder. The cancellation property requires $h_1(n_1, n_2)$ and $h_2(n_1, n_2)$ to have certain well-known properties. It

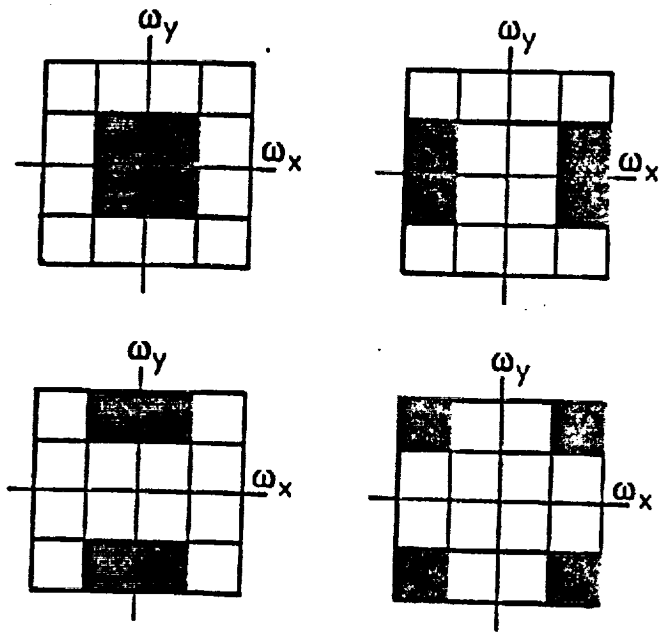

Figure 2: Idealized partition of the frequency domain by separable application of two-band one-dimensional QMFs.

is also known that the ripple balance condition must be satisfied for a perfect reconstruction. We minimize a weighted sum $E_r + \alpha E_{sb}$, where α is the weight-factor, E_r is the passband ripple energy and E_{sb} is the stop-band residual energy. The user can specify the stopband frequencies $\omega_{sb}^x, \omega_{sb}^y$, the weight-factor α and of course the number of taps N. There is every expectation that the convergence to the optimum is stable and thus does not require manual intervention (from repeated trials with different start-up guesses; also note that this feature is very important in the Kalman filter and it is also the feature that the learning phase of the neural network is trying to achieve).

We will generalize the iterative solution of Crochiere and Rabiner [3] which involves the eigenvectors of matrices with a dimensionality equal to one half the number of the filter taps on both horizontal and vertical axes respectively.

Since this proposed QMF is intended for the applications in image processing, all the important and interesting engineering issues will be addressed throughout the development phase.

Most applications of QMF's are multidimensional and involve separable filters. A two-dimensional example is illustrated in Figure 2.

The frequency spectrum is split into low-pass, horizontal high-pass, vertical high-pass and diagonal band high-pass sub-bands, which contains mixed orientations. We believe this method of decomposition can be improved. The boundary need not necessarily be straight lines. So far, the argument for splitting this way has not been persuasive. In order to reach a better solution, one would have to begin with the analysis of the problem at hand. In other words, for a class of pictures sharing the common characteristics, we make a characterization via Fourier transformation to allow us to quantitatively express such features which would be representatively of the class in the frequency domain. Finally, one determines the boundaries as the results of optimizing some meaningful criteria.

The second part of our proposal is related to the first part, the design of a two-dimensional QMF. The motivation of the second part of the proposal is trying to achieve an extremely high data compression ratio. We believe that is is entirely possible to achieve dramatic results when pattern recognition techniques are employed.

Suppose we have established a new boundary splitting the frequency spectrum into regions different from that of Figure 2. The low frequency region (around the origin) will be encoded using conventional methods. It might require some minor modification, but major modification is not envisioned at this point. It is the high frequency encoding that we anticipate to make significant contribution. In the high frequency spectra, we propose to perform encoding for the purpose of data compression in the spatial domain. It is well known that the high frequency spectrum is related to the "edges" in the spatial domain. The coding of "edges" via pattern recognition techniques is believed to yield extremely high compression ratios. There are several approaches to this problem, most of them fairly well established in the research community of pattern recognition.

The most serious problem in the coding of the "edges" is the uncertainty, small perturbations and errors in the "edge" primitives. This problem can be solved through analytical means. Any departure from the standard masks or primitives must be accounted for and a decision must be made in order to complete the inference process. There are many approaches in pattern recognition field and some of them are quite promising. Once the above major obstacle is overcome, then the high compression ratio can be obtained by taking advantage of the "relationship" of different levels (represented by symbols, such as non-terminal vocabularies etc.) in the overall hierarchical structure.

The final goal of this second part of the proposed research is the demonstration of extremely high data compression ratios using NASA pictures.

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ANALYSES OF COMPOSITE FUSELAGE STRUCTURE UNDER VARIOUS LOADING CONDITIONS

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With the unique characteristics of high strength/weight and stiffness/weight ratios in advanced composite materials, composite plate structures have been successfully applied to secondary load-carrying structural components in the aerospace industry for the past two decades. Recently, filament wound composite shells are being considered for design of primary fuselage structures. To implement the design the structural response under various loading conditions needs to be predicted accurately. Therefore, it is essential to establish a rigorous analytical solution in the area of composite laminated shells. The classical shell theory (CST) (Ambartsumyam, 1961, Dong, Pister and Taylor, 1962) based on Kirchhoff-Love hypotheses has been extensively used for analyzing laminated shells. the theory ignores the effects of of transverse shear and normal strains in the thickness direction and thus is restricted to thin shell construction. These effects are more pronounced in composite laminated shells due to the inherent strong anisotropy and non-homogeneity of the material system. Therefore, it underestimates the deflection and stress responses. Whitney and Halpin (1968) have analyzed off-axis unidirectional, two-layer angle-ply anisotropic tubes under various loading conditions based on Donnell's shallow shell approximations to characterize the mechanical properties and behavior of fiber composites. Reuter (1972) presented solutions for alternate-ply cylindrical shells using Donnell's theory. The stress field of a single layer anisotropic cylinder due to mechanical loadings was considered by Pagano (1972). Ren (1987) obtained exact solutions for cross-ply laminated cylindrical shells in cylindrical bending. Hyer (1988) has evaluated the stress distribution of cross-ply laminated shells under hydrostatic pressure. Recently, Reddy (1984) and Abu-Arja and Chandhuri (1989) have studied the behavior of moderately thick composite shells by including transverse shear deformation. Byon and Vinson (1989) used a finite cylindrical element to study the stress and displacement response in laminated anisotropic shells under external hydrostatic pressure.

In this present work a closed form solution is presented that predicts the response of a composite shell subjected to internal pressure, axial tension, bending and torsion. The material of the shell is assumed to be general cylindrically anisotropic. Based on the theory of cylindrical anisotropic elasticity coupled partial differential governing equations are developed using Lehknitskii's stress function approach. The general expressions for the stresses and displacements in the composite cylinders under these loading conditions will be discussed. Three examples: A) [45] off-axis unidirectional, B) [45/-45] unsymmetric and C) $[45/45]_S$ symmetric angle-ply fiber-reinforced laminated shells will be shown to illustrate the effect of radius-to-thickness ratios, coupling and stacking sequence.

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APPENDIX V

SAMPLE QUESTIONNAIRES

NASA-ASEE

SUMMER FACULTY RESEARCH PROGRAM

QUESTIONNAIRE FOR RESEARCH ASSOCIATES

Please complete and return to John Spencer by July 30, 1990, NASA MS 105A.

1. Would you say that your Fellow was adequately prepared for his/her research assignment?

   YES NO (Circle One)

   Comments:____

2. Would you comment on the diligence, interest, and enthusiasm with which your Fellow approached his/her research assignment.

   Comments:____

3. Would you be interested in serving as a Research Associate Again?

   YES NO (Circle One)

   Comments:____

4. Would you be interested in having your Fellow (if eligible) return a second year?

YES NO (Circle One)

Comments:____

____

____

____

5. Any recommendations regarding improvement of the program will be appreciated.

Comments:____

____

____

____

____

____

____

Signature______________________

American Society for Engineering Education

NASA/ASEE Summer Faculty Fellowship Program
Evaluation Questionnaire

(Faculty Fellows are asked to respond to the following questions)

Name: ____

Birthdate: ____

Social Security Number: ______________________________________

Permanent Mailing Address: ___________________________________

____

____

____

Home Institution: ______________________________________

NASA Center and (Laboratory) Division: ___________________________

Name of Research Associate: _______________________________

Brief Descriptive Title of Research Topic: ___________________________

A. Program Objectives

1. Are you thoroughly familiar with the research objectives of the research (laboratory) division you worked with this summer?

   Very much so ______

   Somewhat ______

   Minimally ______

2. Do you feel that you were engaged in research of importance to your Center and to NASA?

   Very much so ______

   Somewhat ______

   Minimally ______

3. Is it probable that you will have a continuing research relationship with the research (laboratory) division that you worked with is summer?

   Very much so ______

   Somewhat ______

   Minimally ______

4. My research colleague and I have discussed follow-up work including preparation of a proposal to support future studies at my home institution, or at a NASA laboratory.

   Yes ____ No ____

5. What is the level of your personal interest in maintaining a continuing research relationship with the research (laboratory) division that you worked with this summer?

   Very much so ______

   Somewhat ______

   Minimally ______

B. Personal Professional Development

1. To what extent do you think your research interests and capabilities have been affected by this summer's experience? You may check more than one.

   Reinvigorated _____

   Redirected _____

   Advanced _____

   Just maintained _____

   Unaffected _____

2. How strongly would you recommend this program to your faculty colleagues as a favorable means of advancing their personal professional development as researchers and teachers.

   With enthusiasm _____

   Positively _____

   Without enthusiasm _____

   Not at all _____

3. How will this experience affect your teaching in ways that will be valuable to your students? (you may check more than one)

   By integrating new information into courses _____

   By starting new courses _____

   By sharing research experience _____

   By revealing opportunities for future employment in government agencies _____

   By depending your own grasp and enthusiasm _____

   Will affect my teaching little, if at all _____

4. Do you have reason to believe that those in your institution who make decisions on promotion and tenure will give you credit for selection and participation in this highly competitive national program?

   Yes _____ No _____

C. Administration

1. How did you learn about the Program? (Please check appropriate response)

_____ Received announcement in the mail.

_____ Read about in a professional publication.

_____ Heard about it from a colleague.

_____ Other (explain). ________________________________
____
____

2. Did you also apply to other summer faculty programs?

Yes _____ No _____

_____ DOE

_____ Another NASA Center

_____ Air Force

_____ Army

_____ Navy

3. Did you receive an additional offer of appointment from one or more of the above? If so, please indicate from which. No _____ Yes _____

____

4. Did you develop new areas of research interest as a result of your interaction with your Center and laboratory colleagues?

Many _____
A few _____
None _____

5. Would the amount of the stipend ($900 per week) be a factor in your returning as an ASEE Fellow next summer?

   Yes _____

   No _____

   If not, why ____

   ____

6. Did you receive any informal or formal instructions about submission of research proposals to continue your research at your home institution?

   Yes _____ No _____

7. Was the housing and programmatic information supplied prior to the start of this summer's program adequate for your needs?

   Yes _____ No _____

8. Was the contact was your research colleague prior to the start of the program adequate?

   Yes _____ No _____

9. How do you rate the seminar program?

   Excellent _____

   Very good _____

   Good _____

   Fair _____

   Poor _____

10. In terms of the activities that were related to your research assignment, how would you describe them on the following scale?

Check one per activity	Time Was			
Activity	Adequate	Too Brief	Excessive	Ideal
Research				
Lectures				
Tours				
Social/Recreational				
Meetings				

11. What is your overall evaluation of the program?

Excellent _____

Very good _____

Good _____

Fair _____

Poor _____

12. If you can, please identify one or two significant steps to improve the program.

____

____

____

____

13. For second-year Fellows only. Please use this space for suggestions no improving the second year.

____

____

____

____

D. Stipend

1. To assist us in planning for appropriate stipends in the future would you indicate your salary at your home institution.

   $ ____________per Academic year_____ or Full year _____. (check one)

2. Is the amount of the stipend the primary motivator to your participation in the ASEE Summer Faculty Fellowship Program?

   Yes _____ No _____ In part _____

3. What, in your opinion, is an adequate stipend for the ten-week program during the summer of 1991?

   $ ____________________________________

E. American Society for Engineering Education (ASEE) Membership Information

1. Are you currently a member of the American Society for Engineering Education?
   Yes _____ No _____

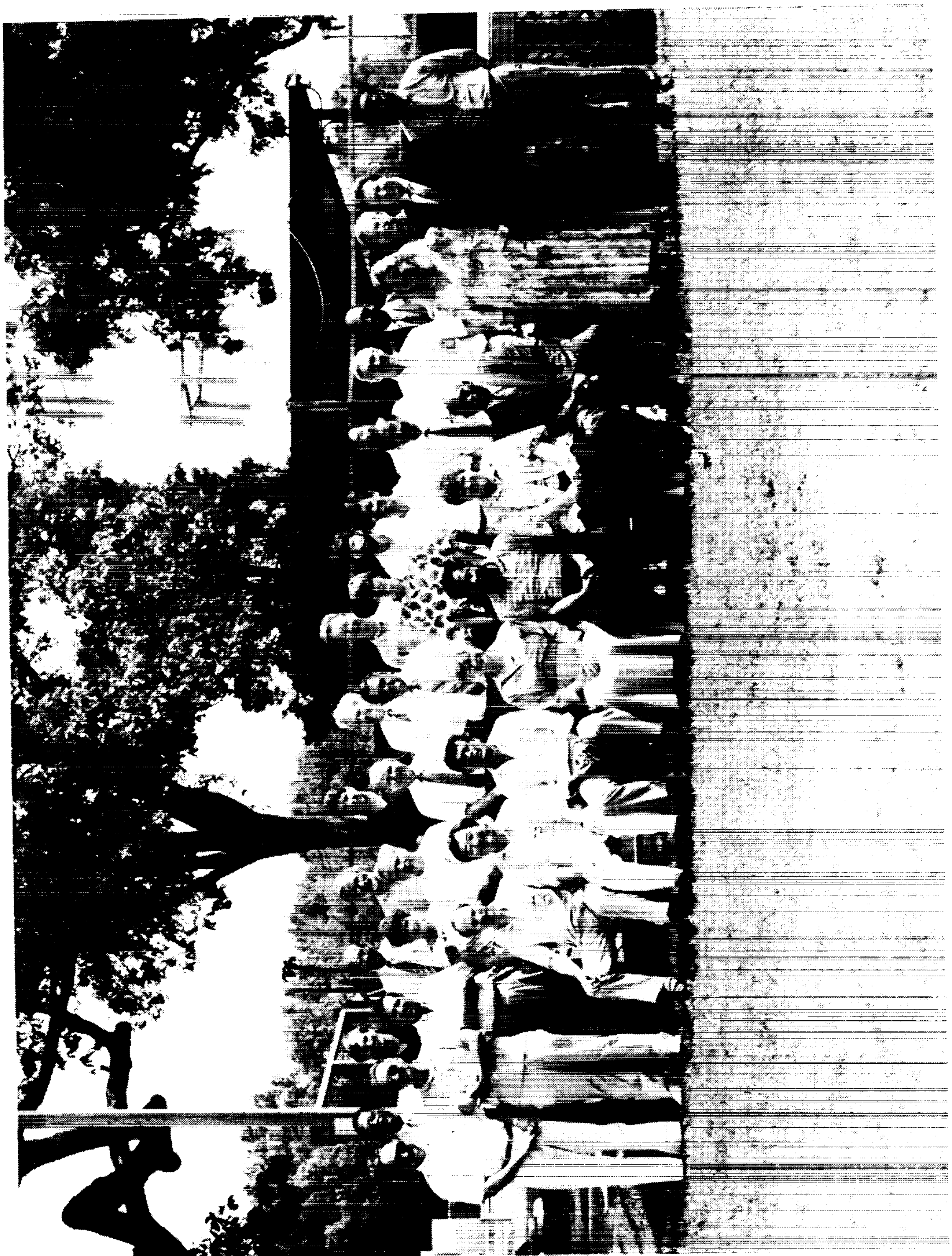
2. Would you like to receive information pertaining to membership in the ASEE?
   Yes _____ No _____

PLEASE USE THIS PAGE FOR YOUR COMMENTS TO ANY QUESTION

APPENDIX VI

GROUP PICTURE OF RESEARCH FELLOWS

ORIGINAL PAGE
BLACK AND WHITE PHOTOGRAPH



NASA/ASEE SFFP
Summer 1990
List of Attendees

Seated Row: Left to Right

1. Dr. Joseph Keiser
2. Dr. Jeng-Nan Juang
3. Dr. Christos Christodoulou
4. Dr. Moira LeMay
5. Dr. Larry Petway
6. Dr. Lila Roberts
7. Prof. John Spencer

Middle Row: Left to Right

1. Dr. Rishi Raj
2. Dr. Paul Wang
3. Dr. Suresh Chandra
4. Mrs. Maggie Manning
5. Dr. Joseph Hafele
6. Dr. Craig Sims
7. Dr. Marvin Klutz
8. Dr. Eleanor Prochaska
9. Dr. Rex Kincaid
10. Dr. Bor Zeng B. Jang
11. Dr. Richard Kiefer
12. Ms. Debbie Young
13. Dr. C. Ray Russell
14. Dr. Johnny Houston

Back Row: Left to Right

1. Dr. Samuel E. Massenberg
2. Dr. Stephen Hodge
3. Dr. Asit Ray
4. Dr. Paavo Sepri
5. Dr. Michael Doria
6. Dr. Louis Gratzer
7. Dr. Steven Hooper
8. Dr. L. Scott Miller
9. Dr. Andrew Meade, Jr.
10. Dr. John Hurley
11. Dr. Robert Orwoll

Not Pictured:

Dr. Peyman Givi
Dr. Byung L. Lee
Dr. Duc Nguyen
Dr. Mark Staknis
Dr. Fuh-Gwo Yuan
Dr. Gene Haertling
Dr. Robert McIntyre
Dr. Kip Nygren
Dr. Resit Unal

Report Documentation Page

National Aeronautics and Space Administration

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Langley Technical Monitor: Dr. Samuel E. Massenberg

16. Abstract Since 1964, the National Aeronautics and Space Administration (NASA) has supported a program of summer faculty fellowships for engineering and science educators. In a series of collaborations between NASA research and development centers and nearby universities, engineering faculty members spend 10 weeks working with professional peers on research. The Summer Faculty Program Committee of the American Society for Engineering Education supervises the programs. Objectives: (1) To further the professional knowledge of qualified engineering and science faculty members; (2) To stimulate and exchange ideas between participants and NASA; (3) To enrich and refresh the research and teaching activities of participants' institutions; (4) To contribute to the research objectives of the NASA center. Program Description: College or university faculty members will be appointed as Research Fellows to spend 10 weeks in cooperative research and study at the NASA Langley Research Center. The Fellow will devote approximately 90 percent of the time to a research problem and the remaining time to a study program. The study program will consist of lectures and seminars on topics of interest or that are directly relevant to the Fellow's research topics. The lectures and seminar leaders will be distinguished scientists and engineers from NASA, education or industry.

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