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TECHNICAL REPORTS



LANGLEY

AEROSPACE

RESEARCH

SUMMER

SCHOLARS

PART 1

JUNE 5, 1995 - AUGUST 11, 1995
NASA LANGLEY RESEARCH CENTER OFFICE OF EDUCATION
HAMPTON UNIVERSITY

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FOREWORD

The Langley Aerospace Research Summer Scholars (LARSS) Program was established by Dr. Samuel E. Massenberg in 1986. The program has increased from 20 participants in 1986 to 114 participants in 1995. The program is LaRC-unique and is administered by Hampton University.

The program was established for the benefit of undergraduate juniors and seniors and first-year graduate students who are pursuing degrees in aeronautical engineering, mechanical engineering, electrical engineering, material science, computer science, atmospheric science, astrophysics, physics, and chemistry.

Two primary elements of the LARSS Program are: (1) a research project to be completed by each participant under the supervision of a researcher who will assume the role of a mentor for the summer, and (2) technical lectures by prominent engineers and scientists. Additional elements of this program include tours of LaRC wind tunnels, computational facilities, and laboratories. Library and computer facilities will be available for use by the participants.

The LARSS Program is intended to encourage high-caliber college students to both pursue and earn graduate degrees and to enhance their interest in aerospace research by exposing them to the professional research resources, people, and facilities of Langley Research Center.

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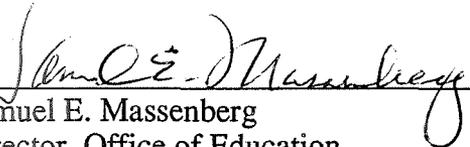
1995 Langley Aerospace Research Summer Scholars Program (LARSS) Technical Reports

The 1995 LARSS program was sponsored by NASA Langley Research Center and Hampton University.

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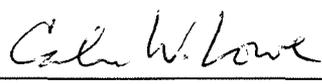
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**NASA Langley Research Center
Office of Education**

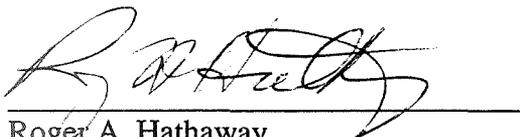


Samuel E. Massenberg
Director, Office of Education

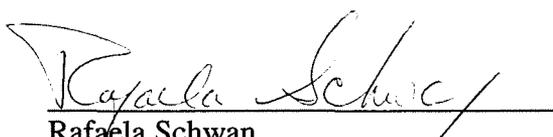
Hampton University



Calvin W. Lowe
Vice President for Research
and Dean of the Graduate College



Roger A. Hathaway
University Affairs Officer



Rafaela Schwan
LARSS Program Coordinator

INTRODUCTION

The LARSS Technical Reports are a summary of the research project developed by the students during the summary of 1995.

The following is a list of the areas where students were placed for the 10-week period.

OFFICE OF EDUCATION

The Office of Education serves as the primary focal point for most educational opportunities through research. The Office of Education also serves as the focal point for internal customers who require information on institutions of higher education and provides selected funding support for research scholarships, fellowships, and post-doctoral research associateships.

OFFICE OF HUMAN RESOURCES

The goal of the Office of Human Resources (OHR) is to maximize the performance potential of the employees of NASA Langley Research Center through planning, policy formulation, and administration of human resource programs and procedures. The areas of emphasis include: position classification, recruitment, career development, labor relations, performance management and awards, training and education, employee benefits, organizational development, occupational health, and retirement. Research opportunities exist in the following categories of effort: personnel information systems, human performance technologies, learning support and transfer techniques, organization design, and change dynamics.

OFFICE OF EXTERNAL AFFAIRS

The Office of External Affairs manages a broad range of programs designed to communicate with and monitor the external environment. These programs involve public affairs, congressional affairs, public services, freedom of information (FOI), technical conference management, research, writing and editing, exhibit design and fabrication, speech writing, and a variety of other staff support for the Center. The office includes the Office of Public Affairs (OPA) and the Office of Public Services (OPS). OPA serves as a communications facilitator between center management and news media and the public about research programs and other subjects of interest. OPA issues news releases, etc., and publishes the center newspaper. OPS communicates the Langley and NASA's story through special events, exhibits, Center tours, community services, trade shows, speaking engagements, special publications, and public mail.

OFFICE OF COMPTROLLER

The Office of Comptroller is responsible for the centralized planning and analysis of all Center resources and financial management activities. The office is the focal point for the development and execution of financial and resource decisions. The Comptroller has two divisions: Financial Management Division and Programs and Resources Division.

AERONAUTICS PROGRAM GROUP

The Aeronautics Program Group (APG) is responsible for planning and guiding aeronautics programs for the Center. The Group leads the Center's aeronautics strategic planning and is the single point of contact for committing the Center to aeronautics programs. APG interacts with customers and performs aircraft vehicle studies to obtain an integrated set of research objectives. APG also provides program management for focused programs when implementation is distributed across several Langley organizations. APG vehicle class leaders work with external customers and other Langley groups to define specific programs to accomplish the objectives. The group is responsible for resource allocation and reporting aeronautics program results. The APG contains the Aeronautics Systems Analysis Division, Systems Analysis Branch.

INTERNAL OPERATIONS GROUP

The Internal Operations Group (IOG) supports the Center's research programs and project activities, with special emphasis on formulating and implementing major policies and programs relating to resources management, acquisition and contracting activities, data systems management and technical support services. This support also includes the Center's Construction of Facilities program; all functions necessary to design, install, operate and maintain large mechanical and electrical systems, complex research facilities and equipment and test apparatus; all functions necessary to provide and maintain institutional buildings, structures, and grounds; all functions necessary to provide design, analysis, fabrication and operation of complex aerospace systems and research test articles; Center-wide electronic discipline for projects and programs; the operation and maintenance of the Center's central computer complex and simulation facilities; and all functions necessary to operate and maintain the Center's daily flight operations inclusive of aircraft and avionics maintenance, research pilot staff management, and direction of all related design, fabrication, testing, and certification of experimental flight control and display systems. The following items represent active research disciplines: Electronic and Information Systems, Advanced Sensor Systems, Measurement Science and Instrument Technology, Advanced Computational Capability, Engineering, Mechanical Systems Engineering, Facility Systems Engineering, Materials Characterization Technology, and Engineering Laboratory Unit.

RESEARCH AND TECHNOLOGY GROUP

The Research and Technology Group consists of approximately 800 scientists, engineers, technicians and support personnel who are responsible for performing basic research and technology development in a broad range of aeronautical and selected space disciplines. Through an interdisciplinary approach, the group produces proven and usable technology for aerospace and non-aerospace customers. The Research and Technology Group program includes research activities in: Aerodynamics, Flight Dynamics and Controls, Fluid Mechanics and Acoustics, Gas Dynamics, Competitiveness, Information and Electromagnetic Technology, Materials, and Structures.

SPACE AND ATMOSPHERIC SCIENCES PROGRAM GROUP

The Group conducts the Atmospheric Sciences Research Program; leads Space Project Management; provides management of the space-focused technology programs of Space Transportation, Spacecraft, and Remote Sensing; and conducts system analysis for technology planning, assessment, and prioritization. The program includes the following specific research activities: Stratospheric Aerosol and Gas Experiment (SAGE), Climate Research Program, Tropospheric Chemistry Research Program, Upper Atmosphere Research Program, Earth Radiation Budget Experiment (ERBE), Halogen Occultation Experiment (HALOE), Global Biogeochemical Cycling, Transportation Systems, Spacecraft and Sensor Systems Definition and Analysis Tools, Conceptual Designs for Small Spacecraft and Instruments, and In-Space Technology Experiments.

TECHNOLOGY APPLICATIONS GROUP

The Technology Applications Group (TAG) leads the Center's technology transfer and commercialization program. This includes the early identification of technologies of high commercial potential and promoting the expedient transfer of new technologies to the commercial sector focusing primarily on the nonaerospace community. This is accomplished by identifying potential technology applications and creating teams of nonaerospace customers and LaRC technologist to accomplish the transfer process. In addition, the TAG has the lead in determining and protecting the government's rights to patent inventions made by NASA and contractor employees and providing counsel with respect to NASA's rights in intellectual property matters. TAG also provides the overall leadership for planning and implementing the Center's Small Business Innovation Research Program (SBIR) and the Small Business Technology Transfer Program (STTR). The Agency conceives and matures innovative concepts and methodologies applicable to its focused research programs in aeronautics and space. Langley seeks synergistic partnerships with industries and universities in these mission programs. A dynamic, cooperative teaming with national laboratories, industry, and universities creates a win-win situation. Industry has access to state-of-the-science experts, facilities, and intellectual property; universities have access to enabling research topics and teams for student growth and faculty focus; and NASA benefits through the mission-related accomplishments. As students graduate, they have improved opportunity for jobs, and industry has in addition to a new product, a well-trained work force familiar with their products and initiatives. In practice, depending on the relationship of the work to our mission and technology thrust, industry funds a university faculty member and a

student to work on a technical problem related to one of their products, and LaRC signs a Space Act Agreement spelling out our respective responsibilities. The parties work together as a team, bringing their collective strength to bear on a specific problem. Colleges and universities complement NASA's basic research by introducing and formulating theoretical bases for new concepts and ideas for inclusion in NASA's mission and programs. In addition, academic institutions facilitate, promote, and support technology transfer and commercialization of advanced aeronautics, space, and related technologies to both technical and non-technical settings through creation or enhancement of courses and curricula to reflect knowledge transferred from NASA-conceived methodologies or technologies, direct student involvement in NASA-sponsored research projects and missions, and publication and presentation of research findings.

Listing of the 1995 Langley Aerospace Research Summer Scholars

<u>Name/University</u>	<u>Title</u>	<u>Group/Mentor</u>
Julia A. Barsi Rochester Institute of Technology	Clouds and the Earth's Radiant Energy System Visualization Single Satellite Footprint Plot Generator	Space and Atmospheric Sciences Program Group Jon C. Currey
Danielle L. Beck University of Utah	Oshkosh Logistics Management and Public Relations Responsibilities At NASA Langley	Office of External Affairs Margaret Hunt
Kory L. Bennett North Carolina A&T State University	Development of a 3-Phase CCD Timing Generator	Internal Operations Group Preston I. Carraway
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Chad J. Billings University of Utah	Geographic Information System Data Analysis	Internal Operations Group William B. Ball
Hollie N. Bodiford Hampton University	Polarization and Characterization of Piezoelectric Polymers	Research and Technology Group Joycelyn O. Simpson
Kimberly R. Bullock North Carolina A&T State University	Technology Transfer	Technology Applications Group Rosemary Baize
Jason G. Bush Old Dominion University	A Numerical Study of Hypersonic Fuel Injectors	Research and Technology Group Griff Anderson
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Howard T. Johnson Gallaudet University	17-4 PH & 15-5 PH	Internal Operations Group Larry Cooper

<u>Name/University</u>	<u>Title</u>	<u>Group/Mentor</u>
Kimberly D. Johnson Old Dominion University	The Effect of Different Materials on the Accuracy of the HYDRA Optical - Fiber - Coupled Coherent Range/Pressure Measurement System and The Development of the Health Care Database System at Old Dominion University	Research and Technology Group Sixto Vazquez
Rashunda K. Johnson University of Arkansas at Pine Bluff	Geographic Information System Data Analysis	Internal Operations Group William B. Ball
Tameka J. Johnson Virginia Union University	Payload Planning for the International Space Station	Space and Atmospheric Sciences Program Group David T. Shannon, Jr.
Jason S. Kiddy University of Maryland at College Park	Free-Flight Evaluation of Forebody Blowing for Yaw Control at High Angles of Attack	Research and Technology Group Kay Brandon
John M. Kruep Virginia Polytechnic Institute and State University	Conversion of the Aerodynamic Preliminary Analysis System (APAS) to an IBM PC-Compatible Format	Space and Atmospheric Sciences Program Group Walter C. Englund
Craig A. Kruschwitz College of William and Mary	Modeling of the Expected Lidar Return Signal for Wake Vortex Experiments	Space and Atmospheric Sciences Program Group Lamont R. Poole
Susanna Lai Rochester Institute of Technology	Langley Sign Language Home Page	Internal Operations Group Jerry Hoerger
Catherine G. Lebiedzki University of Virginia	A Variational Formulation for the Finite Element Analysis of Sound Wave Propagation in a Spherical Shell	Research and Technology Group Jay Robinson
Michael J. Leonard Roanoke College	Synthesis and Characterization of Poly (Arylene Ether Benzimidazole) Oligomers	Research and Technology Group Joseph G. Smith, Jr.

<u>Name/University</u>	<u>Title</u>	<u>Group/Mentor</u>
Anthony Linton Florida A&M University	Importance of the Office of Inspector General to the Efficient Operation of Langley Research Center	Office of Inspector General Lee Ball
Calvin T. Locklear Pembroke State University	Effects of Nose Strakes On Transport Aircraft	Research and Technology Group Gautam Shah
John M. Locklear Pembroke State University	Geographic Information System Data Analysis	Internal Operations Group William B. Ball
Michelle R. Lujan University of Texas at El Paso	Home Page: The Mode of Transport Through The Information Superhighway	Research and Technology Group Odilyn L. Santa Maria
Brian D. Marchesseault Embry-Riddle Aeronautical University	Design Considerations For The Next Generation of General Aviation Designs	Research and Technology Group H. Paul Stough
Brian C. Mays Hampton University	Creating a Database	Office of Human Resources Janet McKenzie
Timothy M. McBride Boston University	Materials For The General Aviation Industry: Effect of Environment on Mechanical Properties of Glass Fabric/Rubber Toughened Vinyl Ester Laminates	Research and Technology Group H. Benson Dexter
Sean M. McBurney Rochester Institute of Technology	Using The World-Wide Web to Facilitate Communications of Non-Destructive Evaluation	Internal Operations Group Lawrence Cooper
Kristi D. McRacken Christopher Newport University	Technology Applications Group Multimedia CD-ROM Project	Technology Applications Group Stuart Pendleton
Laurie A. Meade Tufts University	Development of a Small Area Sniffer	Research and Technology Group Jerome Kegelman

<u>Name/University</u>	<u>Title</u>	<u>Group/Mentor</u>
Eric O. Mejdrich St. Cloud State University	Terminal Area Productivity/Airport Surface Traffic Automation Flight Demo Data Analysis	Research and Technology Group Steve Young
Golnar G. Miamer Old Dominion University	Multimedia Information Kiosk	Internal Operations Group Lillian Ross
Tiffany N. Mitchell University of Virginia	Introducing Current Technologies	Technology Applications Group Barry Gibbens
Michael J. Monroe Virginia Polytechnic Institute and State University	Product Assurance For Spaceflight Hardware	Office of Safety , Environment and Mission Assurance John Greco
Scott C. Moore North Carolina State University	Finite Element Analysis of an Energy Absorbing Sub-floor Structure	Research and Technology Group Benson Dexter
Timothy E. Morgan Norfolk State University	Reusable Software Technology	Space and Atmospheric Sciences Program Group Calvin Mackey
Matthew D. Oser University of Illinois	Eliminating Flow Separation and Reducing Viscous Drag Through Boundary Layer Analysis and Manipulation	Research and Technology Group Richard L. Campbell
Meredith L. Payne Rochester Institute of Technology	Electronic Photography	Internal Operations Group Thomas E. Pinelli
Nina P. Paynter Swarthmore College	Technology Transfer: A Contact Sport	Technology Applications Group Marisol Romero
LeRuth Q. Pendergrass Hampton University	Fabrication of Fabry-Perot Interferometer Sensors and Characterization of their Performances for Aircraft Inspection	Research and Technology Group Robert S. Rogowski
Stephen A. Penn Hampton University	Geographic Information System Data Analysis	Internal Operations Group William B. Ball

<u>Name/University</u>	<u>Title</u>	<u>Group/Mentor</u>
Jennifer K. Phillips University of Illinois	Performance Comparison of a Matrix Solver on a Heterogeneous Network Using Two Implementations of MPI: MPICH and LAM	Research and Technology Group Jerold M. Housner
Kathleen A. Pierucci Illinois Institute of Technology	A Study of How Stitch Placement Affects the Open Hole Tension Strength of Stitched Textile Composite Materials	Research and Technology Group Keith Furrow
India Pinkney University of Virginia	A Summer in Public Affairs	Office of External Affairs Keith Henry
Tori D. Rhoulac Howard University	Geographic Information System Data Analysis	Internal Operations Group William B. Ball
Nature A. Richard Hampton University	1995 Summer Intern NASA Langley Research Center Office of Education	Office of Education Roger A. Hathaway
Myrna S. Rivera Christopher Newport University	TAC CD-ROM	Technology Applications Group Stuart Pendelton
Ivan Roman University of Puerto Rico	Correlations of Difference Surfaces Tests, Tire Behavior Math Model for the High Speed Civil Transport (HSCT) and Michelin Tire Properties Tests for Boeing 777	Research and Technology Group Robert H. Daugherty
James H. Rowbottom Norfolk State University	The Use of the Internet to Support General Aviation Research	Internal Operations Group Gretchen L. Gottlich
Antoinette M. Scott Norfolk State University	Aviation Research and the Internet	Internal Operations Group Gretchen L. Gottlich
Adam H. Shay University of Virginia	Geographic Information System Data Analysis	Internal Operations Group William B. Ball
Kantis A. Simmons Norfolk State University	Development of a Pressure Sensitive Paint System With Correction For Temperature Variation	Internal Operations Group Billy T. Upchurch

<u>Name/University</u>	<u>Title</u>	<u>Group/Mentor</u>
Nanette R. Smith College of William and Mary	Technology Transfer	Technology Applications Group Robert L. Yang
Kenneth R. Smith Hampton University	Langley Learning Laboratory	Office of Education Marchelle Canright
Seth S. Sobel James Madison University	Characteristics of Three-node Smoothing Element Under Penalty Constraints	Research and Technology Group Alexander Tessler
Mary M. Spracher Virginia Polytechnic Institute and State University	Office of Public Affairs	Office of External Affairs Keith Henry
David Stang Old Dominion University	Langley Research Center - Soluble Imide (LaRC-SI)	Internal Operations Group Carl Voglewede
Ronald E. Stephenson Virginia Polytechnic Institute and State University	Congressional Affairs	Office of External Affairs Lee Rich
Christopher S. Steward Norfolk State University	The Calibrations of Space Shuttle Main Engines High Pressure Transducers	Internal Operations Group Allan J. Zuckerwar
Melissa C. Stewart Rensselaer Polytechnic Institute	The Dependence Of The Change In The Coefficient Of Thermal Expansion Of Graphite Fiber Reinforced Polyimide IM7-K3B on Microcracking Due To Thermal Cycling	Research and Technology Group Craig W. Ohlhorst
Edwood G. Stowe Washington University	Analog Processing Assembly For The Wake Vortex Lidar Experiment	Internal Operations Group Phil Brockman
Corey V. Swenson St. Cloud State University	Parallel Processing with Digital Signal Processing Hardware and Software	Research and Technology Group Robert L. Jones
Antone L. Taylor Hampton University	Geographic Information System Data Analysis	Internal Operations Group William B. Ball
Erene Tcheng University of Virginia	Technology Transfer - Marketing Tomorrow's Technology	Technology Applications Group Barry V. Gibbens

<u>Name/University</u>	<u>Title</u>	<u>Group/Mentor</u>
Tamera L. Thomas Hampton University	Open Loop Simulation	Internal Operations Group John White
Karina M. Thorpe University of Utah	Geographic Information System Data Analysis	Internal Operations Group William B. Ball
Wilmer B. M. Ullmann University of Kansas	Entrepreneurship Within General Aviation	Research and Technology Group Daniel J. DiCarlo
Bryan C. Valek Georgia Institute of Technology	Determination of Stress- Corrosion Cracking in Aluminum-Lithium Alloy ML377	Research and Technology Group Marcia S. Domack
Luis H. Valencia University of Puerto Rico	A MATLAB/Simulink Based GUI For The CERES Simulator	Space and Atmospheric Sciences Program Group Calvin Mackey and John Chapman
Victor M. Valentin University of Puerto Rico	Oxidation Behavior of Carbon Fiber Reinforced Silicon Carbide Composites	Research and Technology Group Wallace Vaughn
Jessica Venable Princeton University	Validation of Global Climatologies of Trace Gases Using NASA Global Tropospheric Experiment (GTE) Data	Space and Atmospheric Sciences Program Group Joel S. Levine
Eugene L. Ward Norfolk State University	Homepage For The Global Tropospheric Experiment	Space and Atmospheric Sciences Program Group Jim Hoell
Douglas P. West Eastern New Mexico University	System Construction For The Measurement of Bragg Grating Characteristics In Optical Fibers	Research and Technology Group Robert S. Rogowski
Mark E. Whitlock University of Illinois	Analysis Of a High-Lift Multi- Element Airfoil Using a Navier- Stokes Code	Research and Technology Group Kenneth M. Jones
Jeffrey M. Wilson University of Kansas	Wake Vortex Encounter Research	Research and Technology Group Robert A. Stuever

<u>Name/University</u>	<u>Title</u>	<u>Group/Mentor</u>
Terri L. Wilson Virginia Polytechnic Institute and State University	Langley Aerospace Research Summer Scholars (LARSS) Program Coordination	Office of Education Roger A. Hathaway
Robert G. Wright University of Missouri	Converting The Active Digital Controller For Use in Two Tests	Research and Technology Group Sheri Hoadley
Sara J. Yancey College of William and Mary	My Networking and Interpersonal Skills Developed At NASA Langley Research Center	Office of Education Marchelle D. Canright
Michael K. Zyskowski University of Kansas	Very Light Aircraft: Revitalization Through Certification	Research and Technology Group Natale Strain

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CERES Visualization SSF Plot Generator

Julia A. Barsi
Rochester Institute of Technology
Langley Aerospace Research Summer Scholar

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Mentor

Data Management Office
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Abstract

The first Clouds and the Earth's Radiant Energy System (CERES) instrument will be launched in 1997 to collect data on the Earth's radiation budget. The data retrieved from the satellite will be processed through twelve subsystems. The SSF (Single Satellite Footprint) Plot Generator software was written to assist scientists in the early stages of CERES data analysis, producing two-dimensional plots of the footprint radiation and cloud data generated by one of the subsystems. Until the satellite is launched, however, software developers need verification tools to check their code. This plot generator will aid programmers by geolocating algorithm results on a global map.

Introduction

Interest in the radiation levels of the Earth's atmosphere goes back to the 1960's when the first instruments aboard satellites measured Earth's radiation budget. Recently, the greenhouse effect and global warming has brought much attention to the way the atmosphere absorbs and reflects visible and invisible wavelengths. In the 1980's, the Earth Radiation Budget Experiment (ERBE) was launched to better understand the radiation budget. In 1997, the first Clouds and the Earth's Radiant Energy System (CERES) will be launched to continue the ERBE data collecting, but also expand to increase our knowledge of our atmosphere.

The purpose of this paper is to give the background behind the development of the SSF Plot Generator, software created for CERES software developers and scientists.

The Earth Radiation Budget Experiment

The Earth Radiation Budget Experiment (ERBE) began observing the Earth in 1984. The three satellites in the experiment each had aboard them two instruments, a scanner and a nonscanner, to measure the monthly average radiation budget for regional, zonal and global scales; equator-to-pole transport gradient; and the monthly average diurnal variation in radiation budget on a regional scale.

The scanner instrument has three detectors to measure different wavelengths: shortwave (0.2 to 5 μ m), longwave (5 to 200 μ m) and total waveband (0.2 to 200 μ m). The scanner has a sweeping motion, swinging side to side, recording data for the field of view at which the detectors are pointed. The nonscanner produces one channel of solar data, and four channels of earth-viewing data. It has no moving parts, collecting data only in the field of view underneath it and continues to send back data today.

The ERBE data has been archived on magnetic tapes. The Processed Archival Tape S-8 consists of four files: the header, the test record, the scale factor and offset record, and the data record. The header serves as an identifier, storing information regarding date, time, satellite, and orbit number. The test record is included as a check for those using the data. S-8 data is stored in a packed format of integer values which are unpacked using the scale factors and offsets. The unpacked test record values are printed in ERBE S-8 User's Guides to verify the unpacking algorithm. For every S-8 variable, there is a unique scaling factor and offset. The data record contains the actual integer values recorded by the instrument on the satellite.

The Clouds and the Earth's Radiant Energy System

Planned for launch aboard the Tropical Rainfall Measuring Mission (TRMM) in August 1997 and the EOS-AM and EOS-PM in the following years, CERES plans to continue ERBE's mission of tracking the earth radiation budget. CERES will also provide estimates for surface radiation, radiative fluxes within the atmosphere, and cloud properties. As of now, the role of clouds within the atmosphere is unknown. CERES will be able to identify cloud amount, height, optical depth and cloud particle size and phase. Learning more about clouds will help scientists in determining how clouds affect earth's radiation budget.

CERES is a scanner similar to the instrument on ERBE. Modifications were made to improve the data, including smaller field of views, better electronics to reduce the offsets, and the replacement of the longwave channel with a window channel (8 to 12 μ m). CERES also has the capability of operating in a rotating azimuth plane scan (RAPS); instead of collecting all parallel scans, the scanner rotates, collecting data in an asterisk pattern, viewing a more diverse region of the hemisphere.

Since the instrument has not been launched, no CERES data products exist yet. Eventually, the data will be stored in a number of different data products, each having its own use and method of derivation. Subsystem 4, the subsystem of concern in this paper, produces a Single Satellite Footprint (SSF) data product. One SSF footprint contains an array of surface fluxes, top of the atmosphere fluxes and clouds property data. An SSF file stores one hour's worth of footprints, approximately 245,000 footprints, depending on the operational mode and the number of earth viewing footprints with associated imager data.

The ERBE Plot Generator

In 1992, Joseph Henderson, a LARSS student, created software to plot the ERBE S-8 data on a cylindrical world map. Used to visualize the data, it could plot various types of radiometric data, particular orbits, and data from various times of the day. The plots served as a verification tool for the scientists. Henderson's Fortran 77 code used NCAR Graphics, plotting software developed by the National Center for Atmospheric Research.

The original code, however, could only read ERBE data with separate header and data files, one called 'header', the other named 'erbe'. This program was modified so it would read any S-8 file without separating the header and data.

The SSF Data File Generator

In developing software to plot an SSF data file, an SSF data file was necessary to test the algorithm. Since both the ERBE and CERES missions have basic similarities, their data products include much of the same information, merely in different formats. S-8 data could be used to simulate the SSF. Sandy Nolan, a NASA contractor at IESC, had written a program to stuff the test record of a headerless S-8 into an SSF format. (Software is available to remove the header.) However, the test record contains no scientific data and would not be useful to those wanting to test code.

Modifications were made to Nolan's algorithm so a useful product could be created. The program converts a user specified headerless S-8 file into files of SSF format. One S-8 file can produce a maximum of 24 SSF files; the user specifies how many hours to create.

The Obstacles

Fortran 90 is the preferred language on the CERES project; many commonly used routines had already been written with F90, running on the machines *nimbus*, *asdsun*, and *bobill*. However, it still is a young language and the compiler had not been thoroughly tested. Linking a Fortran 90 main program with NCAR functions written in Fortran 77 was a task nobody had attempted before. Theoretically, there should not have been a problem; F90 should have been able to handle the F77 code and calls. However, the loader failed because it could not link to the appropriate libraries. Other flaws found were: the current compiler is not capable of making system calls and it does not find standard libraries during compilation. The system administrators are still working on a solution.

While Fortran 90 was being investigated, it was decided to work with C instead. Small test programs were written to test parameter passing from C programs to Fortran 77 subroutines. However, a sample program making two NCAR calls had linking problems also. After the linking problem was solved, there was still a problem with the versions of C and Fortran. It was discovered that the same versions of the compilers need to be running for the languages to be compatible. Once *bobill* was upgraded to the newer C compiler, the Fortran and C could communicate.

Reverting back to Fortran 77 because of the linking problems, it was discovered that the original S-8 Plot Generator would no longer compile. No changes had been made to this file; the problem was unexpected. After searching through the original files, another NCAR directory was found.

On *nimbus*, NCAR exists in three locations:

- /opt/optional/ncar3.2/bin - The scripts in this directory, supposedly the latest version of NCAR, do not call the appropriate libraries. Compiling Fortran 77 results in an undefined symbol warning.
- /opt/optional/ncar/bin - These scripts result in another list of undefined symbols, although not as long. This is assumed to be NCAR 2.0 because it doesn't support some of the newly documented calls.
- /opt/optional/nbin - The working version of NCAR. It is evidently version 3.2 because of the calls it supports. Fortran 77 files compile and run.

On *asdsun*, NCAR is located in two places:

- /opt/optional/ncar - The scripts call libraries in /usr/local/ncar/lib. The programs compile and execute but crash because it is an old version of NCAR.
- /opt/optional/nbin - The libraries it calls are in /usr/local/lib. Code will compile and execute, but again, the NCAR is an old version.

Using the /opt/optional/nbin/ncargf77 script on *nimbus* or any machine mounted to *nimbus*, both the S-8 Plot Generator and the modified SSF Plot Generator compiled and ran.

The C code looks as if it will run. The sample program making NCAR calls runs using /opt/optional/nbin/ncargcc but the main plotting code was never debugged enough to compile and link.

Within the working NCAR directory, no Fortran 90 script exists. It should be possible to modify the Fortran 77 script to include the necessary F90 libraries and F77 libraries.

The SSF Plot Generator

The current SSF Plot Generator prompts the user for:

- plot type - which SSF variable to plot
- cloud level - cloud data will have a level associated with it
- hours of data - the number of filenames the user will be inputting
- filenames of the SSF files - maximum of 24 since they come in hourly blocks and more would result in overlapping data
- day/night preference - when the time of day is of concern
- output destination - write to screen, printer, or file.

After opening the one hour SSF file, the SSF Plot Generator reads the user-specified data for one footprint, assigns a color to the pixel at that particular latitude and longitude, and repeats the procedure for each footprint in the hour. The procedure repeats for any other hours given, and places the final array on a cylindrical world map. The software was tested with SSFs created with two different methods and with two hours at a time. Because an S-8 was used to produce the SSF, the plots look identical using the S-8 plot generator and the SSF plot generator. Verification is possible by merely comparing the S-8 and SSF plots.

A comparison of Figures 1 and 2 show the SSF is created correctly. The SSF and S-8 plots are identical except for the amount of data shown. The S-8 Plot Generator plots orbits which are about ninety minutes long; Figure 1 is three orbits. SSFs are developed in hourly products; Figure 2 is two hours long.

The SSF Plot Generator has the capability of plotting up to 24 SSFs as requested by the user. The hours need not be consecutive but the data products must be entered sequentially for the begin and end times on the plot header to be correct. Figure 2 illustrates two hours of data; Figures 3 and 4 are each one hour long.

The plot generator distinguishes between night and day by the solar zenith angle, the location of the sun with respect to the satellite. The amount of sunlight affects the readings for shortwave and longwave radiation; shortwave only occurs during the day. Figure 5 has noticeable radiation data; Figure 6 has no radiation because of night wavelengths. By distinguishing between night and day, scientists have a simple check on the data.

The S-8 contains no cloud data, an important aspect of the CERES project. Chuck McKinley of SAIC created another SSF with only 140 footprints but containing cloud data. Three Imager Radiation options were added to the plot generator and tested with this SSF. Figure 7 is the whole plot from the short SSF; Figure 8 shows the details of Figure 7. The 140 footprints are located over the North Pacific.

The Applications

Currently, the software is being used as a verification tool. The other programmers on the project need to be sure their code is working. The ability to view the plotted data helps them analyze what their programs may or may not be doing.

When the first CERES data products are produced from CERES, scientists will quickly need to verify the data looks similar to the expected results. This plotting software will allow them to immediately view the product.

The modified original program which reads any S-8 file is saved on *bobill* in *jbarsi/ceres_ssf/plot_s8/read_any_s8*. The recompile command is 'recompile_mod' and the execute command is 's8erbepl'.

The software to remove the header of the S-8 is located on *bobill* in *jbarsi/ceres_ssf/make_ssf/removeheader*. To compile, execute 'write_s8.exe' and supply the program with the filename of an S-8 file. The headerless S-8 will be stored as the same filename, with the 'new_' prefix added to the name.

The code to convert S-8s to SSFs is available on *bobill* in *jbarsi/ceres_ssf/make_ssf*. To compile, execute the Makefile. The executable, 'fill_ssf.exe', will ask for the headerless S-8 filename and a filename for the initial SSF. The SSF filenames will each be appended with its hour number.

The SSF Plot Generator software, on *bobill*, is in the directory *jbarsi/ceres_ssf/plot_ssf*. There are two versions of the *ssf_user* file - 'ssf_user.f' and 'ssf_user2.f'. The file 'ssf_user.f' has the data ranges for true SSF data, as specified by the SSF definition, while 'ssf_user2.f' contains the data ranges for the S-8 file. The compile line, 'ssf_compile', will need to be edited when using a real SSF file. To execute, run 'ssf_plot'.

Acknowledgments

I would like to thank my mentor Chris Currey and Erika Geier for supporting all my questions and Jim Kibler and Marsha Sherland for attempting to solve the impossible.

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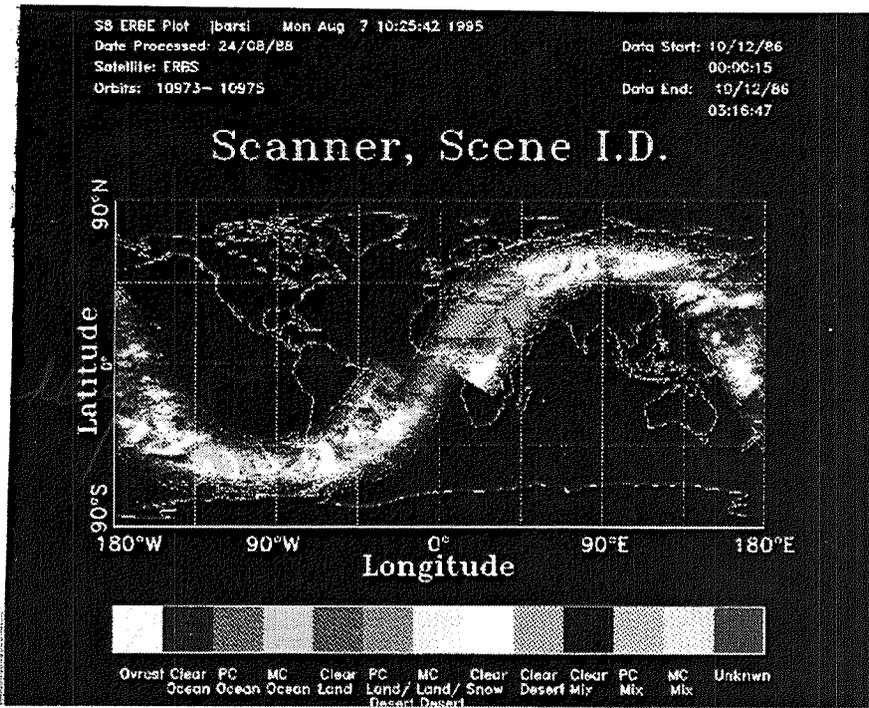


Figure 1. ERBE S-8 Plot of Scene Identification

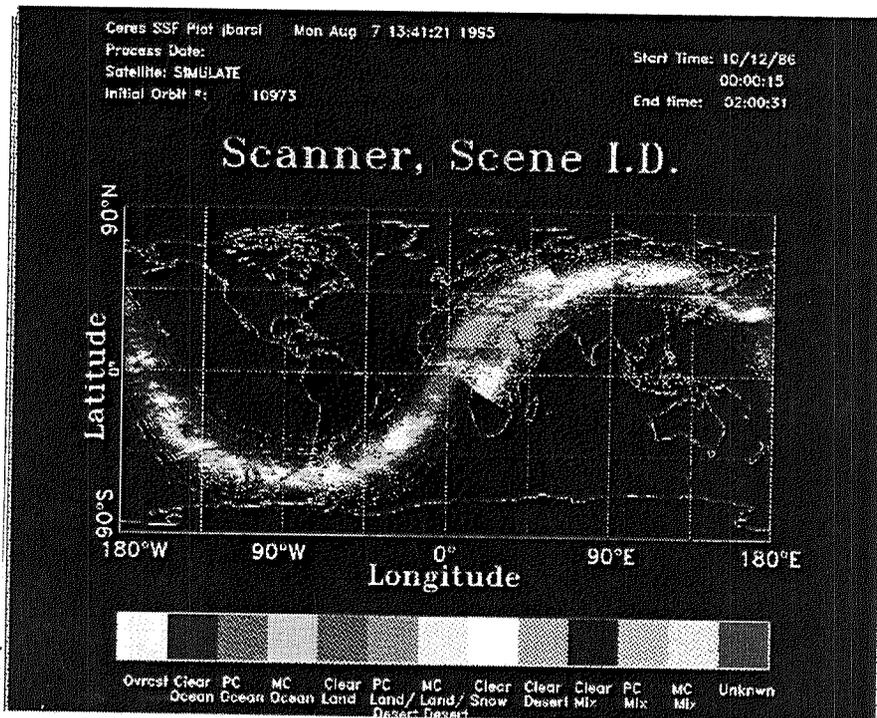


Figure 2. CERES SSF Plot of Scene Identification

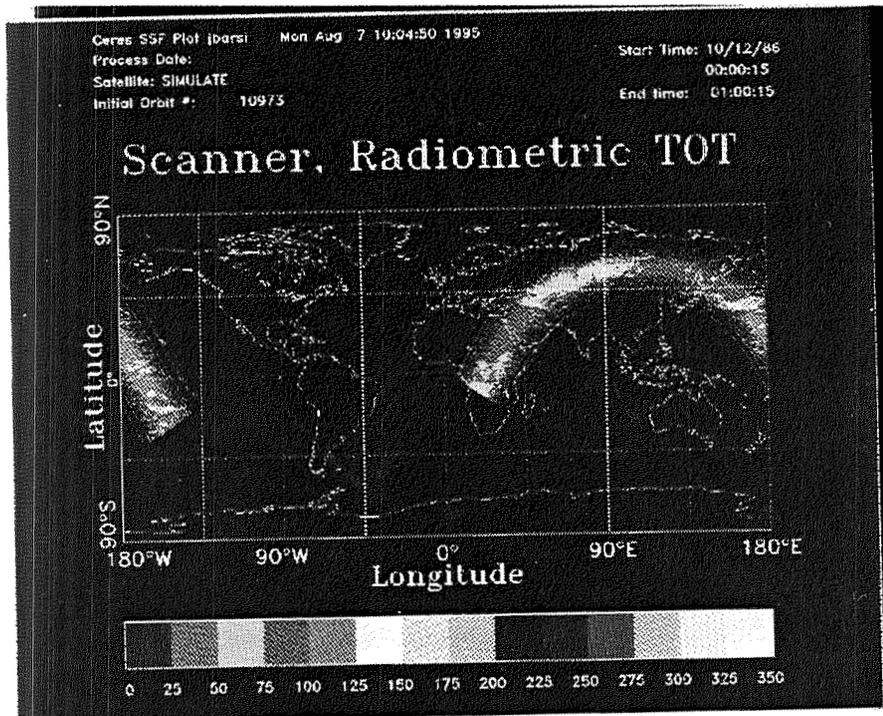


Figure 3. CERES SSF Plot of Radiometric Total Channel for the first hour of data.

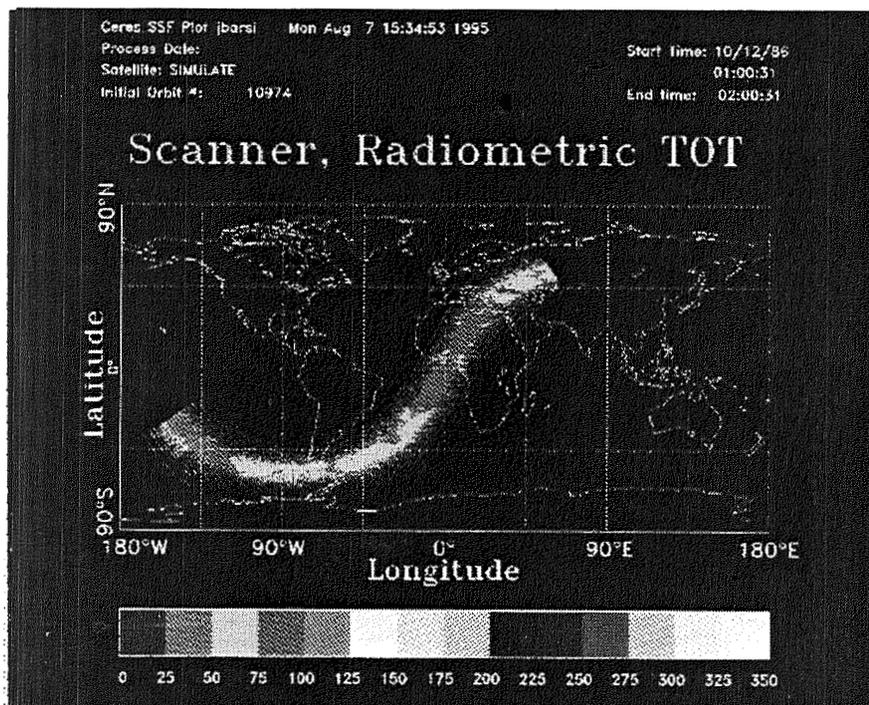


Figure 4. CERES SSF Plot of Radiometric Total Channel for the second hour of data.

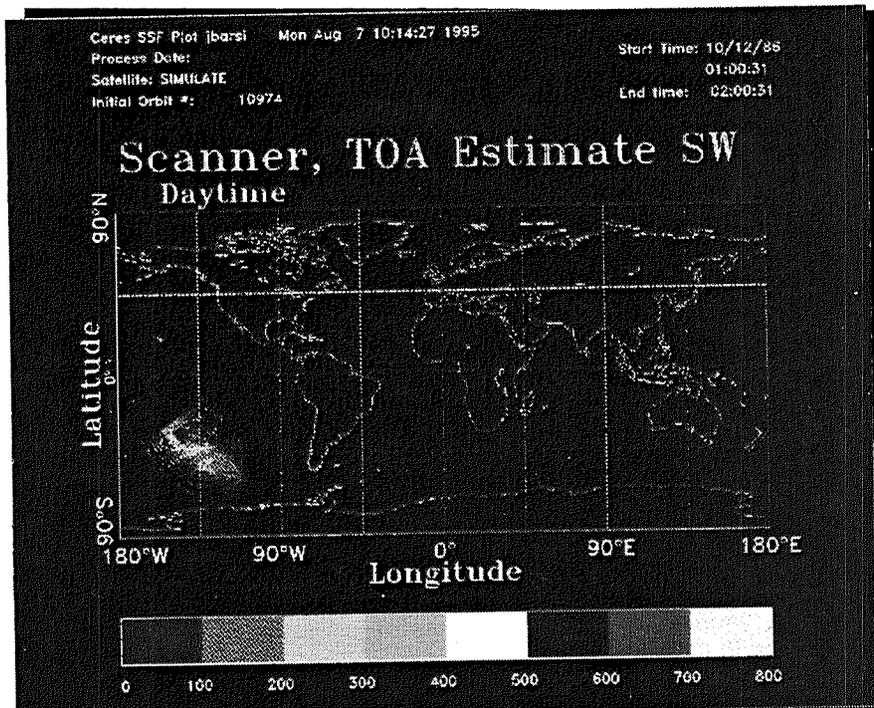


Figure 5. CERES SSF Plot of Top of the Atmosphere Flux for daytime data.

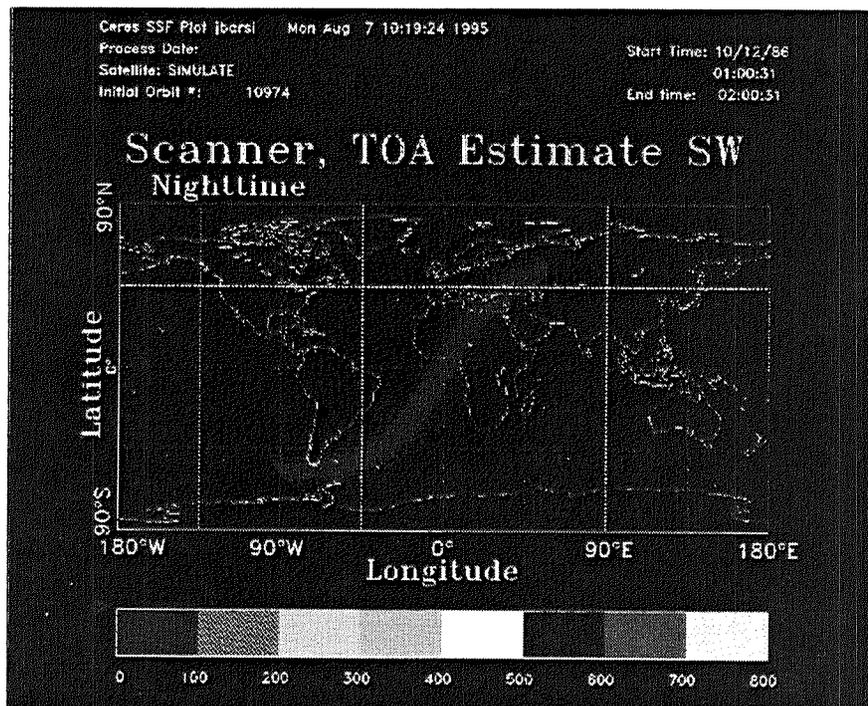


Figure 6. CERES SSF Plot of Top of Atmosphere Flux for nighttime data.

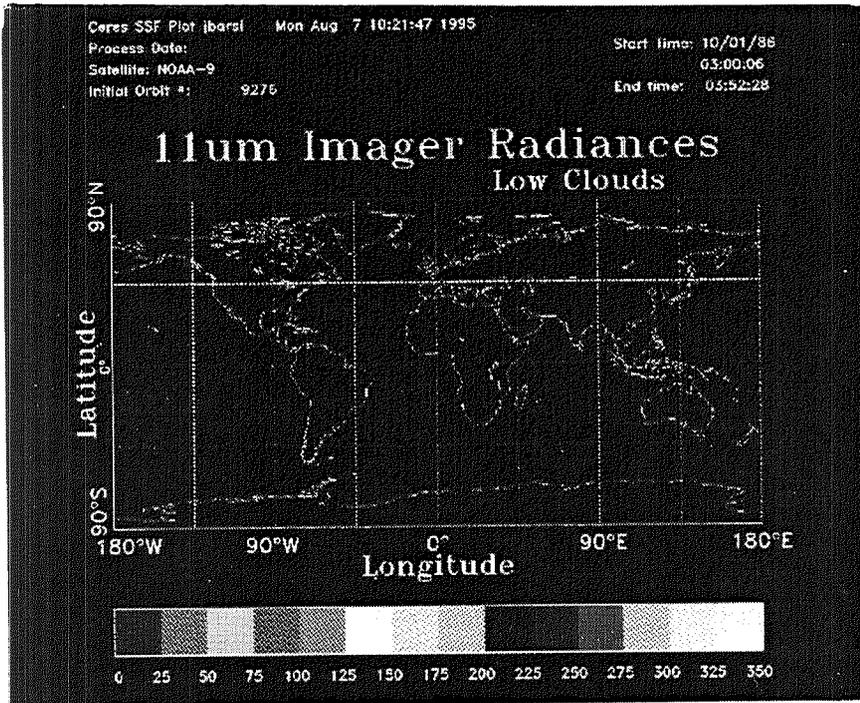


Figure 7. CERES SSF Plot of Imager Radiances at 11um.

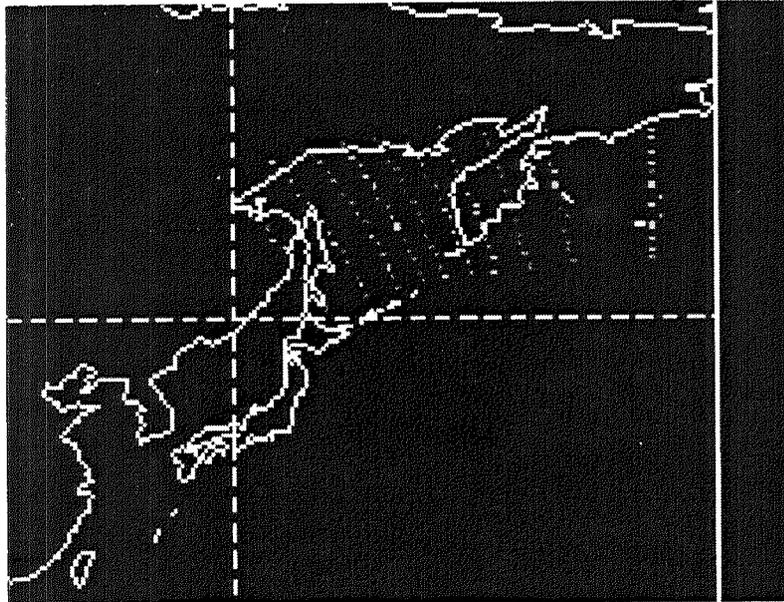


Figure 8. Detail of Figure 7. Data located over east Asia.

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Oshkosh Logistics Management and Public Relations Responsibilities
At NASA Langley

Danielle Beck

Margaret Hunt, Mentor

NASA Langley Research Center
External Affairs, Office of Public Service

ABSTRACT

The central focus of my study for the summer of 1995 was to provide logistical support to Margaret Hunt, the logistics manager of the OSHKOSH airshow. In this capacity responsibilities included making arrangements for participants from NASA centers and SBIR companies for their stay in Wisconsin, while visiting the airshow, and managing staff for exhibits and the aerospace theater. A secondary purpose was to serve in other public service capacities by writing news releases, fact sheets, announcements, and articles for the Researcher News.

BODY

The primary function of this internship was to provide logistical support to Margaret Hunt, logistics manager of the OSHKOSH airshow. Secondary functions included serving other public relations purposes such as preparing news releases, fact sheets, announcements, and articles for the Researcher News. Various assignments were given during this summer session and summaries of all activities will be provided below. For a comprehensive overview see attached summer calendars.

OSHKOSH AIRSHOW

The Experimental Aircraft Association Fly-In Convention and Sport Aviation Exhibition, also fondly known by many as the Oshkosh Airshow, provides a great opportunity for NASA to present its work in aeronautics. This is where a logistics manager becomes necessary. Approximately 120+ participants from NASA centers and SBIR companies needed arrangements to be made for their participation in the airshow. The efforts to coordinate these participants, and their numerous individual requests, was facilitated by the logistics manager. As the assistant logistics manager, it was my duty to keep a majority of these details in order. It was my responsibility to serve as a liaison to participants and NASA Langley. I oversaw hotel reservations, rental car arrangements, orders for NASA attire and other details regarding the time to be spent at Oshkosh. It was also my responsibility to manipulate exhibit floor staffing and aerospace theater staffing schedules for NASA exhibitors.

RESEARCHER NEWS

Submitting articles to the Researcher News was a secondary function of this internship position. Included in Volume 9, Issue 15, July 28, 1995, is an article about the astronaut training selection process and training programs; and an announcement for the Virginia Air and Space Center special promotion (see attached). In the upcoming edition, articles about the Poquoson Odyssey of the Mind Team, the NACA Airfoil Report, and the Space Flight Manifest are scheduled to appear. Articles still underway include pieces on the 7- X 10- foot conference room, the availability of the Newsroom, the Grand Opening of the Pearl I. Young Theater, the 10th anniversary of the Childcare Development Center, and a piece on the Transonic Dynamic Tunnel. Each article requires research, interviews, and patience as rewrites are always a necessity.

EXCURSIONS

Another facet of this position was the opportunity to take excursions outside of the office. One such opportunity was assisting the current astronaut candidate class when

they came to tour Langley. It was a great honor to meet with the astronauts and to speak with them one on one. On another occasion, I was given the opportunity to shadow Jim Schultz, the science and technology reporter for the Virginian-Pilot. He showed us around the newsroom and introduced us to numerous individuals who work within the field of journalism. Following a news crew around the base as they performed a live interview was yet another adventure. The highlight of my outside excursions was a trip to Washington, D.C., to visit NASA headquarters. The department of Public Affairs, and its many facets was a prime target for this visit. It was interesting to see the operations of this major center and speak with the people working within the system. I also had a chance to meet with personnel from the Education Department, who gave advice for future career and educational plans.

WRITING FOR PUBLIC RELATIONS

As need arose, I also completed various pieces of public relations related writing. These included but were not limited to, a fact sheet on the MEEP/Mir Shuttle Payload, monthly story opportunities releases (see attached), announcements for the Virginia Air and Space Center and the Pearl I. Young Theater opening (see attached). All gave me practical experience in preparing and writing these necessary types of writing.

CONCLUSION

Time spent at Langley was very beneficial as it has aided in the creation of numerous skills needed for the professional world. The opportunity to interface with many individuals and heed the advice they provided was priceless. My work with the Oshkosh logistics was challenging, yet very enjoyable as I love to manipulate details. The opportunity to practice and polish my writing skills will be a benefit for a lifetime.

Assignments/ Calendar for Danielle Beck

WEEK ONE/ June 19- 23

- 19- Lecture 10:00
OSHKOSH Logistics

WEEK TWO/ June 26-30

- 26- Lecture 10:00
- 29- AP Style Workshop
9:00-11:00
- Article: NACA Airfoil Report*
- Announcement VASC promotion*
- OSHKOSH Logistics

WEEK THREE/ July 5-7 (Holiday)

- 5- *RN Layout Training*
- OSHKOSH Logistics

WEEK FOUR/ July 10-14

- 10- Lecture 10:00
- 11- Astronaut Tour
- 14- Career Seminar
- Article: Astronaut Candidate Tour*
- OSHKOSH Logistics

WEEK FIVE/ July 17-21

- 18- *RN Deadline Due: Astronaut Candidate Tour, NACA Airfoil*
- 19- OSHKOSH Meeting
- 20- Headquarters Tour
- OSHKOSH Logistics

WEEK SIX/ July 24-28

- 24- Lecture 10:00/ Group Photo
- 25- Story Opps Due
- 27- Banquet
- OSHKOSH Logistics
- Article: Odyssey of the Mind, LaRC This Week*
- Announcement: Pearl I. Young Theater Opening/ LARC This Week*

WEEK SEVEN/ July 31- Aug. 4 OSHKOSH AIR SHOW

- 31- Lecture 9:00
- 31- Tour of Virginia Pilot
- 31- Send Story Opps
- 1- *RN Deadline Due: Odyssey of the Mind, Space Flight Manifest*
- 4- Experiment/ Career Seminar
- Article: Space Flight Manifest*

WEEK EIGHT/ Aug. 7-11

- 8- Report to Office of Education due
- 11- LARSS Check out
- Fact Sheet/ Shuttle Payload

WEEK NINE/ Aug. 14-18

- 15- *RN Deadline Due: Transonic Dynamic Tunnel, 7 -x 10- foot completed, Childcare*
- 16- Story Opps Due

WEEK TEN Aug. 21-25

- 22- Pearl I. Young Theater Opening
- 25- *RN Deadline Due: Pearl I. Young Theater*
- 25- Last Day
- 26- Fly to Phoenix 9:00 AM
- 27- Fly home to Utah 6:47 am
- 28- Send Story Opps

AUGUST

- 1 **RN Deadline** Odyssey of the Mind, Space Flight Manifest
 - Work on Report
 - Make contact with Shuttle Payload
- 2 Make contact with Childcare/ Tour Wind Tunnel with Child Care
- 3 Work on Report/ Visit Exhibits
- 4 Experiment 10-11/ Career Seminar
 - Contact Keith re: Story Opps

- 7 Send Story Opps Reminder
 - Contact Keith re: Sept Story Opps
 - SS Fact Sheet
- 8 LARSS Report Due
 - Write Child Care
- 9 Write 7X10 Conference Room
- 10 Work on Story Opps
 - Aricraft Grant News Release
- 11 Send Story Opps Reminder
 - Write Transonic Dynamic Tunnel

- 14 Finish Articles
 - Contact Keith re: Sept Story Opps
- 15 **RN Deadline** Transonic Dynamic Tunnel, 7x10 Conference Room, Childcare
- 16 September Story Opps Due
- 17 SS Fact Sheet
- 18 Write Newsroom Completed

- 21
- 22 Pearl I. Young Theater Grand Opening/ Write Article
- 23
- 24 Finish Payload Fact Sheet
- 25 **RN Deadline** Pearl I. Young Theater Opening, Newsroom Completed

NASA News

National Aeronautics and
Space Administration

Langley Research Center
Hampton, Virginia 23681-0001

For Release: Immediately

Release No. 95-071

NASA Langley Story Opportunities-August

GENERAL AVIATION IS GIVEN NEW LIFE. A network of partnerships between government, industries, universities and nonprofit organizations is breathing new life into general aviation. The official signing ceremony of the AGATE (Advanced General Aviation Transport Experiments) Consortium took place on July 29 in Oshkosh, Wis., home of the Experimental Aircraft Association (EAA) annual Fly-in Convention and Sport Aviation Exhibition. AGATE is a multifaceted organization formed by NASA, FAA and the general aviation industry aimed at increasing revenue and creating jobs. **PUBLIC AFFAIRS CONTACT:** Keith Henry (804) 864-6124

10,000 PAGES ALL ON ONE LITTLE DISC. "Legacy," a joint project between the NASA General Aviation Program Office and the NASA Langley Technical Library, is a CD-ROM program for anyone with an interest in the NACA's and NASA's contribution to aviation. It is comprised of the agency's most requested historical and current technical reports on general aviation. Hard copies would cost as much as \$3,000, yet the CD-ROM is available for \$75 plus \$6 for shipping and handling. The disc is available through the National Technical Information Service (NTIS). **NTIS CONTACT:** (703) 487-4650
NASA LANGLEY TECHNICAL LIBRARY CONTACT: Susan Adkins (804) 864-2390

*****NASA/FAA CHALLENGE STUDENTS TO INNOVATE IN 1996.** NASA and the FAA are sponsoring a general aviation design competition for aeronautical and engineering students. The competition challenges student teams to develop small aircraft transportation system innovations in various technical areas. The purpose of the competition is to encourage involvement of all members of the aviation community. Design packages are due May 6, 1996, and the winners will be presented in July 1996. Copies of competition guidelines can be obtained from the Virginia Space Grant Consortium. **VIRGINIA SPACE GRANT CONSORTIUM:** (804) 865-0726
PUBLIC AFFAIRS CONTACT: Keith Henry (804) 864-6124

*****DESIGN COMPETITION WINNERS ANNOUNCED.** A student team from three Kansas universities -- the University of Kansas, Kansas State and Wichita State -- introduced an operator-friendly aircraft design earning them first place in the first annual NASA/FAA National General Aviation Design Competition. Embry-Riddle Aeronautical University, Daytona, Fla., took second; Mississippi State University took third; and a design group representing the University of Virginia, the Pratt Institute at Brooklyn and Mallen Research Corp. of Charlottesville took an honorable mention. **PUBLIC AFFAIRS CONTACT:** Keith Henry (804) 864-6124

AUGUST STORY OPPORTUNITIES/2

REMINDER: 'SEAFOOD FARMING' TALK AUG. 1. Michael J. Oesterling, an aquaculture specialist, will speak Aug. 1 at NASA Langley on "Virginia Marine Aquaculture: Research and Product Development." He will trace the development of Virginia's marine aquaculture industry and methods of production. Media are invited to the 2 p.m. talk and to a media briefing at 1:15 p.m. at the H.J.E. Reid Conference Center. Will be repeated at Virginia Air & Space Center, Hampton, at 7:30 p.m.
PUBLIC AFFAIRS CONTACT: Catherine E. Watson (804) 864-6122/3

AERONAUTICS IN THE 21ST CENTURY. James A. Blackwell, the president of the Aeronautics Sector of Lockheed Martin, will share his views of the future of aeronautics with NASA Langley employees at 2 p.m., August 15 in the H.J.E. Reid Conference Center. A media briefing will be held in the Wythe Room at 1:15. Blackwell will discuss the effects of international competition on the aerospace industry and the importance of a strong partnership between government and industry to maintain U.S. technological leadership. Interviews available.
PUBLIC AFFAIRS CONTACT: Catherine E. Watson (804) 864-6122

MICROGRAVITY EFFECTS ON SPACE STRUCTURES. The Joint Dynamics Experiment (JDX), a cooperative effort between NASA Langley and Utah State University, will be flown aboard Endeavour (STS-69) in early August. The experiment is designed to study how well joints on space structures dissipate vibrations. The data is important for building the International Space Station. Interviews, photos available.
PUBLIC AFFAIRS CONTACT: Catherine E. Watson (804) 864-6122

STUDYING THE EFFECTS OF BIOMASS BURNING. Scientists from NASA Langley will spend six weeks in central Brazil studying the atmospheric effects of biomass burning. The field experiment, which begins Aug. 16, will involve coordinated aircraft, surface and satellite measurements of smoke characteristics and the interaction of the smoke with clouds. More than 80 researchers from four NASA centers, two U.S. agencies, five U.S. universities, 12 Brazilian agencies and six Brazilian universities will participate. The experiment, called SCAR-B (Smoke, Clouds, and Radiation - Brazil), is managed by NASA Langley. Interviews, photos available.
PUBLIC AFFAIRS CONTACT: Catherine E. Watson (804) 864-6122

RESOURCE PHOTOGRAPHS:

REUSABLE LAUNCH VEHICLES. Color 8 x10 photos are available of two reusable launch vehicle (RLV) models being tested in the 31-Inch Mach 10 Hypersonic Wind Tunnel at NASA Langley. The RLV program calls for development of one or more launch vehicles that could deliver payloads and people to space, fly back to Earth, and be used again. Marshall Space Flight Center in Huntsville, Ala., is host center for the industry-led RLV effort.
PUBLIC AFFAIRS CONTACT: Michael Finneran (804) 864-8150.

LOOKING AHEAD:

NASA LANGLEY GOES TO THE FAIR. Look for NASA Langley's exhibit at the Virginia State Fair, Richmond, from Sept. 21 to Oct. 1.
PUBLIC AFFAIRS CONTACT: Keith Henry (804) 864-6124

- End -

"So, You Want to Be an Astronaut"

BY DANIELLE BECK

For many, the dream of becoming an astronaut is a far-fetched idea, a career for someone else. For others, the fantasy of having their heads in the stars can become a reality. The astronaut candidate program, operated by Johnson Space Center in Houston, Texas, is ongoing and accepts applications from qualified individuals, with both civilian and military backgrounds. Qualifications for this program are numerous, yet they are achievable. All applicants must be citizens of the United States; other requirements vary with the different positions.

Pilot

Pilot astronauts serve as commanders or pilots on space shuttle missions. Basic qualifications for pilot astronauts include a bachelor's degree in biological or physical science, engineering, or mathematics. A graduate degree is desired, but not necessary. The applicant must have accrued 1,000 hours of flight time in a jet aircraft; experience as a test pilot is also desirable. Aca-

demic requirements aside, the applicant must pass a strict physical examination, including visual acuity, blood-pressure readings and a height restriction of 64 inches to 76 inches tall.

Mission Specialist

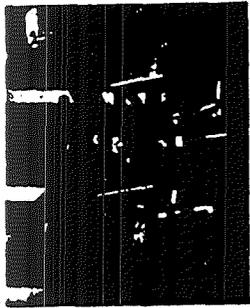
Mission-specialist astronauts are an integral part of the crew. These individuals work closely with all portions of crew life aboard the shuttle including payload activities, experiments and monitoring the use of consumable items, such as food and fuel.

A mission specialist is not required to meet physical requirements as stringent as the pilot candidates; yet they too must meet visual standards and height restrictions of between 60 inches and 76 inches. Academic standards also must be met. A bachelor's degree in mathematics, biological or physical science, or engineering is required with an additional three years of related and progressively responsible professional experience. An advanced degree may be substituted for

SPACE CAMP

For those of you who still have the burning desire to try your hand at the astronaut career, but do not meet the qualifications, SPACE CAMP may be the answer for you. Facilities in Alabama and Florida host numerous programs

for astronaut hopefuls of all ages. In addition to youth camps, sessions are offered for educators; adults of all ages and special parent and child camps are available. For more information, write the U.S. Space and Rocket Center, One Tranquility Base, Huntsville, Ala. 35807, or call 1 (800) 63-SPACE.



The candidate class continued its look at Langley in the atmospheric sciences facility. Projects using lidar (laser radar) were discussed. Langley's Lidar In-Space Technology Experiment (LITE) takes readings from space to help predict weather patterns on Earth. Other Lidar experiments are flown on airplanes and use a laser to measure humidity and other variables in a "slice" of air. The astronaut candidates were interested in this type of technology because of its relation to their basic training curriculum in Earth science. Other technologies related to aerospace research were demonstrated to the candidates, including the crack-finder and the thermal bond tester. The class especially seemed to enjoy hearing about the practical applications of the two systems.

One of the final stops for the visitors was at the lunar-landing simulation site where Langley innovations helped put a man on the moon. This gave the astronaut candidates a feel for Langley's history and a look at past events that have shaped the U.S. space program.

Training

After meeting the qualifications for the astronaut program, applications are reviewed and selections are made for the next group of astronauts. Upon selection, the astronaut candidates must complete a year-long training process.

Johnson Space Center is the host for astronaut-training facilities. The training process is both academic and hands-on to ensure complete knowledge of shuttle systems. The hands-on training for the pilots and

part of all of the experience requirement.

Payload Specialist

A payload specialist is a professional in the physical or life sciences or a technician skilled in operating shuttle-unique equipment. Payload specialists are not required to be U.S. citizens but they must meet the standards for health and physical fitness. These individuals are also required to complete a comprehensive flight-training course to familiarize themselves with shuttle systems.

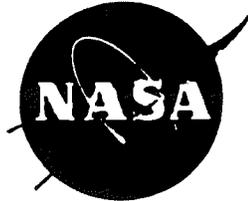
See Astronaut on Page 4

Astronaut

Continued from page 5

mission specialists includes flying T-38 high-performance jets, while others familiarize themselves with other high-performance jets. All candidates learn to adapt to the weightlessness of space by training in a "neutral buoyancy" water tank, which allows for a longer training session. The sensation of weightlessness can also be accomplished by a modified KC-135 set on a parabolic course, during which the aircraft is able to create up to 30 seconds of weightlessness. Flight simulators also allow for a type of hands-on training in the area of shuttle systems.

Following the full year of training, the astronauts complete advanced training, both system-related and phase-related. System-related train-



ing is designed to teach the astronaut about what it is like to live and work in space, yet it is not mission-related. Phase-related training provides the astronauts with the necessary skill for a specific mission.

Information

Consult the Johnson Space Center Home Page on the Internet to investigate your questions about the astronaut program. For an application, call the Astronaut Selection Office at 1 (713) 483-5907.

Danielle Beck is a 1995 LARSS participant.

Pearl L. Young Theater Grand Opening!—The Federal Women's Program Committee would like to invite NASA employees and contractors to the Pearl L. Young Theater Ribbon Cutting Ceremony and Open House, 9:30 - 10:00 a.m., August 22, 1995. The Center Director will be joined by Hewitt and Viola Phillips, a close friend and co-worker of Pearl Young, who will speak about her time with Young at Langley. Following the ceremony, there will be refreshments and a showing of original NASA footage titled "Apollo 13—Houston, We Have a Problem." The building will remain open until 3 p.m. for employees to visit the theater. NASA employees may charge time to JO AS267. If you have any questions, please contact, Patsy Campbell, 43291.

***Sample Announcements

***Continuation of Astronaut Article

Free Admission

The Virginia Air and Space Center, Langley's Visitor Center, is offering a special promotion for NASA active civil service employees and on-site contractors with photo identification badges.

Throughout the summer months of July to September, free admission to exhibits will be given to civil service employees and contractors who present NASA photo identification badges.

Accompanying family members will be admitted to exhibits at the discounted rate.

In addition, the Virginia Air and Space Center is offering a special promotion on annual family memberships. From July 1995 to June 1996, civil service employees and on-site contractors are entitled to receive a 20-percent discount on family memberships which includes:

- * Free exhibit admission *
- * IMAX discounts *
- * 10-percent gift-store discount *
- * Quarterly newsletter *
- * Invitations to exhibit and film openings *
- * Various discounts and coupons provided by local merchants and attractions*
- * Discounts on camps and other activities *



Virginia Air and Space Center
Hampton Roads History Center

SPECIAL BONUS FOR NEW MEMBERS

As of July 1, free Apollo 13 gifts such as tee shirts, caps and books will be available while supplies last.

For information and membership fees, call 727-0900.

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**DEVELOPMENT OF A 3-PHASE CCD TIMING
GENERATOR**

Kory L. Bennett (Student)
Preston I. Carraway III (Mentor)

Internal Operations Group (IOG)
Aerospace Electronic Systems Division (AESD)
Electro-Optics and Controls Branch (EOCB)

ABSTRACT:

Charge-Coupled Devices (CCDs) are used in a wide range of commercial, scientific, and defense applications. They are primarily utilized for imaging and spectroscopic functions. Compact, cost-effective technology to miniaturize the auxiliary electronics required to operate the CCD is highly desirable. Because of the importance of reducing size and weight in defense and space applications, emphasis must be placed on the reduction in size.

The purpose of this project is to minimize the CCD timing generator electronics for 3-phase CCDs by replacing conventional ICs with a single programmable IC. This timing generator will give the user the ability to vary the number of horizontal and vertical pixels and to choose between integration and readout modes. This, in turn, will reduce the size and weight of CCD focal plane assemblies as a whole.

Charge coupled devices are semiconductor devices which employ storage elements (pixels) capable of transferring electric charge. For a 2 dimensional array, the charges stored in the pixel elements are usually read out row by row. Once a row is transferred into the horizontal or serial register, each pixel of that row is read out before another row is transferred. Ultimately, these packets of electrical charge are converted to voltage levels, digitized, and stored in memory. However, because there are various manufacturers of 3-phase CCDs, different types of auxiliary electronics, ranging in size, are necessary to support the CCDs. The size of the supporting electronics can pose a problem when limited space is available. My project is one proposed solution to this problem.

The first step, which is still underway, in my approach was to survey commercially available 3-phase CCDs, determine how they function, and become familiar with the various engineering software design tools on the CAEDE system. The design tools which will be needed for this project are;

1. VHDL (hardware descriptive language) is an alternative to physically drawing numerous logic gates in order to create a logic diagram. The types & functions of logic gates can be represented linguistically rather than graphically. VHDL saves time and makes it easier to understand the operability/function of the design being described.
2. LEAPFROG is a design tool that detects errors in the VHDL program, simulates the VHDL program, synthesizes, and converts the VHDL description into a diagram of logic gates in simplest form.
3. XILINX is a type of programmable logic device which consists of Field Programmable Gate Arrays. The VHDL program can be synthesized through the Leapfrog simulator into the final XILINX product (chip).

In order for the timing generator to successfully operate 3-phase CCDs, a study of timing diagrams from the leading manufacturers had to be conducted in order to note any similarities or differences in the phase relationships, pulse widths, delay times, and other timing parameters. The review of timing diagrams for 1024 x 1024 CCDs manufactured by Loral, EG&G Reticon, and Scientific Imaging Technologies is still in progress and the results of the review are not final at this time.

The second step in my approach will be to incorporate the results of the study of various timing diagrams into a final timing generator recipe for either a XILINX product or an ASIC fabricated at a foundry yet to be determined. The design will be produced through the use of the design tools mentioned above using various logical elements such as shift registers and state machines. The work on this design will be continued at North Carolina Agricultural & Technical State University with access to NASA's CAEDE system enabling more efficient design work.

Through discussion with my mentor and responsible engineers, this project was determined to be too involved for a summer project. Therefore, it was concluded, in agreement with my academic advisor Dr. Busaba, that the topic would be an excellent topic for a master's thesis. Provisions for the use of NASA's facilities, especially interaction with the CAEDE system, will be made prior to the end of this summer's LARSS program. The thesis will be completed prior to graduation (Summer of 1996).

In conclusion, the development of a single programmable IC (timing generator) which miniaturizes CCD auxiliary electronics will result in a reduction of the size and weight of focal planes based on CCDs. This will be very beneficial to a wide range of commercial, scientific, and defense applications.

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**STRUCTURAL ANALYSIS OF
COMPOSITE TEST PANELS**

Sean Berhan
LARSS student

Marshall Rouse
LARSS mentor

Structures Directorate
Structural Mechanics Division
Aircraft Structures Branch

ABSTRACT

An analytical study was conducted for a 1/4 scale model skin-stringer compression panel using STAGS (SStructural Analysis of General Shells) code for finite element analysis. This was a study to investigate scaling methods for composite structures using reduced ply thicknesses for 1/2 and 1/4 scale models. A computer model for a curved panel in a pressure-box was also constructed in order to simulate test conditions in the pressure box test machine. The pressure box is a test facility at NASA Langley research center used to simulate flight conditions in fuselage panels. This model will be used to investigate modifications to the pressure-box for curved panels with different radii.

INTRODUCTION/BACKGROUND INFORMATION

Composites are materials in which non-woven fibers are oriented in a specific matrix for the purpose of increasing structural efficiency, i.e. producing stronger, lighter structures. The composite materials are made up of several plies or laminae. Each lamina consists of one row of parallel fibers or filaments. The lamina are stacked with various orientations of the filament directions between each layer, resulting in a laminate matrix which has the desired strength or stiffness.

The use of polymeric composite materials in aircraft structural design can be a major factor in cost and weight minimization. However, the testing of composite structures using scale models have failed in the past to accurately predict the strength of full-scale structures. In response to this, a new method of composite structure scaling has been implemented using reduced laminate ply thicknesses corresponding to 1/2 and 1/4 scale models. Reduction of the ply thicknesses allows for scaling the original structure without changing the ply layups as was the case with previous scaling methods such as the ply-level method. It is believed that this approach will allow for a more accurate modeling of actual components.

Five test panels will be loaded to failure in the testing of this method ; one full scale, two 1/2 scale and two 1/4 scale models. A finite element computer model of a 1/4 scale panel was developed and analyzed in order to predict the structural response which could be expected to be seen in the testing of the actual model.

The curved panel to be tested in the pressure-box test machine has a hybrid composite skin consisting of a Hercules AS4 graphite fiber and Fibrite 938 epoxy material system with intrapplied S2-938 fiberglass-epoxy material straps. The pressure-box test machine is designed to apply axial loads up to 7000 lb/in and internal pressure loads up to 20 psig. Axial loads are applied to the test panel by two 225-kip hydraulic actuators connected to a curved steel plate known as the axial load plate. Circumferential or hoop loads which develop in the skin of the test panel are provided by an annular steel plate known as a hoop load plate and two steel rods connected to the sides of the panel. The steel rods include turnbuckles which are used to regulate the proper hoop loads in the panel for any given load condition. Pressure is applied to the concave side of the test panel using a 100 psi air supply source and a pneumatic control system.

Finite element analysis of the test panel is needed as an analytical tool to determine the turnbuckle forces needed to create an appropriate stress state in the panel. It is also used to compare analytical and experimental results when using different loading conditions.

SUMMARY

The panel design is a five-stringer composite stiffened compression panel. They are made from Hercules AS4/3502 CFRP graphite epoxy material. They include aluminum ribs with shear-ties to simulate how the fuselage panels would be fastened to the aluminum frame in an actual aircraft. The skin of the panel has a quasi-isotropic laminate with 0° , $\pm 45^\circ$, 90° plies.

A linear finite element analysis of the 1/4 scale model was conducted using STAGS (STructural Analysis of General Shells) computer code developed at Lockheed Palo Alto Research Laboratory. STAGS is a finite element code for general-purpose analysis of shell structures. In order to perform the analysis the panel was broken down into rectangular shell units which were individually specified as to their geometry, position, material composition, etc. Each shell unit was designated with a specific number of rows and columns, according to their size and shape, to create enough nodes for an accurate finite element analysis. The shell units were combined to form a shell structure of the panel. A 10,000 lb load was applied to simulate the conditions that the panel will be exposed to during testing.

The finite element model was post-processed using PATRAN 3 computer code. First, a model file was created from the STAGS code, along with a nodal displacement file and an integrated element stress file. These files were imported into PATRAN 3 for the post-processing. PATRAN 3 was used to generate a graphical representation of the model and computer-enhanced images of the stresses and displacements caused by the applied load. Figure shows the finite element model.

Figures 1 and 2 show the panel with strain contours in the X and Y directions, respectively. Both plots clearly show the areas of greatest stress intensity surrounding the point on the panel where the compressive load was applied parallel to the X-axis. Figure 3 is a displacement plot, again showing the greatest deformation at the point of the applied load.

The same procedure utilizing STAGS and PATRAN 3 was used for a quarter model of a curved panel in the pressure-box test machine described above. This model included a hoop load plate, an axial load plate, test panel, turnbuckles, and an axial load actuator. The computer simulation included an axial load of 1000 lbs applied through the actuator and a 1000 lb load through the turnbuckle, as well as a uniform pressure of 18.2 psi applied to the concave side of the curved test panel. The boundary conditions around the straight edges of the model were fixed to permit radial displacements only. This was done to more accurately simulate a cylindrical shell subjected to internal pressure. Figures 4 and 5 represent strain contour plots of the curved panel model in the X and Y directions, respectively.

Fringe: LC=2.1-RES=1.1-P3/PATRAN R.1.2-Membrane Strain-X-PATRAN 2.5-10-Aug-95 1

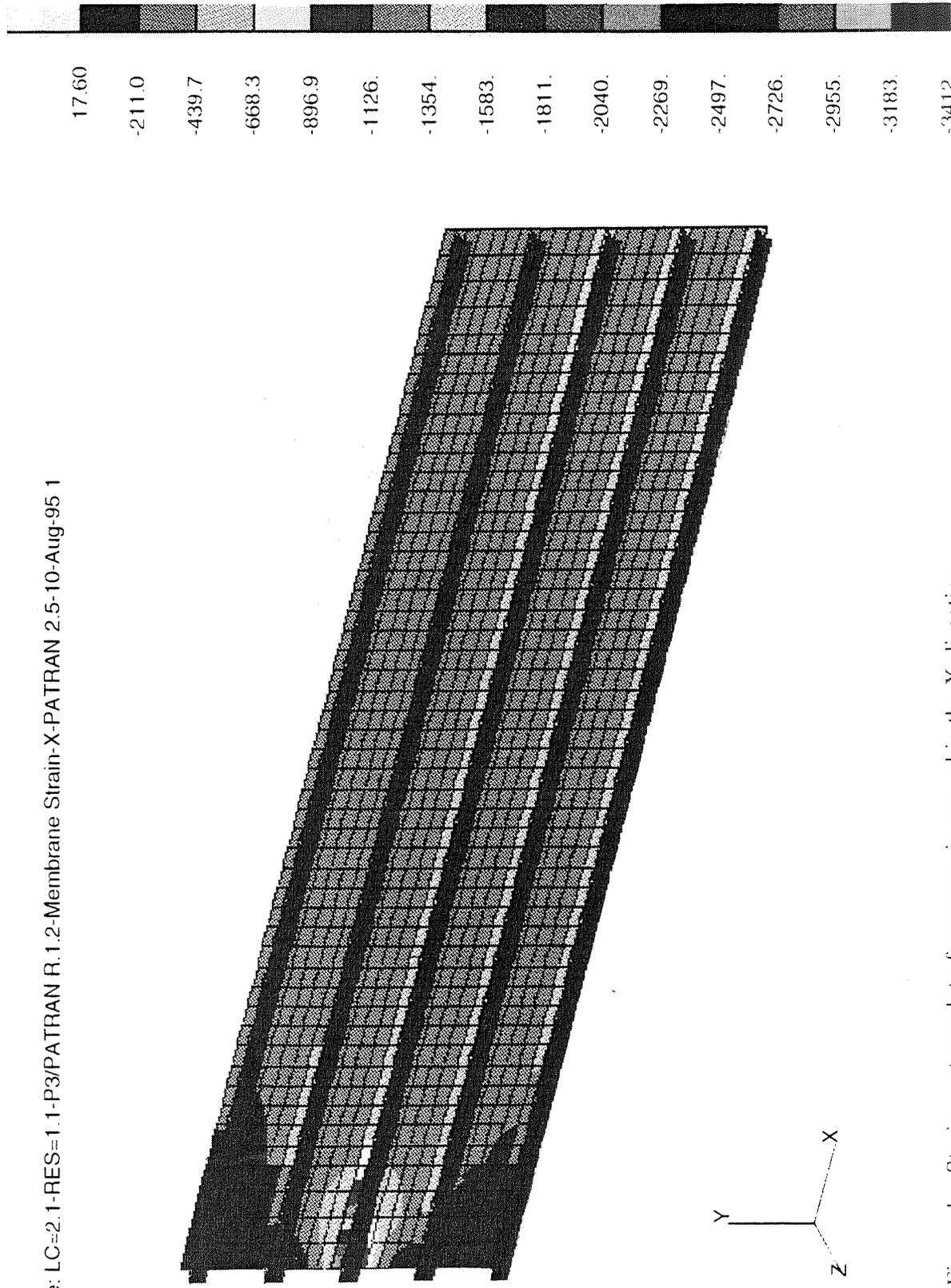


Figure 1. Strain contour plot of compression panel in the X-direction

Fringe: LC=2.1-RES=2.1-P3/PATRAN R.1.2-Membrane Strain-Y-PATRAN 2.5-10-Aug-95 1

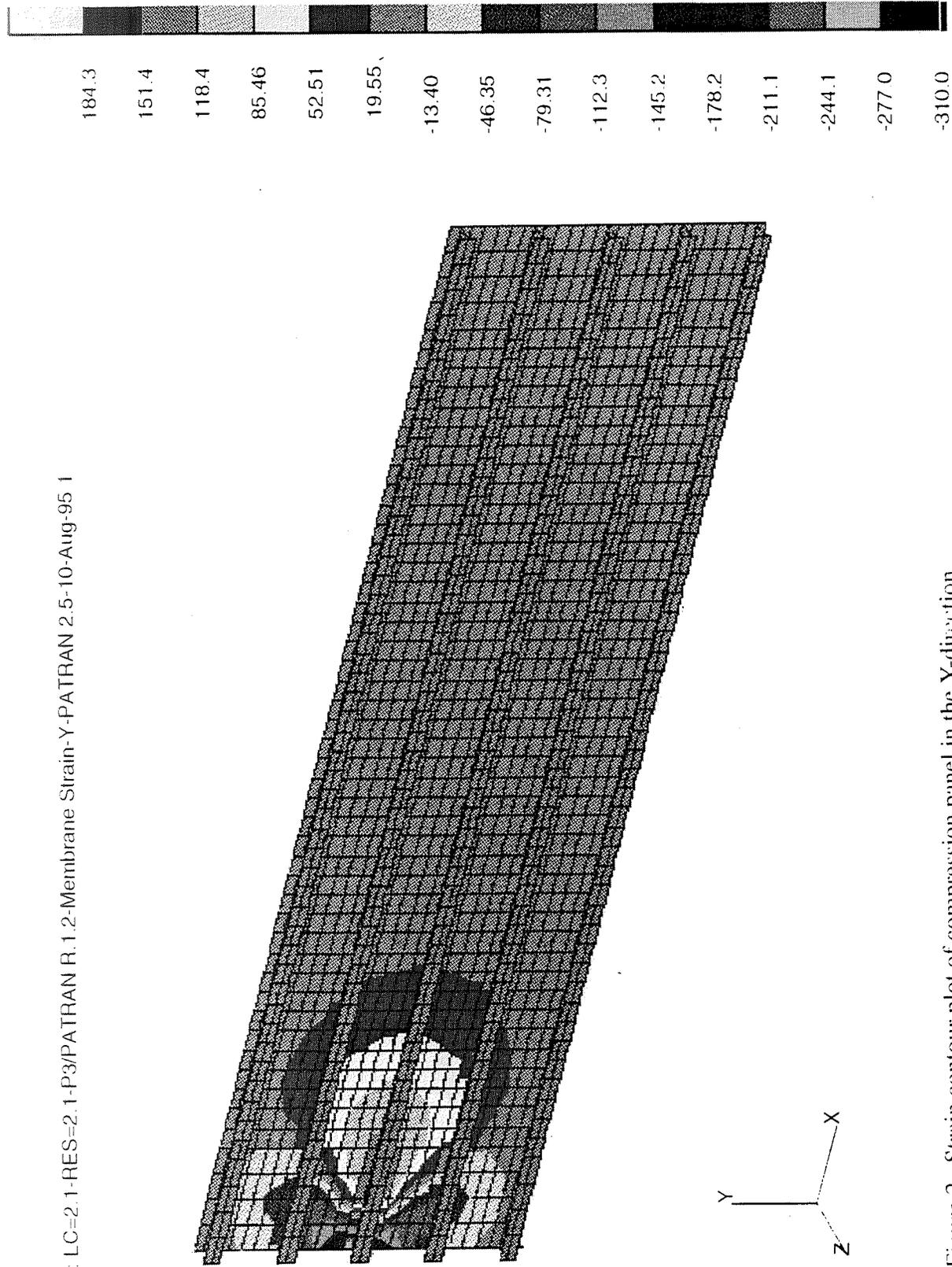


Figure 2. Strain contour plot of compression panel in the Y-direction

Fringe: LC=2.1-RES=1.1-P3/PATRAN R.1.2-Membrane Strain-X-PATRAN 2.5-10-Aug-95 1
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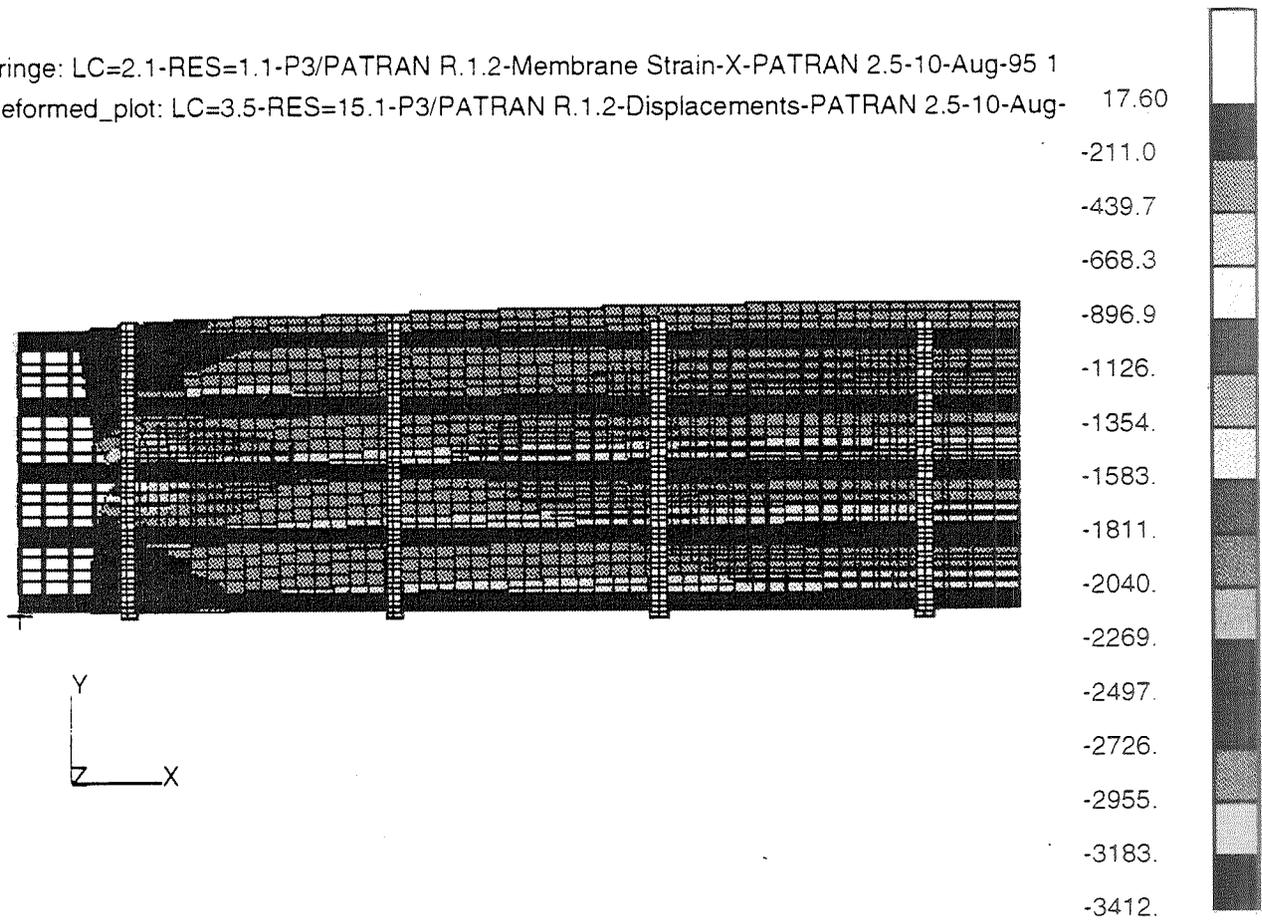


Figure 3. Deformation plot of compression panel

Fringe LC 3.2 HES 2.1 P3/PATRIAN R.1.2-Membrane Strain-X PATRAN 2.5-17-Jul-95 0

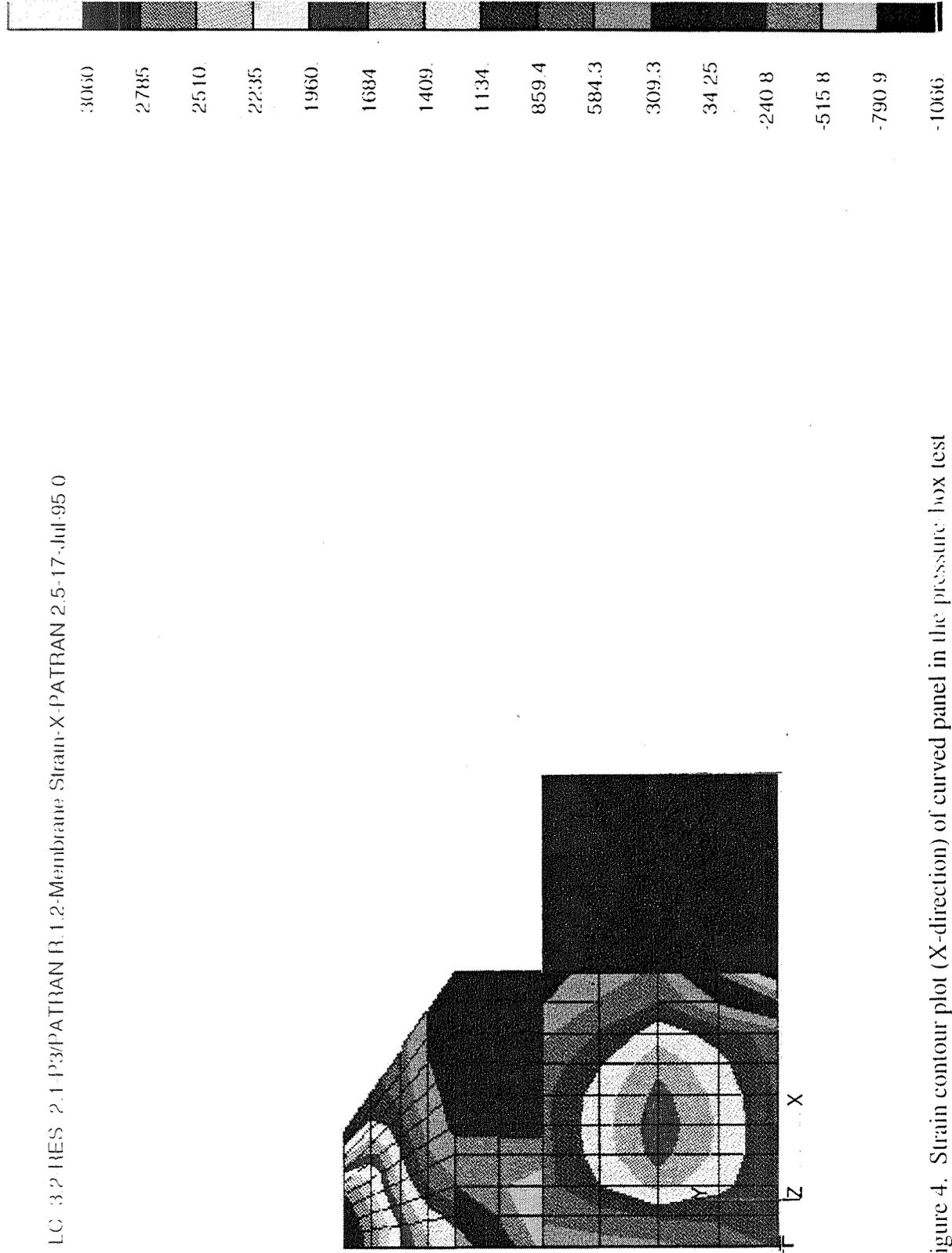


Figure 4. Strain contour plot (X-direction) of curved panel in the pressure box test machine

Fringe: LC_3_2_HES_3.1_P3/PATRAN R.1.2-Membrane Strain-Y-PATRAN 2.5-17-Jul-95 0

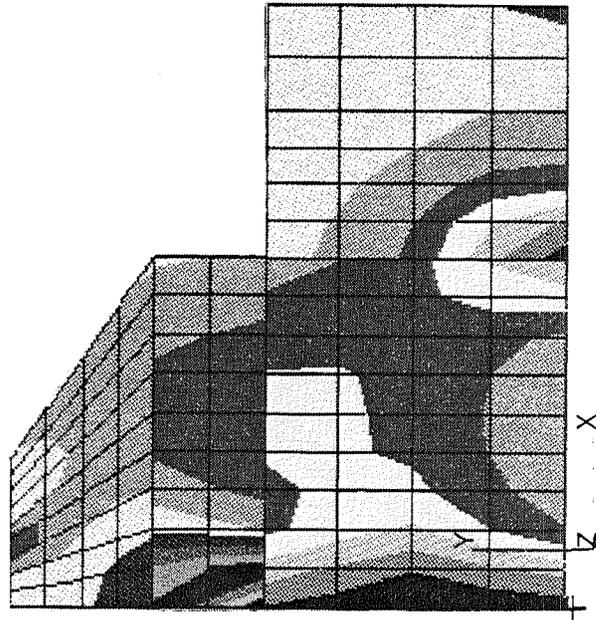
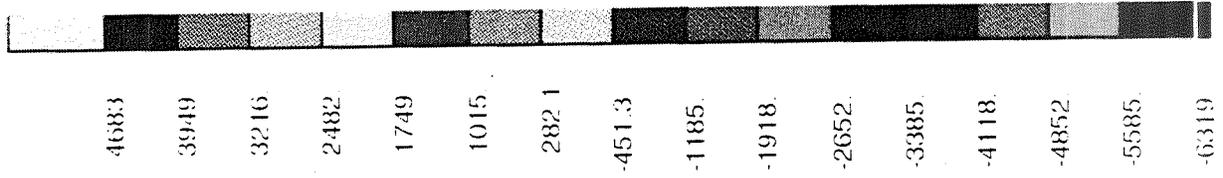


Figure 5. Strain contour plot (Y-direction) of curved panel in the pressure-box test machine

RESULTS/CONCLUSION

A finite element model has been developed to study the structural response and scaling effect of stiffened compression panels. This model will serve as a basis for further analysis to conclude these objectives. The finite element model of the curved panel in the pressure-box will be used to develop modifications to the pressure-box test machine for panels with different radii. Further refinement of the model will be carried out to serve this purpose.

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Geographic Information System Data Analysis

Internal Operations Group
Facilities Program Development Office
Imaging and CADD Technology Team

Chad Billings
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Tracie Hill
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J. Mark Locklear
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Adam H. Shay
Antone Taylor
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August 7, 1995

ABSTRACT

Data was collected in order to further NASA Langley Research Center's Geographic Information System(GIS). Information on LaRC's communication, electrical, and facility configurations was collected. Existing data was corrected through verification, resulting in more accurate databases. In addition, Global Positioning System(GPS) points were used in order to accurately impose buildings on digitized images. Overall, this project will help the Imaging and CADD Technology Team(ICTT) prove GIS to be a valuable resource for LaRC.

INTRODUCTION

Geographic Information System(GIS) is an integrated system of computer hardware, software, and trained personnel linking topographic, demographic, utility, facility, image, and other resource data that is geographically referenced. In other words, the data is being related to images, maps, or easily understood graphics. GIS can support decision making in areas such as planning design, maintenance, and repair. It can allow for increased efficiency and accuracy and also provide improved decision making tools. The import and export of database, computer aided design, spreadsheet, word processing applications, and electronic images make GIS a valuable resource for organizing and displaying data.

In order to facilitate the implementation of NASA Langley Research Center's GIS, communication, electrical, and facility configuration information was collected.

PROCEDURE

The initial project for the Imaging and CADD Technology Team's (ICTT) summer students was the exterior verification of NASA Langley facilities. Original building brochure drawings, obtained from AutoCAD files and aerial photography, were used in recording outside measurements. Each building had specific measurements which needed to be taken. These were labeled on a hard copy drawing and given to teams made up of three people. A World Wide Web building locator, on ICTT's homepage, was needed to locate LaRC facilities. Far too often, buildings could not be found on a conventional map and the locator proved to be a useful and time efficient source. Once actual verification began, digital measuring devices were used. However, factors, such as low batteries and noise, made these tools inaccurate and unpredictable; therefore measuring tapes were ultimately used. The results were then recorded and were later transferred to the drawings and compared to the original brochures for any discrepancies. Once the nearly two hundred facilities associated with the NASA Langley Research Center were measured, the next phase of the summer project began. This involved the use of the Global Positioning System (GPS). The GPS, developed by the Department of Defense, is a system of 24 functional satellites operating in six orbital planes which can give exact positioning of any object using X-Y coordinates and GPS points through a signal from a transmitter. Teams used fluorescent paint to mark GPS points from where the signal would be transmitted. By tracking the signal transmitted from the point, GPS uses time and known variables in order to determine the coordinates of each points placed next to the building. The

Standard Positioning Service (SPS), a subsidiary of GPS, allows for horizontal accuracy of 100 meters, vertical accuracy of 140 meters, and timing accuracy of 340 nanoseconds.

Another vital part of the project dealt with interior verification of the Langley facilities. This involved going to each room and noting whether a room was a conference room or office, the type of flooring in the room, phone and video jack locations, and the configuration of each room. In a few buildings, room configurations were wrong and changes on the floorplans were made. A major part of the interior verification was the locating of the IDF/BDF systems. These systems are the power source of each facility. IDF (Intermediate Distribution Frames) deals with the phone jacks and the associated currents. Similarly, BDF's (Building Distribution Frames) involve the circuits and electrical aspects of a facility.

Using original floorplans information was transferred onto "D" size floorplans to indicate where the jacks should be located (Figure A). This verification process was not difficult to complete. Problems arose only when rooms had been reconfigured or if furniture, such as book shelves, file cabinets and desks covered the jacks.

Following the completion of both interior and exterior verification, video footage was taken from each facility. Conference rooms, IDF/BDF systems and the exterior characteristics of each facility were recorded. This would later be implemented into the GIS. The possible additional use of this footage would be a multimedia tour of NASA Langley Research Center facilities.

Finally, having gathered all the information, the process of data entry began. Several students trained in the use of Microsoft Access entered the information into a custom form in the database (Figure B). The buildings and room numbers were entered along with all information gathered for each room.

RESULTS

Many inconsistencies were found while trying to locate buildings using the current NASA Langley facility maps. Some buildings indicated on the map were no longer there due to removal or relocation. In other cases, new buildings had not yet been added to the facility map.

Once the buildings were located and measured it was found that original building measurements were not consistent with the actual building measurements. Many buildings dimensions varied from a few inches to a few feet. As mentioned before, due to construction, remodeling or relocation of personnel, results varied when gathering IDF/BDF, phone and network jack information. While the IDF/BDF 's for the most part were consistent with floor plans, many of the phone jacks were not and were reconfigured on drawings giving an accurate account of where each jack was located.

There were also many structural changes in buildings. New rooms were added and walls had been rearranged. These changes were noted on the plans. After all these changes were made, the above information was entered into a database making this information accurate and organized to make it possible to obtain in time of need. The final result is a new updated database and drawing with all vital information needed to support the implementation of the GIS.

CONCLUSION

The gathering of information and use of the GPS unit on facilities at LaRC was used by the Imaging and CADD Technology Team (ICTT) in an effort to correct the electronic Master Plan, Building Brochure, and associated databases. After exterior verifications, interior details, and master plans have been digitized they will be translated to the GIS, which allows the user to obtain information through a visual image of LaRC and its facilities. ICTT also uses GIS for space utilization as well as emergency response. The information gathered will eventually make the GIS an even more efficient and accurate tool to be used at Langley.

Apart from the research oriented skills acquired this summer, the Imaging and CADD Technology Team's summer student learned three valuable lessons in the form of teamwork, communication, and organization. From the onset of the data collection, teamwork was implemented into the daily schedule. Teams measured buildings, completed interior verification, and video taped the exterior of buildings.

Communication was a vital part of each team's success. Ideas and methods had to be properly conveyed between team members and problem resolution was achievable only through appropriate communication. Finally, organization was a high priority. It was imperative to maintain the drawings, database, information, and floorplans in an orderly fashion. Each of these aforementioned qualities has helped develop the overall, individual character of each LARSS summer student.

RI209T-8 IMAGING AND CADD TECHNOLOGY TEAM (FIGURE A)

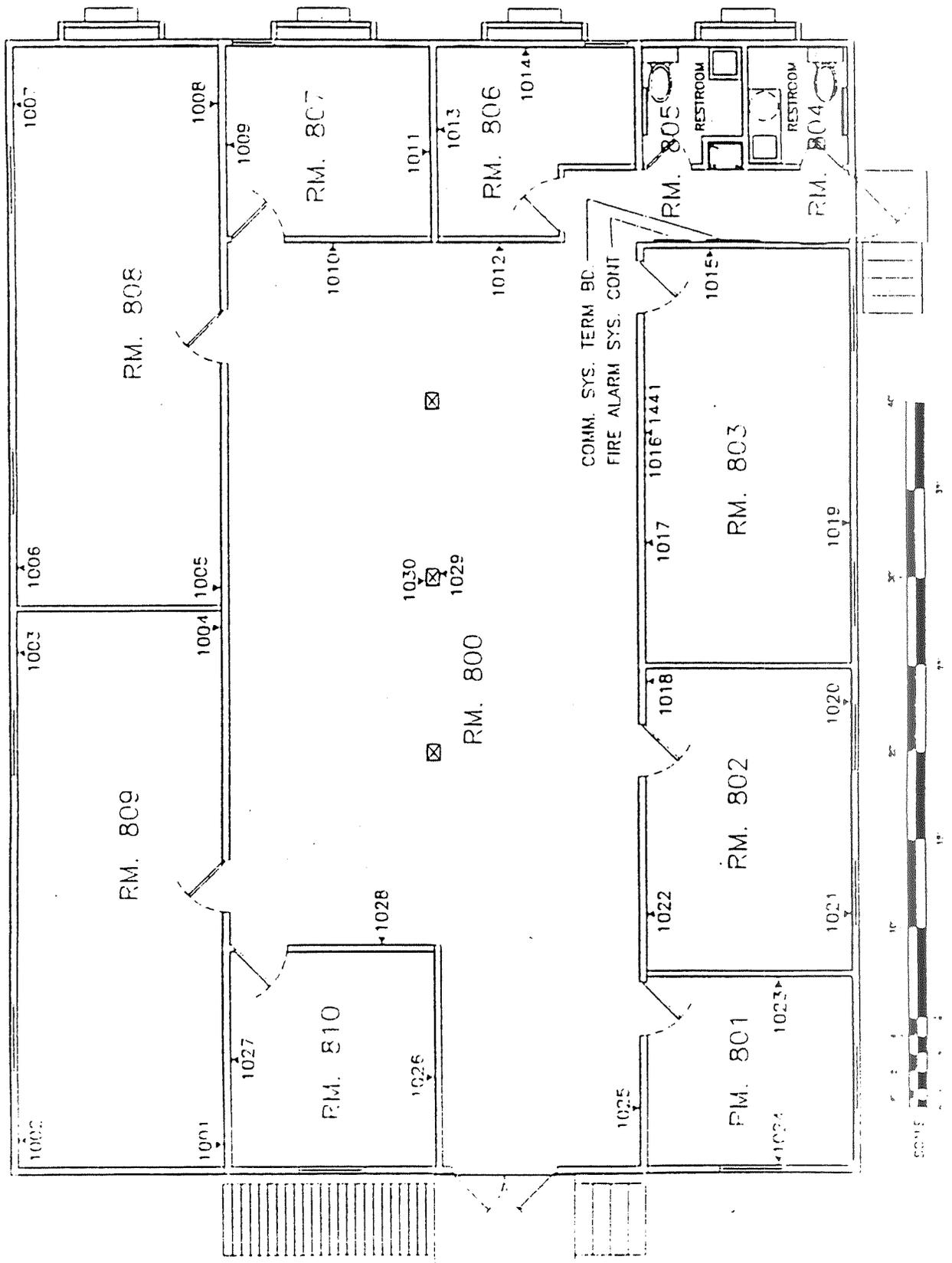


Figure B

Jacks Form

Building Number:	1293A
Room Number:	01
Jack Number:	1001
Confidence Level:	HIGH
Jack was absent from original DB:	<input type="checkbox"/>
Jack in DB but was not in room:	<input type="checkbox"/>
Video Jack Number:	
Video Confidence:	
Flooring:	CARPET
Conference Room:	<input type="checkbox"/>
Notes:	

Building Number:	1293A
Room Number:	01
Jack Number:	1062
Confidence Level:	HIGH
Jack was absent from original DB:	<input type="checkbox"/>
Jack in DB but was not in room:	<input type="checkbox"/>
Video Jack Number:	
Video Confidence:	
Flooring:	CARPET

Conference Room:

Notes:

Building Number: 1293A

Room Number: 01A

Jack Number: 1002

Confidence Level: HIGH

Jack was absent from original DB:

Jack in DB but was not in room:

Video Jack Number:

Video Confidence:

Flooring: PLASTIC

Conference Room:

Notes:

Building Number: 1293A

Room Number: 02

Jack Number: 1003

Confidence Level: HIGH

Jack was absent from original DB:

Jack in DB but was not in room:

Video Jack Number:

Polarization and Characterization of Piezoelectric Polymers

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LARSS Summer Research
NASA Langley Research Center
Composites and Polymers Branch
Materials Division

August 8, 1995

Abstract:

Piezoelectric materials exhibit an electrical response, such as voltage or charge, in reaction to a mechanical stimuli. The mechanical stimuli can be force, pressure, light, or heat. Therefore, these materials are excellent sensors for various properties. The major disadvantage of state of the art piezoelectric polymers is their lack of utility at elevated temperatures. The objective of this research is to study the feasibility of inducing piezoelectricity in high performance polymer systems. The three aspects of the research include experimental poling, characterization of the capacitance, and demonstration of the use of a piezoelectric polymer as a speaker.

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Introduction:

"Piezo" is the Greek word that represents "pressure." Hence, piezoelectricity describes the relationship between pressure and electricity. Piezoelectric materials are those materials that transform mechanical force into an electrical response. The mechanical response may be a force, pressure, light, or heat. Conversely, a piezoelectric material will transform an electrical signal into mechanical motion. The direct and inverse piezoelectric effects are illustrated in Figure 1.1. Piezoelectricity is utilized in a variety of applications as sensors and actuators. One aspect of this research project was to design an amplifier to demonstrate the use of a piezoelectric RAINBOW ceramic wafer as a speaker.

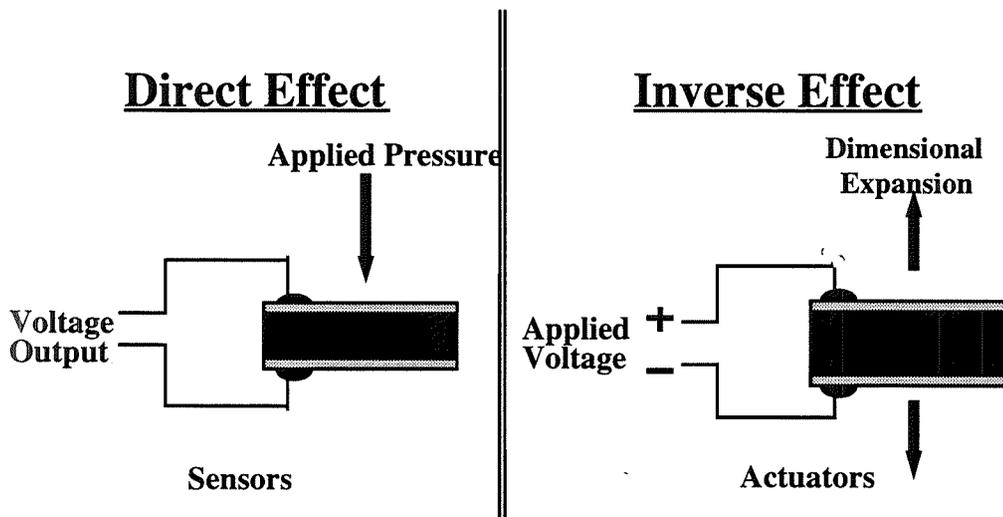


FIGURE 1.1. The direct and inverse effects of piezoelectricity.

Piezoelectricity occurs naturally in some materials or can be induced in polymeric and ceramic materials. Some known materials in which piezoelectricity occurs naturally are quartz and barium titanate. The initiation of

piezoelectricity in polymers and ceramics is created through a process called poling. In the poling process, molecular dipoles in the materials are aligned by an external force field. This field may either be mechanical, magnetic, or electrical. In this research, strong electric fields were utilized to pole polymer systems.

Pioneering work in the area of piezoelectric polymers by Kawai [1] in 1969 led to the development of piezoelectric activity in a polarized fluoropolymer, polyvinylidene fluoride (PVDF) [2]. Currently PVDF is the only commercially available piezoelectric polymer. A major problem with PVDF as a piezoelectric polymer is that it can not be used at temperatures above 50 degrees Celsius. This is because the dipole alignment induced in the poling process is spontaneously reversed at temperatures significantly above the glass transition temperature (T_g) of the polymer. The glass transition temperature is defined as the temperature region through which the mechanical properties change from those of a brittle glasslike material to those of a flexible rubbery material.

This research proposes to develop and characterize a novel class of high performance piezoelectric polymers that have several distinct advantages over state of the art materials. These advantages include high temperature stability, high mechanical integrity and utility in the space environment.

The aspect of the research targeted during the LARSS program was to utilize the poling process for polyimide films. This research also included characterizing the capacitance as a function of temperature of unpoled, poled, and poled/clamped polymers and demonstrating the use of a piezoelectric polymer as a speaker.

Poling Polymers:

The process that induces piezoelectricity in polymers is known as poling and is illustrated in Figure 1.2. In the poling process polymers are subjected to electric fields large enough to preferentially orient electrical moments. The normal poling procedure implemented in these experiments consisted of several steps. First a gold electrode with leads was evaporated on each side of the polymer film.

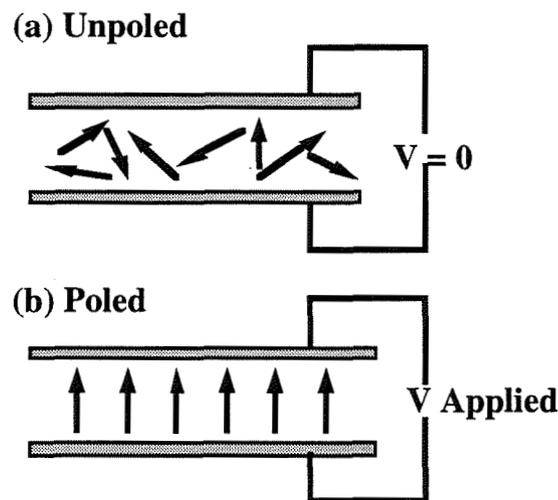


Figure 1.2. Orientation of dipole moments in the polymer during poling.

The electroded film was then attached to the high voltage poling apparatus. The poling set-up is shown in Figure 1.3. It consists of a Trek Model 20/20 High Voltage Amplifier from which a voltage of approximately 3,500 volts was applied across the film. The setup consists of two Fluke 8842A multimeters which monitor the voltage and current during poling.

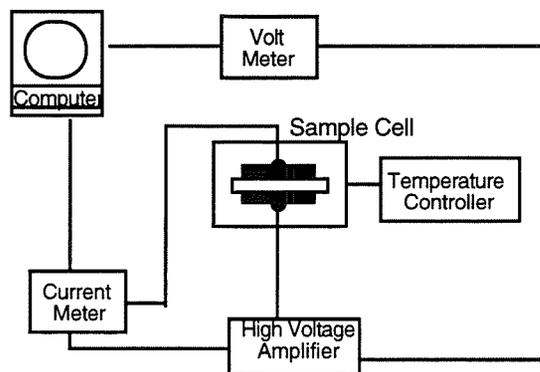


Figure 1.3. Poling set-up

The film was heated at a temperature 10 degrees below the specific polymers' glass transition temperature (T_g), to increase the mobility of the molecular dipoles. Each polymer was poled at a constant time, approximately 5 minutes. After 5 minutes the polymer was taken out of the silicon oil bath and quenched with isopropyl alcohol. It was necessary for cooling to take place with the electric field on in order to freeze in the dipole orientation.

There were three conditions that remained constant during the poling process, the electric field (E_p), temperature (T_p), and poling period (t_p). As shown in Figure 1.4 the polymers were poled for approximately 5 minutes at a constant temperature (approximately 210°C). The voltage was ramped to 3,000V and held constant for the duration of the experiment. The current increased to a value of $1.8\mu\text{A}$ and leveled off. The large spikes in the current are due to arcing in the polymer.

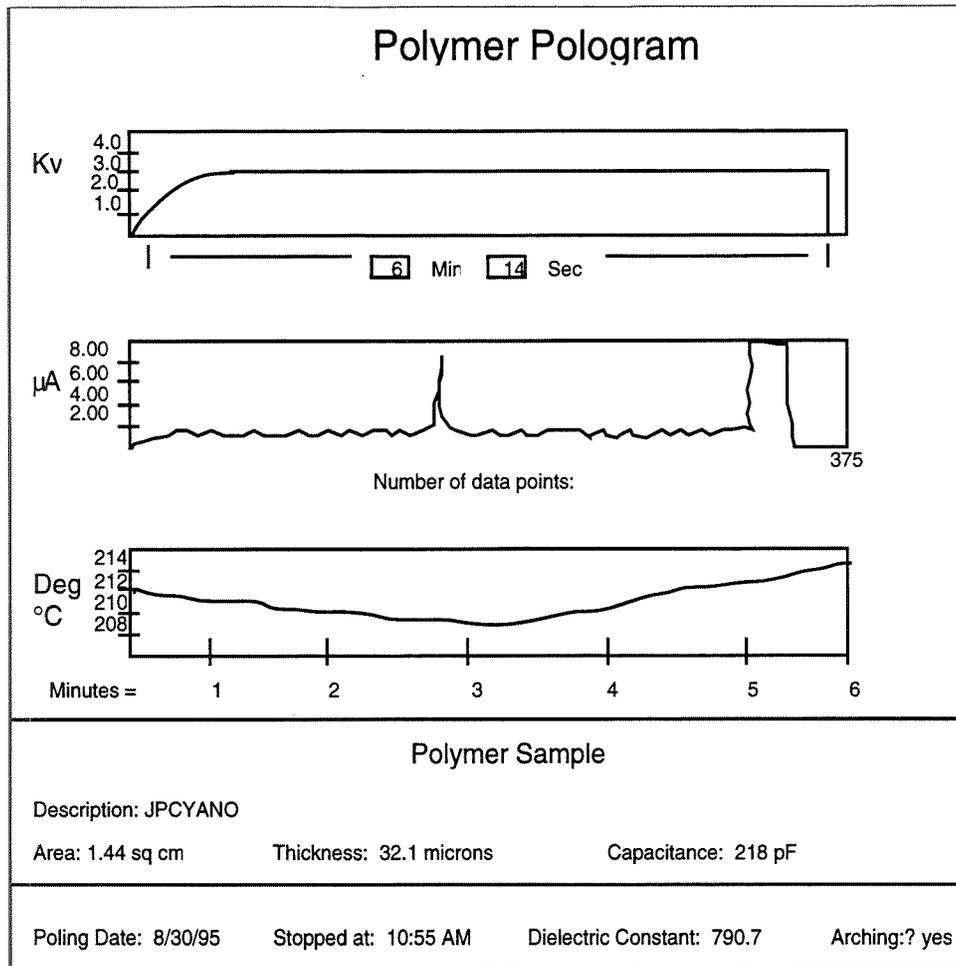


Figure 1.4. Pologram for a polyimide

Characterization of Capacitance Properties:

One method for characterizing materials is to evaluate their capacitance as a function of temperature. In this research a technique called parallel plate capacitance was used. Parallel plate capacitance measurements are taken by applying an electric field across a dielectric medium to measure its polarization. The polymer is the dielectric and the electrodes are the parallel plates, as shown in Figure 1.5.

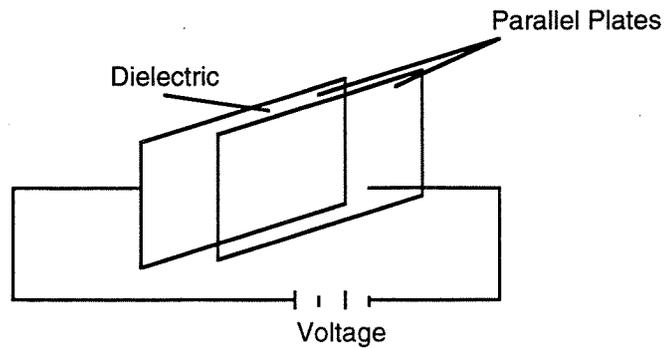


Figure 1.5. Parallel Plate Capacitance

From the capacitance measurements the dielectric constant, k , can be calculated using equation 1.1.

$$k = \frac{Cd}{A\epsilon_0} \quad (1.1)$$

where d = thickness between polymer plates
 ϵ_0 = permittivity of free space and is equal to $8.854 \times 10^{-12} \text{F/m}$
 A = area of the parallel plates
 C = capacitance of the polymer

Various steps were taken to compare capacitance as a function of temperature of the polyimide shown below in Figure 1.6.

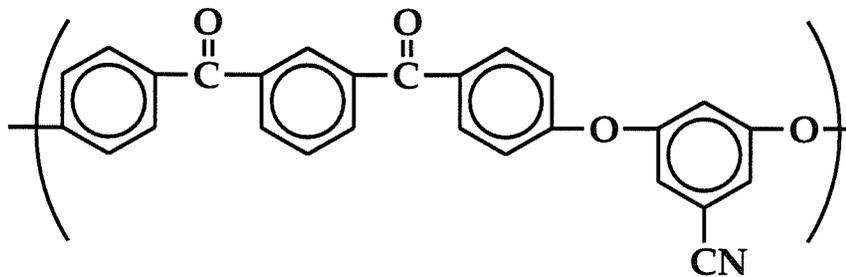


Figure 1.6. Chemical structure of JPCYANO polyimide.

A Data Precision Capacitance meter model 938 was used to measure capacitance in a Blue M mechanical convection oven model OV-472A-3. Measurements were taken at 10° C intervals starting at room temperature and ending at 211°C for an unpoled sample. This sample was poled at 210°C for approximately 6 minutes and quenched with isopropyl alcohol. The capacitance of the unpoled sample was then measured over the same temperature range. The capacitance measurements of the unpoled and poled samples were used to calculate the dielectric constant as a function of temperature using equation 1.1.

Capacitance measurements as a function of temperature were taken for the polyimide JPCYANO shown in Figure 1.6. This polymer contains a highly polar cyano group (CN) which should preferentially align with the electric field during poling. In order to characterize the difference poling makes in the dielectric properties of a polymer, the capacitance was measured for both poled and unpoled samples of JPCYANO. As shown in Figure 1.7, the dielectric constant increases with increasing temperature for both samples. This rise in dielectric constant is due to an increase in molecular mobility which occurs as the viscosity of the polymer decreases at increasingly higher temperatures. The dielectric constant is a measure of the polarizability of a material. The unpoled sample has a higher dielectric constant at temperatures well below the glass transition temperature than the poled sample because in the poled sample all of the molecular dipoles are already been polarized in the poling process.

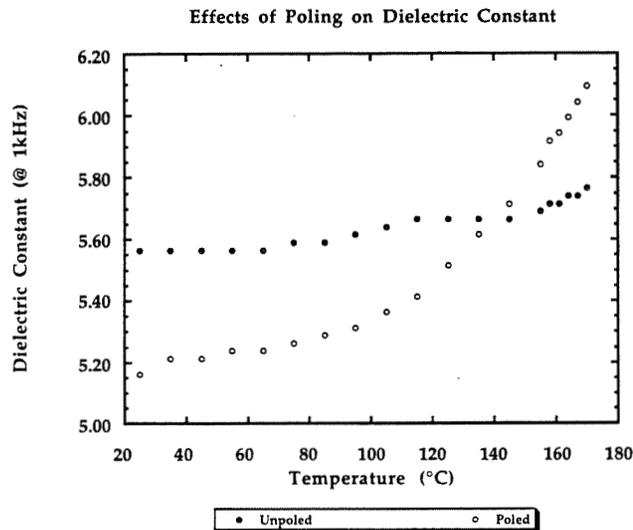


Figure 1.7. Dielectric constant as a function of temperature.

Demonstration of Piezoelectric Effect:

The final phase of the LARSS research project was to demonstrate the use of a PLZT ceramic RAINBOW wafer, as a speaker. In order for the speaker to amplify signals from the piezoelectric ceramic, a step-gain amplifier was created. The following materials were utilized in the assembly of the amplifier: a printed circuit board which contained a 10 k potentiometer, an LM386 amplifier chip, capacitors with values of 100 micro-F, 250 micro-F, 10 micro-F, .05 micro-F disk, and resistors with values of 1.2 kilo ohms, 600 ohms, and 10 ohms. Additional parts included a 9 volt battery holder, chassis (bud box), a four position wafer switch, and a terminal switch.

The design was assembled in the following manner: first the printed circuit board was configured using the necessary components. The circuit diagram is shown in Figure 1.6. The second step was to draw the layout of the bud box, place screw holes where necessary, and cut out necessary holes. All of the materials were then placed in the bud box. The leads were then attached to the PLZT

ceramic RAINBOW wafer and the amplifier. The bud box was closed and the leads from the headset were attached to the screws on the outside of the bud box.

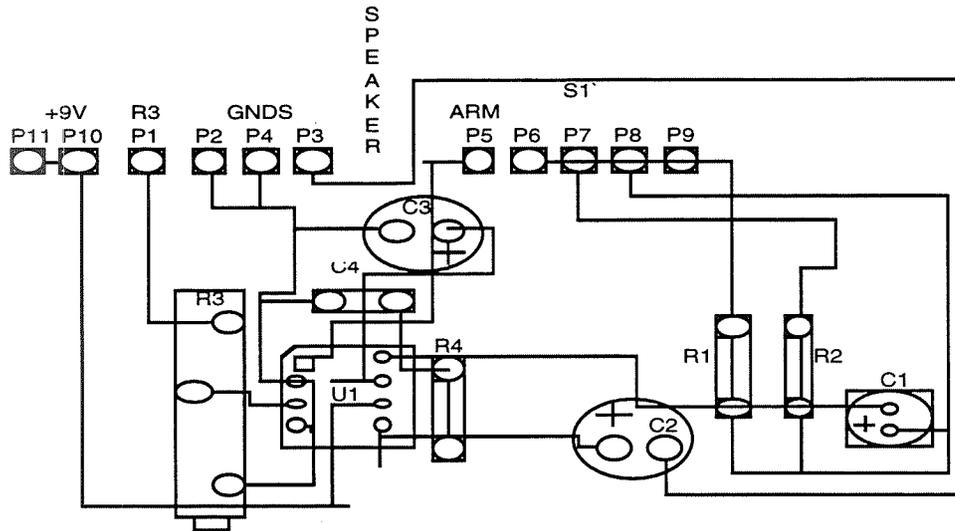


Figure 1.7. Circuit diagram for printed circuit board.

The frequency signals from the headset were sent through the amplifier to the PLZT ceramic rainbow. The amplifier buffed or made the sound clear. The sound then traveled to the ceramic where the vibrations caused the ceramic to pulsate producing music. The piezoelectric ceramic also acted as a microphone when the cycle was reversed. External noise was input directly into the ceramic and sent through the amplifier. The external noise traveled to the headset where the sound was recorded. The overall quality of the speaker was excellent.

Conclusions:

The process of using parallel plate capacitance was successfully completed by applying an electric field of approximately 10^6 V/cm below the glass transition temperature across the polymers. From the graph of capacitance as a

function of temperature, it was observed that the capacitance increased with an increase in temperature due to increase in molecular mobility. The final aspect of the summer research was to use a piezoelectric RAINBOW ceramic as a speaker. A step-gain amplifier was created in order to construct a circuit that would use the piezoelectric RAINBOW ceramic, PLZT, as a speaker.

References

1. Kawai, Jpn. J. Appl Phys., 8, 975 (1969).
2. M.G. Broadhurst and G.T. Davis, Ferroelectrics, 60, 3 (1984).

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6 P.

Technology Transfer

by

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Langley Aerospace Research Summer Scholar

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Mentor

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**Technology Applications Group
Technology Transfer Team**

ABSTRACT

The development and application of new technologies in the United States has always been important to the economic well being of the country. The National Aeronautics and Space Administration (NASA) has been an important source of these new technologies for almost four decades. Recently, increasing global competition has emphasized the importance of fully utilizing federally funded technologies. Today NASA must meet its mission goals while at the same time, conduct research and development that contributes to securing US economic growth. NASA technologies must be quickly and effectively transferred into commercial products. In order to accomplish this task, NASA has formulated a new way of doing business with the private sector. Emphasis is placed on forming mutually beneficial partnerships between NASA and US Industry. New standards have been set in response to the process that increase effectiveness, efficiency, and timely customer response.

This summer I have identified potential markets for two NASA inventions: including the Radially Focused Eddy Current Sensor for Characterization of Flaws in Metallic Tubing and the Radiographic Moiré. I have also worked to establish a cooperative program with TAG, private industry, and a university known as the TAG/Industry/Academia Program.

Technology Transfer

The development and application of new technologies in the United States has always been important to the economic well being of the country. The National Aeronautics and Space Administration (NASA) has been an important source of these new technologies for almost four decades. Recently, increasing global competition has emphasized the importance of fully utilizing federally funded technologies. Today NASA must meet its mission goals while at the same time, conduct research and development that contributes to securing US economic growth. NASA technologies must be quickly and effectively transferred into commercial products. In order to accomplish this task, NASA has formulated a new way of doing business with the private sector. Emphasis is placed on forming mutually beneficial partnerships between NASA and US Industry. New standards have been set in response to the process that increase effectiveness, efficiency, and timely customer response.

The Technology Applications Group (TAG) at Langley Research Center has developed a process to effectively transfer NASA-developed technologies and expertise to the private sector. This summer I worked under the mentorship of Rosemary Baize and Cheryl Allen, both of whom are part of the Medical/Instrument/Sensors/Environment and Energy (MISEE) team of TAG. I have had several tasks throughout the ten week period and I have worked with many people in TAG.

My first task was to search for a potential market for a patented invention that was developed in the Non-Destructive Evaluation (NDE) Sciences Branch. NDE technologies are used to remotely inspect an object without having to destroy the subject. I started off by obtaining a list of NASA researchers from Ms. Baize. I then utilized the LaRC patent office by getting a list of all patents and invention disclosures by each researcher. After reviewing the list, we were able to narrow it down to a shorter list of inventions that may be used for some type of NDE. I then pulled each patent/invention disclosure file and read through each one. I divided the files up into different types of NDE. The categories were eddy current/electromagnetic flaw detector, ultrasound, x-ray, and acoustic emission. I then decided that I was most interested in pursuing an invention that could inspect pipelines in a non-destructive manner.

The oil refinery industry uses thousands of miles of steel and stainless steel pipelines. The weld joints between them are 3 to 4 inches thick and are wrapped with an aluminum layer. Corrosive materials that flow through the pipes in time cause the pipes to rupture due to wall thinning. The oil leak can cause extreme environmental damage and it can also cause the company to lose money. Since access to the welded joints is often limited, a device is needed that can remotely inspect weldments and critical pressure vessel joints in the pipes. The problem is that many current methods have high sensitivity to small changes in the conductivity and permeability of the test piece which is known to vary at the weldments.

I chose a patented eddy current invention by Buzz Wincheski called Radially Focused Eddy Current Sensor for Characterization of Flaws in Metallic Tubing. This invention is a modification of the already patented NASA invention called the "Simpson Probe" and it helps to alleviate the high sensitivity of current eddy current methods. This modified probe can be placed into a tube to detect longitudinal fatigue cracks and flaws. The probe then induces eddy currents into the tube walls. The magnetic flux is such that in the absence of damage, there is no link between the coil so no signal is produced. If there is a flaw, the induced eddy currents in the tube walls are forced to flow around the flaw. The magnetic field associated with the currents links the pickup coil and an emf is generated across the pickup coil leads. The induced voltage indicates the presence of a flaw.

After thoroughly reading the invention disclosure to understand the invention, I proceeded to search for commercial partners that might be interested in licensing the

technology. Thanks to a report from the Research Triangle Institute, I was able to obtain a list of Market Share Estimates for Manufactures of Eddy Current Testing Equipment. Upon locating a company, we came to the realization that the invention had only been disclosed and that it wouldn't be filed with the US Patent and Trademark Office until mid-September. We were unable to begin working with a commercial partner on this particular invention because the case had not been filed and we were concerned about protecting NASA's intellectual property.

Since I was unable to complete the process for the eddy current, I moved on to another category of NDE. This time I chose x-ray inspection. The "Radiographic Moiré" was invented by LaRC researcher Eric Madaras. Originally, this invention was designed to remotely detect stresses and strains in the free wall of space shuttle tires. The radiographic moiré or X-ray moiré is accomplished by attaching a fine grid of radio opaque lines to the surface of the area to be inspected. The pattern can also be embedded within the material or the pattern already existing in the material may be used. X-rays are passed through the test specimen and detected on photographic film. The compilation of the two sets of lines produces the moiré effect which is used to locate strains in a particular area. In this case the area would be the cords and belts in radial tires.

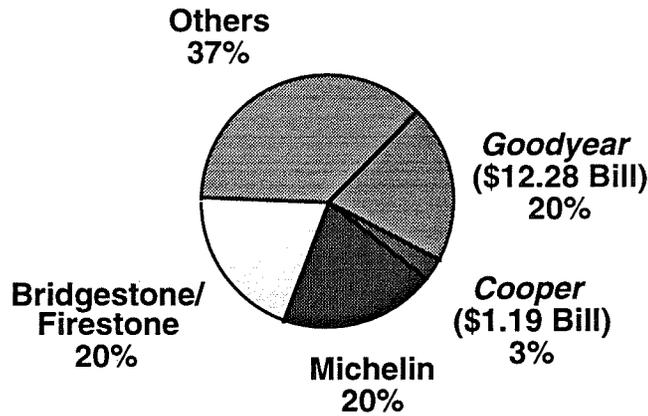
We felt this invention could be of great use to the commercial tire and retread industry. I familiarized myself with CD-ROM in the library to access business directories. I obtained a list of only American tire companies since the patent does not have foreign protection. I also made contacts with the International Tire Association and the American Retreader's Association. These two associations helped me to get an idea of what tire companies controlled the new tire and retread market in the US for manufacturing. (see Fig. 1-A, 1-B) Rosemary, Cheryl, and I then met with Eric Madaras, the inventor, to discuss our plan with him and to get some feed back from him. The meeting went very well and Mr. Madaras was interested in finding some commercial use for the technology. Also to better understand how retreads are manufactured, we took a plant tour of Bandag, Inc. in Newport News, VA. The trip was beneficial in that we were able to see the current methods used in detecting flaws in tires and how those flaws are repaired. Interestingly, several x-ray manufacturing companies submitted request about the new technology rather than tire companies. I believe this may have been because tire companies are looking for technologies they can buy off the market rather than potential license agreements. Hopefully, one of the x-ray companies will be interested in forming a partnership with NASA to further develop the radiographic moiré.

My second major tasks this summer has been to develop a TAG, industry, and university cooperative program. Bob Yang in the Technology Applications Group has developed the TAG/Industry/Academia Exchange Program. (see Fig. 2) Since government funding for many programs is in decline, this new program would solicit funds from private industry to be donated to the university for further development of a NASA technology. Cooperation between NASA, academia, and the private sector will help to better solve market needs. Together TAG and North Carolina A&T State University are searching for the appropriate industry partners. Once this is accomplished, the University will be able to make contact with NASA researchers and facilities through the Virtual Tech Transfer Center or Picture Tel. Students and faculty will have the funding to develop the product for the interested commercial partner who will in turn have their need or want satisfied. The long-term outlook of this process is to have a COMmercialization OPportunity PROgram (COOPR) that will allow universities to compete for the chance to further develop a technology.

Some other minor tasks I have completed this summer include answering information requests on thermographics and heat flux microsensors. I have also pursued my interest in patent law by working with members of the LaRC patent counsel team.

Figure 1-A

Tire Industry



American Companies Italicized

Figure 1-B

Retread Industry (All American Companies)

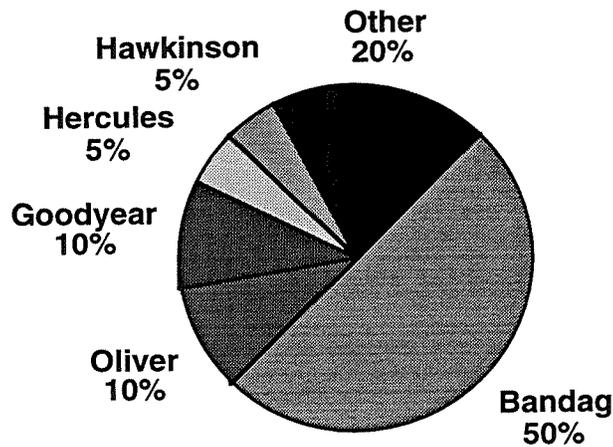
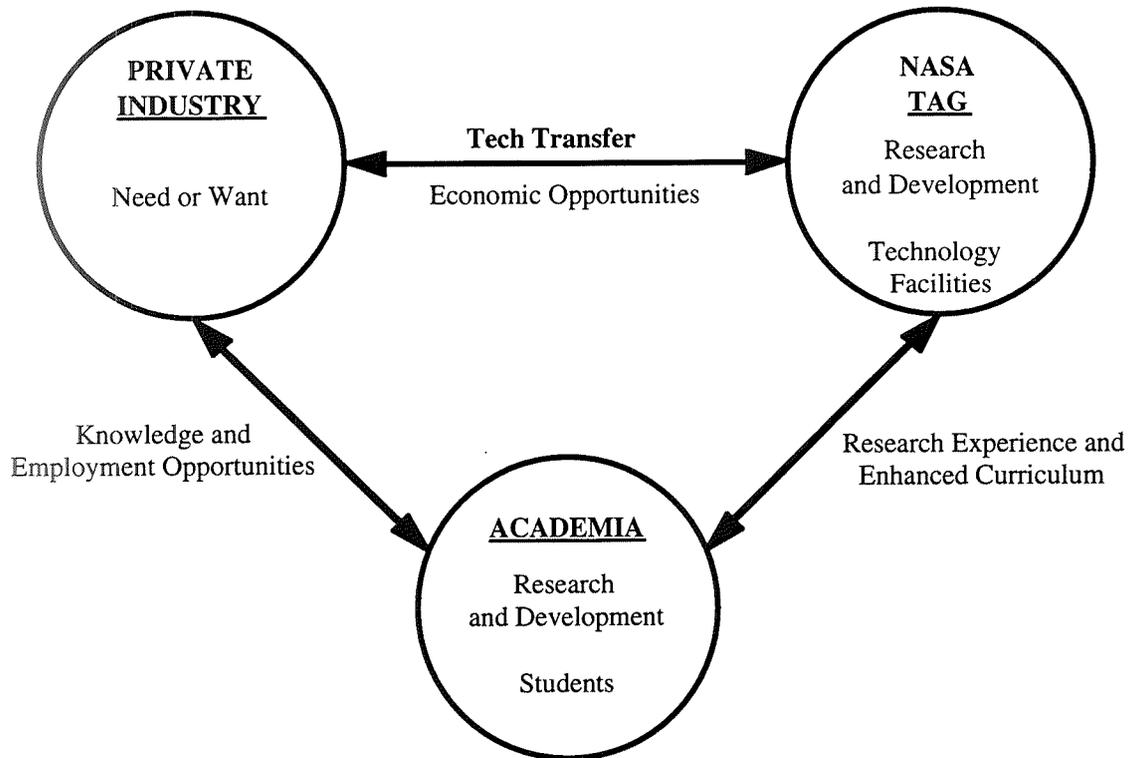


Figure 2

TAG / Industry / Academia Exchange Program



A Numerical Study of Hypersonic Fuel Injectors

Jason G Bush

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Research and Technology Group
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Abstract

The work conducted during the Summer of 1995 for the Langley Aerospace Research Summer Scholars, or LARSS, Program was a continuation of Master's Degree work being conducted for the Mechanical Engineering Department at Old Dominion University. Since this work is not yet complete, an update of progress is provided here along with a generalized background. The main emphasis of this research is to find predicted correlations in the database generated by the SHIP3D code, which modeled different scramjet combustor configurations.

Introduction

The next step in the evolution of aerospace propulsion is the bridging of the gap between today's high performance jet engines, known as ramjets (Mach 3-6), and rockets (Mach 25 +). The engine which fills this gap is the supersonic combustion ramjet. Ramjets are essentially self-propelling engines except that they need to be brought to an initial speed of approximately Mach 2.0 before they can operate. This engine is comprised of an inlet, a subsonic diffuser, a combustion section, and an exit nozzle. Air entering the engine is initially slowed in the inlet causing its static pressure to increase by use of oblique shocks. The air then passes through the subsonic diffuser where it is compressed further. This compressed air is subsequently heated in the combustor and then expanded through the exit nozzle at a velocity exceeding the inlet velocity. This increase in the speed of the working fluid is what provides thrust in the direction of flight. Ramjets require the velocity of the incoming air to be decreased in the supersonic and subsonic diffusers in order to prevent the combustor flame from blowing out.

At speeds greater than Mach 6, ramjets become inefficient due to the incoming air being slowed down to subsonic speeds. These inefficiencies manifest themselves as pressures too high for the combustor structure, excessive wall heat transfer rates, high total pressure losses from strong shocks, and energy losses to chemical dissociation¹. To overcome these limitations, it is desired to induce combustion while the engine internal velocities are supersonic. Hence the need for a supersonic combustion ramjet, or scramjet. In order to bridge the gap between ramjets and rockets, it is desired that vehicles propelled by scramjets are able to obtain orbital velocity (\approx Mach 25). Studies have shown that in order to propel a vehicle to Mach 25, internal flowrates through the scramjet will need to be between Mach 2 and Mach 8².

When low earth orbit is desired, hypersonic airbreathing propulsion (Mach 5+) is an economically viable alternative to rocket propelled vehicles. The table below shows a takeoff weight breakdown of a typical aircraft and a conventional rocket launcher.

Typical takeoff weight breakdowns. From Heiser et al.³ p.16

Takeoff Weight Fraction	Aircraft	Rocket
Payload	15 %	4 %
Empty	55 %	7 %
Fuel	30 %	24 %
Oxygen	0 %	65 %

Note that the largest fraction of a rocket's takeoff weight is oxygen and that this large investment of weight takes away from the vehicle's empty and payload weights. It is

important to note that 'empty weight' includes items such as life-support, fuel tanks, power, controls, and engines.

A hypersonic airbreathing vehicle, on the other hand, acquires its oxygen from the medium through which it traverses. This allows more takeoff weight to be invested in the payload as well as the vehicle empty weight. It has been proposed to reduce the fuel weight by using cryogenic hydrogen as the fuel, thus allowing for further reduction in takeoff weight as well as providing vital cooling potential for the internal engine components. Another important advantage to using hypersonic airbreathing vehicles based upon conventional aircraft design is the ability to use existing conventional runways, thereby not requiring any special launch facilities.

In order to obtain escape velocity, an airbreathing hypersonic vehicle will have to spend a majority of its acceleration time under power of scramjets. Therefore, the design optimization of this engine system is of greatest importance. The key to this optimization is the efficiency with which the fuel is mixed with the air passing through the engine. Work is currently underway at NASA Langley Research Center in Hampton, VA on the theoretical, as well as experimental, development of fuel mixing in scramjet engines.

Due to the cost of physical experimentation for these high-speed conditions, computational modeling is an attractive option. The use of Computational Fluid Dynamics (CFD) has been a great boon to hypersonic research. One code used to model the three dimensional physical processes inside a scramjet combustor is the Supersonic Hydrogen Injection Program, or SHIP3D. This code uses a four species combustion model in conjunction with the parabolized, mass-averaged equations for the conservation of mass, momentum, total energy, total fuel, and turbulence fields. The governing algorithm is the SIMPLE (Semi-Implicit Method for Pressure-Linked Equations) algorithm created by Patankar and Spalding. For a more in depth discussion of SIMPLE the reader should refer to reference 4. SHIP3D was run modeling three different types of fuel injector (ramp, flush wall, and strut) with various parameters (i.e., fuel/air ratio, combustor length, injection angle, etc.) being changed. The objective of this Master's thesis is to look at various physical processes occurring around the injectors themselves and create a computationally derived database of these processes.

Summary

The following is a summary of work done as of August 8, 1995.

At the present time, a complete and thorough literature search is underway as well as developing plots of mixing efficiency vs. combustor length. Upon receiving the output from one of the flush wall injector cases, as well as a copy of SHIP3D, the first task was to see what the total stagnation enthalpy, total pressure, and the temperature were doing as the flow progressed through the computational combustor. After determining that mass conservation was being maintained by the code, it was desired to see what the individual species stagnation enthalpies were doing. This had a two fold effect. It allowed for a microscopic understanding of the combustion reactions taking place, but more importantly, it allowed for an in depth understanding of just what exactly the code is calculating and how it is calculating it.

One of the biggest difficulties in this project has been figuring out just how SHIP3D computationally recreates the various physical processes occurring within the combustor. This code has been modified for well over 15 years and was called HISS (Hydrogen Injection of a Supersonic Stream) as far back as 1977. Due to the years of modification by numerous individuals, as well as a lack of a concise cataloging document listing these changes, it has become difficult to have questions concerning the inner workings of the code answered quickly. This has led to a heavy investment of time in deciphering just how SHIP3D operates.

After determining the stagnation enthalpies for the individual species, it was decided to look at the pressure and viscous drags across the fuel injector. This was when some problems began to arise. In order to determine the pressure drag across the injector itself, the code had to be rerun so that the output would contain information for the desired locations in the combustor. After rerunning the code, it was found that the momentum losses were not adding up to equal the change in integral stream thrust. This is currently assumed to be due to mass loss inherent in the code itself as a result of the grid patching⁵. It was also found that when the code was rerun, the values for pressure drag began to diverge from previously calculated values (i.e., the database currently under study). The reasons for this have yet to be determined. It was assumed that the same input file was being used as in previous runs, so in order to maintain any consistency, the previously calculated values are going to be assumed to be the correct values.

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LARSS TECHNICAL REPORT - 1995

STRESS TUNING OF LASER CRYSTALS

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ABSTRACT

The topic of stress tunable laser crystals is addressed in this study with the purpose of determining the piezo-optic coefficients of a new laser material. This data was collected using a quadruple pass birefringence technique because of its high degree of sensitivity relative to the other methods examined including fringe shift analysis using a Mach-Zender interferometer. A green He-Ne laser was passed through a light chopper and Glan-Thompson prism before entering a crystal of Erbium doped Yttrium Aluminum Garnet (Er:YAG) (used in order to validate the experimental technique). The Er:YAG crystal is mounted in a press mechanism and the laser is quadruple passed through test specimen before being returned through the prism and the orthogonally polarized portion of the beam measured with an optical sensor. At a later stage, the Er:YAG crystal was replaced with a new crystal in order to determine the piezo-optic coefficients of this uncharacterized material. The applied load was monitored with the use of a 50 lb. load cell placed in line with the press. Light transmission readings were taken using a lock-in amplifier while load cell measurements were taken with a voltmeter from a 5 volt, 0.5 amp power supply. Despite the fact that an effective crystal press damping system was developed, size limitations precluded the use of the complete system. For this reason, data points were taken only once per full 'turn' so as to minimize the effect of non uniform load application on the collected data.

Good correlation was found in the transmission data between the experimentally determined Er:YAG and the previously known piezo-optic constants of non-doped crystal with which it was compared. The variation which was found between the two could be accounted for by the aforementioned presence of Erbium in the experimental sample (for which exact empirical data was not known).

The same test procedure was then carried out on a Yttrium Gallium Aluminum garnet (YGAG) for the purpose of establishing values of its unknown piezo-optic constant tensor using experimentally collected transmission data. Significant variation between the piezo-optic constants of YAG and YGAG crystals was found however, the excellent data correlation of separate experimental runs carried out on the YGAG sample demonstrates the validity of these results. The data collected during the stressing of the YGAG was of high quality, however the amount of data collected was somewhat limited by a fracture of YGAG specimen which undoubtedly altered the crystalline lattice structure and hence precluded any further testing.

Introduction

A solid state laser is typically thought to operate at a particular wave length (such as the Helium Neon laser). In the case of those using lanthanide series atoms, however, the lasers have a slight tunability around the line center. Different wave lengths of light are employed in various applications because of the optical properties (such as absorption or transmission) which a given applications requires. Light is transmitted and absorbed by different media at various wavelengths and often, a given laser will not operate at an ideal wavelength for a desired application. As one solution to this problem a laser may be essentially tuned using a variety of photoelastic methods. As a stress is applied, the predominant effect is a proportional change in the element overall dimensions, mainly a compression in the direction of the applied stress and an expansion perpendicular to it. Other such techniques have been employed which, as a second order effect, change the refractive index of the laser through direct manipulation of the laser crystal itself. One manifestation of this photoelastic effect involves the heating of the laser crystal in order to bring about thermal expansion to introduce a strain, which yields a change in the optical path length and hence the resulting change in the material through the thermo-optic constant. The topic of this report, however, involves the application of mechanical rather than a thermal stress (through the use of a screw press) which compresses and eventually strains the material, altering its refractive index, and consequently changing the values of the piezo-optic constants used to theoretically predict the effect of stress on the refractive index .

The experimental intention is to first establish an accurate method of incrementally stressing an erbium doped yttrium aluminum garnet and to replicate the previously determined values of the piezo-optic constants of the sample for validation purposes. Next, the same experimental procedure is carried out a second time on a material for which the piezo-optic constants are not known. Utilizing the validated photoelastic technique, a value of the transmission through the laser material per incremental load applied is obtained and evaluated with the use of a theoretical model in order to 'back-calculate' the values of the piezo-optic constants of this unknown material.

THEORY

The purpose of the experimental research addressed in this report is to facilitate the tuning of the wavelength of a laser through the application of a direct mechanical stress in order to alter the crystalline lattice structure and hence, the performance characteristics of the laser itself. Theoretically, this change in the lasing material's optical properties is evident in a fourth rank tensor composed of the piezo-optic constants (denoted q_{ijkl}). The below relationship relates these piezo-optic coefficients, the applied stress tensor and the relative dielectric tensor 'K' where repeated indices indicate summation:

$$\Delta(K^{-1})_{ij} = q_{ijkl} * \sigma_{ijkl}$$

The piezo-optic constants describe the effect of stress on the index of refraction of the material and it is the index of refraction which dictates many of the optical properties which a given material exhibits. In carrying out calculations on the photo elastic effect, the inverse of the relative dielectric tensor (called the relative dielectric impermeability tensor and expressed as 'B') is used in defining equations. The components of this 'B' tensor are the coefficients of the 'indicatrix'; a graphical representation of optical properties expressed as an ellipsoid of wave normals. The value of the semi-axis of these wave normals are the square roots of the dielectric constants which compose the 'B' tensor and coincide in orientation with the principal dielectric axis of the laser material as well. The unstressed material has an index ellipsoid equation similar to that of a sphere, however after a stress is applied, this 'indicatrix' equation changes significantly and correspondingly, alters the values of the refractive indices as well. Nevertheless, if shear stresses are minimal, the local material axes will remain oriented with the principle axes.

The elasto-optic constant (expressed as 'p') relates changes in the refractive index to strain and also yields information pertaining to the aforementioned piezo-optic constants of the material strain as well via the following relationship:

$$P_{ijkl} = q_{ijrs} * c_{rskl}$$

The materials to be tested are of a crystalline atomic structure therefore, in their least symmetric form can have up to 36 independent piezo-optic constants and 21 independent elastic constants. Due to the benefits of symmetrical lattice structure however, many of these values go to zero. A cubic material will typically possess only three such independent, non-zero constants and in the case of the isotropic materials, only two. Because the dielectric impermeability tensor, stress and strain tensors are all symmetric, a more simplified notation for these expressions is typically adopted as follows where 'c' is a component of the elastic stiffness tensor:

$$\Delta(B_m) = \Delta(K^{-1})_m = q_{mn} * \sigma_n$$

$$q_{mn} = p_{mr} * s_{rn}$$

$$p_{mn} = q_{mr} * c_{rn}$$

The theoretical basis for the experiment is the relationship which expresses the difference in optical path length between the two components of a beam of light incident on a crystalline specimen. The beam exits the crystal, having split into two components parallel and perpendicular to the optical axis and differing in optical path length as follows :

$$\Delta = d * (n_o - n_e)$$

The length of the crystal is 'd' and n_o & n_e are the differing indexes of refraction of the two components. Expressed in terms of phase shift the above expression becomes:

$$\Delta \Phi = (2\pi / \lambda) * [l * (n_o - n_e)]$$

Recall prior mention of the form of the refractive index ellipsoid and its sensitivity to the photo-optic effect. Assuming a cubic material, the equation of the 'indicatrix', which had been that of a sphere, is now of the following form as a result of the applied stress:

$$(1 / n^2 + q_{12} * \sigma_2) * x^2 + (1 / n^2 + q_{12} * \sigma_2) * y^2 + (1 / n^2 + q_{12} * \sigma_2) * z^2 = 1$$

Solving this equation for the index of refraction in the x and y directions :

$$n_x = n * (1 + n^2 * q_{12} * \sigma_2)^{-1/2} \quad \text{and} \quad n_y = n * (1 + n^2 * q_{22} * \sigma_2)^{-1/2}$$

If these values are inserted into the previous expression of phase difference through the specimen:

$$\Delta \Phi = ((\pi * n^3 * l) / \lambda) * (q_{11} - q_{12}) * \sigma_2$$

With an expression for the phase difference, the transmission of a polarizer plus wave plate plus analyzer assembly on a quadruple pass is expressed as:

$$T = S / S_o = \sin^2 (\Phi / 2) \cong \Delta \Phi^2 / 4$$

$$T = S / S_o \cong \{ [(4\pi * n^3 * l) / \lambda] * (q_{11} - q_{12}) * (F / A) \}^2 / 4$$

It is this expression which is used to validate the experimental method by matching the theoretically determined transmission of a material with known optical properties to that obtained by examining the coefficients of the curves fitted to the experimental data. In addition, this expression is then used to 'back-calculate' the piezo-optic coefficients of a new material using experimentally determined transmission values.

Experimental Apparatus

Throughout the course of the experiment three different optical assemblies were utilized; a Mach-Zender interferometer as well as both a single and double pass variations of birefringence analyzers in order to obtain improved sensitivity and resolution. Throughout this series of experimentation however, several of the experimental components have remained constant.

The light source used for all three cases was a green Helium-Neon laser operating at a wavelength of 543 nanometers. In addition, the specimen stressing apparatus was a spring loaded crystal press. The base and threaded screw head are constructed of a stainless steel, however the frame was made of a plastic. The screw shaft itself was also constructed of steel with a spring loaded tip capable of applying approximately fifty pounds of force over 9-10 full turns. The screw shaft originally contacted a precision machined stainless steel piston with provisions for a sub-surface mounted thermocouple.

Over the early portion of the experiment it became evident that it would be necessary to characterize the performance of the press in order to draw some correlation between the number of turns and the actual load being applied as well as to establish what degree of uniform loading could be obtained using the basic assembly. In order to determine the load/turns relationship in effect, it was necessary to measure the compressive stress being applied at specified radial positions. A 50 pound load cell was enlisted for this task which used a four strain gauge arrangement in a Wheatstone bridge circuit measure load. The strain gauge measures change in dimension of a specimen (a load cell in this case) by passing a small current through a fine conducting wire which is attached securely to the surface of the loaded specimen. Half an amp of current from a five volt power source is put across two legs of the bridge (that is through the strain gauges) and is ultimately measured across the other two legs by a voltmeter. As a load is applied, the gauge and the specimen are deformed, resulting in a change in the resistance since the resistance of a conductor is a factor of, among other things, its cross-sectional area. The change in the circuit resistance is reflected in a voltage reading which may be converted directly into a load value, so long as the value of the shunted bridge is known as well. This value is used in the calibration of the load cell, in conjunction with additional manufacturer supplied calibration constants to account for changes which have occurred in the bridge circuit due to temperature variation, variation in electrical connection quality and so on. It is obtained by inserting a calibration resistor in parallel into the Wheatstone bridge circuit to obtain a shunt calibration value, from which the circuit sensitivity is found and, when multiplied by the transducer (load cell) output, is the applied load in pounds.

Early data readings lead to a suspicion that loading conditions were strongly dependent upon the azimuthal position of the screw shaft and readings obtained from the load cell confirmed this suspicion. The applied load, although linear in its overall trend, is oscillatory in nature about a linear mean value which strongly suggests non-uniform loading conditions. In order to remedy this situation, several damping mechanisms were introduced to the system. In order to eliminate variation in the load application point (suggested by the small circular pattern etched into the top piston face) a two piece piston / shaft assembly was fabricated with a ball spacer between them was utilized and a clear damping effect was observed in the resulting data. In addition, a hard rubber disc was also placed on the bottom face of the piston (which contacts the test specimen) which proved to have a substantial additional damping effect when used in conjunction with the two piece piston. Satisfactory data was obtained with this experimental assembly however for the actual experiment, the load cell was placed in line with the test specimen. This experimental

setup eliminated the need for a load / turns correlation but also precluded the use of the complete damping assembly as there was not enough room in the screw shaft to accommodate both the load cell and the shaft portion of the piston /shaft assembly. The shortened piston along with the rubber padding and the ball-bearing were used in all the experimental runs.

The Mach-Zender interferometer allows the projection of light interference fringes which, when a load is applied are caused to move. This shift in the interference fringes with applied load results in a series of nulls in output intensity which can be expressed in fringe shift per unit load with the below equation and hence, yield the desired piezo-optic constants. In the Mach-Zender the laser is passed through a beam splitter, resulting in two beams of like characteristics. One of the beams is then passed through the test specimen and the two beams are then made to interfere. Destructive interference fringes occur essentially when the 'peak' and a 'trough' of a two photon waves interact and produce a null. Since the two beams travels different path lengths, they are out of phase when they do interfere, the fringes are visible. As a load is applied a fringe shift occurs (a phase difference of 2π corresponds to one whole fringe) but it is often difficult to apply a sufficient load to cause a shift of even one fringe without fracturing the test material. This proved to be true in our case and the Mach-Zender approach to interferometry had to be abandoned in favor of a system with greater sensitivity.

The second experimental arrangement employed light polarization as the measurement tool with which the birefringence was observed. The same He-Ne laser and crystal press were used, but this time in conjunction with a Glan-Thompson prism in order to facilitate examination of photoelastic effects using a birefringence measurement. The Glan-Thompson prism illustrated in figure #5 is made by diagonally cutting a single rectangular calcite crystal, grinding and polishing the cut inner faces and then bonding the calcite wedges together with a small gap. Calcite crystal is an anisotropic crystal which has the property of double refraction when struck by an incident beam. A single laser beam which enters the crystal will then leave it as two beams, not only separated, but also orthogonally polarized. The crystal essentially resolves the incident beam into two perpendicular plane polarized rays due to the crystals birefringent properties. The effect of the Glan-Thompson arrangement of two such prisms is to essentially eliminate one of two incident waves which pass through it. Since the air spacer which separates the two prisms has an index of refraction lower than that of the two emerging beams, the essentially undeflected beam of higher refractive index is removed by total internal reflection at the interface while the beam of lower index of refraction is transmitted.

The now polarized beam is passed through the specimen which if it is unstressed, does not alter the optical path length. The specimen itself acts as a waveplate, breaking the plane polarized light again up into two components. That component with vibrations parallel to the specimen optic axis moves faster through the specimen than that which vibrates perpendicular to it, thus resulting in a difference in optical paths as well as corresponding phase difference. The stressed specimen's optic axis has a single axis of symmetry with respect to crystal form, atomic structure and in this case, the applied stress as well.

The beam passed through the specimen, is reflected, and is passed through a second time. The benefit of this 'double pass' setup (or the 'quadruple pass' used in third and eventually final experimental set up) is to effectively double (or quadruple) the magnitude of the change in optical path length due to the application of the load to the specimen and hence affect a corresponding magnification in phase shift and optical sensor signal intensity. The beam is then directed back into the Glan-Thompson prism where the orthogonally polarized portion of the beam is reflected into an optical sensor with which the return beam intensity is measured. This sensor effectively converts the photon signal of the light into an electrical signal which is expressed as a voltage.

When used in conjunction with a light chopper and a lock-in amplifier, the beam of interest may be modulated at a given frequency by the chopper, and only that frequency signal received by the sensor will be reported by the amplifier.

EXPERIMENT

In order to validate the experimental method, an Er:YAG laser crystal was tested initially. Incremental data readings were taken from zero to approximately fifty pounds - the maximum load of the press and the design limit of the load cell. Next, 'Zero' readings were then subtracted from both the transmission and applied load data and the load data was converted from a millivolt reading into pounds of force using the procedure outlined in appendix A. Using this data, transmission versus load graphs were generated and a theoretically predicted curve fitted to it. As described in the previous section, the transmission of the experimental system being used (polarizer plus waveplate plus analyzer) is given by a sinusoid squared relationship which may be mathematically modeled as a Taylor polynomial. Neglecting higher order terms and fitting the resulting fourth degree polynomial to the data set we are able to obtain an experimentally determined value of transmission, expressed in terms of the independent 'force' variable. The system has been predicted to behave as sine squared and so we expect a very small constant, linear and cubic terms and very large quadratic and quartic terms. Squaring the applied load data values allows us to fit the data to a simple quadratic and by dividing through by the experimentally determined maximum signal intensity (S_0) and the load cell sensitivity, we obtain a result in terms of force squared.

The experimental procedure used in testing the Yttrium Gallium Aluminum Garnet (YGAG) crystal was the same as the used in the previous case however, the data reduction procedure was altered slightly. The overall specimen size was reduced by 75% while the overall length remained the same resulting in greater applied force per unit area. It is then reasonable to expect the resulting data to extend further into the quartic portion of the sine squared curve (the 'peak' of the sinusoid curve if you will) and the resulting curve fit to be dominated by the higher order quartic terms. For this reason the transmission data was first linearized by taking the arcsine of the square root of the transmission and then fitted directly rather than linearly (i.e. $y = b x$ rather than $y = a + b x$). In addition, once the value of transmission has been found it is necessary to determine the YGAG material's refractive index as well. One may then solve for the piezo-optic constants of the YGAG crystal using the aforementioned theoretical determined equation for transmission and the experimentally determined data values.

RESULTS

The following set of result are of the Er:YAG crystal which was tested for the purpose of validating the experimental method and compared with theoretical calculations. The percentage difference between the two results is most likely due to the fact that experimental analysis was performed on an Erbium doped YAG crystal while the theoretical calculations were carried out using the piezo-optic constants of a non-doped conventional YAG crystal.

EXPERIMENTAL LASER TRANSMISSION : $35.8542 \times 10^{-6} F^2$ (#)
THEORETICAL LASER TRANSMISSION : $30.38 \times 10^{-6} F^2$ (#)
PERCENTAGE DIFFERENCE : 15.27%

Listed below is the experimentally determined 'b' coefficient of the applied force over two separate runs) obtained in directly curve fitting the experimental data ($y = bx$), along with the percentage difference between them. Also listed are the experimental YGAG piezo-optic constants (q_{11} - q_{12}) calculated using the data from these two runs along with their percentage difference as well. Finally, the percentage difference is given of the average value of the experimentally determined YGAG piezo-optic constants and that of the YAG crystal which was used previously in the validation of the experimental method.

DIRECT FIT 'b' COEFFICIENT - RUN#1 : 9.33×10^{-3}
DIRECT FIT 'b' COEFFICIENT - RUN#2 : 9.43×10^{-3}
PERCENTAGE DIFFERENCE : 1.06%

EXPERIMENTAL ($q_{11} - q_{12}$) #1: $0.1313 \times 10^{-12} Pa^{-1}$
EXPERIMENTAL ($q_{11} - q_{12}$) #2: $0.1328 \times 10^{-12} Pa^{-1}$
PERCENTAGE DIFFERENCE : 1.13%

($q_{11} - q_{12}$) YGAG / YAG PERCENT DIFFERENCE - 23.18%

CONCLUSION

The transmission data collected during the experimental test validation showed good agreement between the experimentally determined Er:YAG and the piezo-optic constants of non-doped YAG crystal with which it was compared. As stated previously, the presence of Erbium in the experimental sample is clearly a potential cause of the variation in results which was found between the two. A non-doped YAG was not available at the time.

The same test procedure was then carried out on a Yttrium Gallium Aluminum Garnet (YGAG) in order to establish its piezo-optic constant tensor. Significant variation of 23.2% between the piezo-optic constants of YAG and YGAG crystals was found however, the excellent data correlation of separate experimental runs carried out on the YGAG sample - a 1.13% percent difference - certainly bolsters the degree of confidence which can be placed in the validity of these results. Unfortunately, during later experimental runs a crack formed in the YGAG specimen and thus the amount of data collected for this particular specimen was somewhat limited.

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Emergency Operations Center

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ABSTRACT

The Emergency Operation Center (EOC) is a site from which NASA LaRC Emergency Preparedness Officials exercise control and direction in an emergency. Research was conducted in order to determine what makes an effective EOC. Specifically information concerning the various types of equipment and communication capability that an efficient EOC should contain (i.e., computers, software, telephone systems, radio systems, etc.) was documented. With this information a Requirements Document was written stating a brief description of the equipment and required quantity to be used in an EOC and then compared to current capabilities at the NASA Langley Research Center.

INTRODUCTION

Emergencies occur everywhere and can strike anyone. In case of an emergency the response is of vital importance in order to control the situation and preserve the lives of the people involved. To do this in a coordinated manner, guidance, control, and equipment are needed. Here at NASA Langley Research Center emergencies such as natural disasters (hurricanes, tornados, floods, etc.) or manmade disasters (fires, spills, etc.) must be managed in a fast and accurate way to ensure the continuous operation of the center. For this to occur, an Emergency Operations Center (EOC) must be established. In this Center, personnel will need access to the most recent and reliable information when an emergency occurs, so they can dispatch the appropriate personnel and equipment to the site of the emergency. Also from the EOC, all other actions will be directed and controlled in order to proceed in a coordinated way and thereby respond in an efficient and effective form.

The LaRC EOC is located in building 1248, Room 114 and it contains some equipment but the EOC is not totally operational at this point. Some equipment is being bought and other has to be ordered. The EOC will be activated in case an emergency occurs on the center and will remain operational until normal operations are restored.

One of the most important aspects in achieving the objectives of the EOC is its equipment. In order to operate under any circumstances, it has to be well equipped with all the tools necessary to access accurate and on-time information and to communicate with the site of the emergency and off-center. Research was conducted to determine what communication capabilities the EOC should contain in terms of equipment in order to provide it's personnel with the proper tools to ensure the operations at this NASA center.

RESEARCH SUMMARY

The search for information on what makes an EOC effective was not an easy task. There were hardly any written sources of information available when search was performed at the LaRC Library. So the approach taken was to compare LaRC's EOC to EOC's at other NASA centers. Several centers were contacted: Kennedy Space Center, Johnson Space Center and Ames Research Center. Wayne Kee, Emergency Preparedness Planning Officer at Kennedy Space Center, mailed some information about their EOC procedures, a brief summary of their equipment and a layout of their EOC. Robert Gaffney, from JSC, electronically sent their Requirement Document and detailed information on their visit to the Los Angeles County EOC and Consolidated Fire Protection District EOC. John Woods, Ames Research Center, is sending some information on their EOC but it has not yet arrived. In addition to contacting these centers, efforts were made to contact the Federal Emergency Management Agency (FEMA), regional agency. Besides all this, research was done on the Internet-Netscape where general information on Greater Houston Transportation & Emergency Management Center, NACEC (North American Center for Emergency Communications Inc.) Disaster Support Services and Minneapolis Emergency Communications Center was obtained. The fire department at LaRC and the Newport News Emergency Response Team were also visited as part of the research. A main source of information was Doug Smith (LaRC Fire Chief), who is currently working on improving the EOC capabilities.

Because Langley Research Center is located on a high risk area for hurricanes and floods it is very important to have equipment that can give real time information on weather prediction and hurricanes or storms tracking. Additional research was done to determine what would be the best system for LaRC needs. The Kavouras company and the Weather Channel were contacted to obtain information on their equipment and services.

In addition, the Security and Fire department dispatch facilities were joined and will now be located in building 1248. To perform this consolidated function, a console was needed. The AMCO company was contacted and a sales representative came to the Center to recommend the most suitable console for this purpose. Several layouts were submitted by the company and one which met the requirements was bought.

After organizing the obtained information, a Requirements Document was written explaining some general requirements that the EOC must satisfy and the type of equipment it should contain in order to meet these requirements. The approach taken to do this Requirements Document was to consider what the EOC personnel need to do in a specific emergency and then state the equipment that will be required to accomplish this. The Requirements Document for the LaRC Emergency Operations Center is as follows:

REQUIREMENT DOCUMENT EMERGENCY OPERATIONS CENTER

General Requirements:

1. Building construction should be resistive to natural hazards (earthquake and storms) and should be located on a high lying area.
2. The EOC must be able to access the most recent and reliable information dealing with weather conditions, building information, hazardous materials (quantity and storage place), pressure isolation valves, electrical disconnect switches or switch gear and fire alarm sensors.
3. EOC 's personnel must be able to communicate with the people at the site of the emergency.
4. The EOC must be capable of communicating with the City of Hampton or the City fire stations.
5. EOC 's personnel shall be able to send emergency messages throughout the center and activate the sirens from the EOC.
6. To ensure reliable operations of the center, backup power systems and redundancy of communication systems are required.
7. Books, references, and all important telephone numbers should be readily accessible to the EOC personnel.
8. The Center should include mark-up boards and maps of the Center (buildings, roads), to be posted on the Center walls.
9. Personnel assigned to the EOC should be knowledgeable and competent when using the equipment.
10. Drills should be conducted to verify the operation of the center and maintenance and inspection of the equipment should be done periodically.
11. EOC should have a storage stocked with food, fuel and water for personnel remaining without outside contact or should have some sort of agreement with the cafeteria in order to be provided with supplies.

In order to satisfy these general requirements, equipment requirements must be specified and they are as follows:

Equipment Requirements:

I. Telephone Systems:

This is the major system used in receiving emergency calls, communicating off-center and can be used to communicate with personnel at the site of the emergency.

This system includes telephones, cellular phones, a fax machine, a paging system and a dedicated telephone line.

The EOC should contain at least one telephone unit, one Telecommunication Device for the Deaf (TDD) unit and an emergency phone-dedicated line used in case of telephone failure. This dedicated line is a separate phone line that can be used to call off-center. In addition the

EOC must have at least one fax machine and one paging system to contact key personnel. Also, a minimum of five cellular phones should be provided for LaRC operations: Fire Chief, Emergency Preparedness Officer, Office of Environmental Engineering, Head of OSEMA, and Head of Security. Besides all this, being a NASA Center, government telecommunications service, the GETS is available, a system which gives phone call priority service.

Currently there is a telephone unit, a paging system, a dedicated telephone line and two cellular phones in the LaRC EOC.

II. Computer System:

This system includes computers, scanners and printers.

Computers are needed on the EOC in order to have access to the most recent and reliable information dealing with building information, hazardous materials (quantity and storage place), pressure isolation valves, electric disconnect switches or switch gears and fire alarm sensors. Computers should be open architecture which allows linkage to other computers at the center.

The EOC should contain at least three computers, (1) FIRST access-graphic interface with the fire department (2) an INDIGO workstation and (3) a PC. In case of a fire alarm, the FIRST access interface will show the building and room where the alarm was generated on a graphic map. In addition, the interface will tell the number of handicapped persons assigned to a building and any chemicals located there. The INDIGO workstation will be tied to FATBOY. Here the GIS and all the building information may be found. This information includes the master plan of building brochure, online high voltages, gas and water, and the information about safety coordinators and safety heads. Approximate measurements of required monitors are 15", 17", and 21". In addition to the computers; the EOC should have at least one color scanner and two printers.

Currently, on the EOC there is one computer, a PC with the software to simulate the other two, but it is very slow and cannot run at the same time. The EOC also includes one black/white scanner and two HP laser jet printers. Also the following networks and software are currently available or accessible on the computer of the EOC.

Networks:

- * larcnet-main system
- * fatboy-GIS, building information
- * harvie-material tracking system, Bionetics server will show the hazardous material and chemicals on the center.
- * DOD material tracking system
- * clairborne-OSEMA sun workstation
- * longstreet-network server tied to nas
- * nas-lessons learned, IEEE parts and world wide interface
- * gidep(Government-Industry Data Exchange Program)-very similar to nas
- * neonet

Software:

- * ARCINFO-imaging language, building brochure it is similar to CAD but better.
- * EXCEED-workstation simulator, turn PC into Sun workstation
- * VGAS-fire alarm graphical display, language for the FIRST access

- * PROLAB-material tracking system used for harvie
- * GIDEP(Government-Industry Data Exchange Program) -own software
- * AUTOCAD

The EOC should contain it's own license for ARCINFO, the latest version of AUTOCAD and software for the INDIGO workstation if needed.

III. Mobile Communication System:

During an emergency, personnel should respond and arrive at the site as quickly as possible. Emergency personnel must be equipped with the necessary equipment to communicate with the EOC or outside the Center if needed. People at the site must be able to have access to the information on the computers in the EOC and send back information to the main computers.

This system should include a portable computer, fax machine, printer, telephone and a scanner (smart case). Also required for this system are cellular phones and a radio system.

Currently there is one "smart case" available on the center but it is only functioning partially, there is access to the main computer but cannot execute programs yet.

The radio system is important for communications with the emergency site and off-center in the event of telephone failure.

This system includes handheld radios, base unit and dedicated handheld radios. The dedicated handheld radios are to be used only by the EOC personnel during an emergency, they serve as a backup system for the regular handheld units.

The EOC should contain at least one base unit, four dedicated handheld radios and approximately 20 units of handheld radios. The radio system should also include a repeater radio system. This allows the user to not to have to go through the base unit in order to communicate to another user, with a 35 miles radius.

Currently there are available the 20 units of handheld radios and a base unit but these are of an older type that have a 10 miles radius and need to go through the base unit to contact another user.

IV. Power Backup System:

In case of an emergency the EOC should be able to operate under any circumstances.

Diesel power generators are required in order to provide power for the EOC 's equipment. Because diesel generators have a three-second lag time, battery backup is also needed. An unlimited power supply, for computers and other equipment without battery backup should be included.

Currently everything in the EOC and fire department has backup from diesel generators which are located behind the fire station in building 1248. These diesel generators will last for hours and once running out of power a fuel truck will supply fuel that will last for weeks.

V. Weather Station:

The LaRC center is located in a high risk area for hurricanes, floods and tornadoes and therefore these natural disasters are more likely to strike this center. Because of this, it is very important for the EOC to have some equipment that can help its personnel have access to the

most recent information on weather conditions; in order to alert the NASA community working here and to take the necessary steps to prevent any fatal outcome that may occur.

The EOC should have equipment that can give real time information on weather prediction and hurricanes or storms tracking. The Kavouras company offers some equipment to meet these needs. Probably the two that can best suit our needs are the RADAC 2100 or VISTA 1500. The RADAC 2100 is a multitasking, on duty, 24 hours a day weather workstation that gives nationwide real time access to weather information and the VISTA is a weather briefing station, quick one touch that gives rapid reviews in real time.

Currently the Weather Channel is available on the center and information can be obtained from the Internet.

VI. Other Equipment:

This includes some other specifications or equipment that is not available now at the EOC.

EOC's personnel should have access to an emergency broadcast system (EBS) as a way of alerting the people throughout the center and giving them directions in case of an emergency.

The EOC should also contain the following:

- TV and VCR

- AM/FM radio, batteries

- At least four units of rechargeable flashlights

CONCLUSION

Because of lack of time, this project was not totally finished. The research or search for information took longer than expected so the project was delayed. Once finished with the Requirements Document, layouts have to be made of the EOC in order to distribute the equipment in the most favorable way.

Through the research conducted a good deal was learned on emergency response. The EOC plays an important role in this and if properly equipped, can help minimize the loss of human life and property damage. In conclusion, although we are now in the process of updating the EOC, once finished, it will contain state of the art equipment that will help its personnel control any emergency on the Center.

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1995 LARSS TECHNICAL REPORT

**NASA LANGLEY TEACHER RESOURCE CENTER (TRC):
BROCHURE AND HOME PAGE DESIGN**

by

Monet Leigh Cogbill
1995 LARSS Participant

Marchelle D. Canright, Mentor

Office of Education
NASA Langley Research Center

ABSTRACT

The NASA Langley Research Center's Educational Programs Officer, Marchelle D. Canright, gave me two main assignments to be completed by the end of the ten-week LARSS Program. These assignments were to redesign the NASA Langley Teacher Research Center (TRC) brochure and create new home page templates for the TRC and Office of Education. I worked with NASA Education Specialist, Jane George and the TRC director Nick Koltun for instruction in completing these assignments. The main objective of my assigned projects was to create designs that reflected NASA's educational goals, related to the TRC, and the Office of Education's desire for high aesthetics in their multimedia materials. The Office of Education did not just want their current TRC brochure and home page to be reworked, but; they wanted these items to be strong visual representations of the TRC's purpose.

1995 LARSS TECHNICAL REPORT

The NASA Langley Teacher Resource Center (TRC) was established to provide educators immediate access to information generated by NASA's programs, technologies and discoveries. Any design for a TRC brochure or home page will have to represent this purpose. NASA Langley Research Center's Education Programs Officer chose me to complete assignments of redesigning these items based on my field of study, graphic design, and the creativeness of portfolio work. As a designer, I have the desire to present ideas that meet the client's expectations using my personal design style. I like to think of this desire as the designer's desire.

I approached redesigning the TRC brochure as if it were a puzzle. All the pieces were laid out for me; I just had to put them together. The pieces I had to work with were the NASA logo, the TRC logo, the Virginia Air and Space Center logo and a wealth of information about the TRC's purpose and services. Simplicity was my goal. I wanted to make the pieces fit perfectly without many useless graphics and jargon. I spent a week at the TRC to get a feel for its system of operation and how the director carried out NASA's purpose for Teacher Resource Centers into an everyday procedure.

I developed three ideas for the new brochure's design. The first idea used the same apple from the original TRC logo and the Virginia Air and Space Center logo, which were linked together, along with the NASA logo, by an airplane. The airplane flies around each logo and symbolizes learning about sciences, math and engineering. The second idea still involved an apple, but this apple was created from the intertwining silhouettes of children's faces. The apple still symbolized educators and the children symbolized learning. The other logos were separated from this new logo and placed in areas where their importance could still be understood. The last idea was to use the logos simply as small graphic elements and illustrate the purpose and services of the TRC using cartoon-like pictures. These pictures involved a teacher visiting the TRC and learning how she could use its materials in the classroom.

The first idea was approved for the brochure design because it truly brings all the pieces together in a way that symbolizes the purpose of the TRC. At the Virginia Air and Space Center, the TRC provides educators the opportunity to use NASA print and multimedia materials related to science, math and engineering for the enhancement of their students learning. The design says all this with visual words.

My approach to designing the home page was creative than precise. A home page design is more visual than verbal. It does not have to say anything, but needs to capture the eye of the viewer. So if someone happens upon the TRC home page, they will be drawn in by the visual. Once you have a viewer's interest on a home page they will more than likely stay to read the information.

I spent the first week of the program surfing the Net to research the basic elements and styles of home pages. The home pages that caught my eye were not necessarily the ones dealing with information I was interested in. I was attracted to their design. The differences in these home pages are plenty of bright color, complex clickable graphics and interesting headings with icons. I knew my design would need to incorporate all these things to be successful. I was advised as to the basic layout of the TRC home page, and from this guide I began creating. The result of this creating is a home page with a series of airplanes in the background, a clickable graphic at the top that introduces the TRC and several smaller clickable icons that provide visual links to other information.

The designs for the TRC brochure and home page were computer generated. For the brochure, I used the computer illustrating software Illustrator 5.5 that allows a designer to create images and layout type within the same program. I created the images for the home page using Photoshop 3.0 and Illustrator 5.5. Photoshop allows you to manipulate photographic images using photographic and illustrating techniques. I made a comp of each final design to show how

each should look when actually produced. The printer will use a comp as a guide in printing the brochure, and the home page programmer will use a comp as a guide to putting the home page together.

I am very appreciative that I was set up in Graphics with a computer, printer, and other materials to complete my assignments. Working in such an atmosphere with advanced equipment and graphic design experts for guidance enhanced my creativity and total LARSS Program experience.

I believe the designs I created for my assignments are successful in representing the NASA Langley Teacher Resource Center's purpose and services. Ms. Canright and Dr. Massenburg are pleased with the outcome of my assignments and their pleasure satisfies my designer's desire.

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Precollege Science Education:
*Development of Distant Learning Laboratory
and Creation of Educational Materials*

Student: *Michelle Considine*

Mentor: *Marchelle Canright*

Office of Education

Abstract

The Office of Education's fundamental goal is to disseminate information, mostly that which relates to science and technology. In this attempt, as I have observed, the Office has many programs bringing both students and teachers to NASA Langley to expose them to the facilities and to teach them some about the scientific theory and about available modern technology. As a way of expanding the audience that can be reached, as the expense of bringing people in is limiting, Marchelle Canright has proposed establishing a center dedicated to researching and producing distant learning videos.

Although distant learning through telecommunications is not a new concept, as many universities, colleges, and precollege level schools offer televised courses, the research in this field has been limited. Many of the standing distant learning broadcasts are simply recordings of teachers in classrooms giving lectures to their own students; they are not aimed at the television audience. In some cases the videos are produced without a Live-lecture atmosphere, but are still only classroom lectures. In either case, however, the full range of capabilities of video production are not being fully utilized. Methods for best relaying educational material have not been explored. Possibilities for including computerized images and video clips for the purpose of showing diagrams and processes, as well as examples in fitting cases, may add considerably to the educational value of these videos. Also, through Internet and satellite links, it is possible for remote students to interact with the teachers during televised sessions. These possibilities might, also, add to the effectiveness of distant learning programs. Ms. Canright's proposed center will be dedicated to researching these possibilities and eventually spreading the results to distant learning program managers.

This is the project I was involved in over the summer. As implied, the center is still at the foundation stages. Ms. Canright has proposed four or five possible series that could be developed, each one aimed at a specific age group of students, or group of teachers. I was involved in the design of the series aimed at the youngest children, the Picture Book Science series. My involvement included proposing and researching topics, writing a lesson for the first show, writing the latter portion of the picture book story (the part including the scientific lesson), and illustrating the story. I also designed and collected the materials for the Learning Center's television studio set as well as finished the painting of the main backdrop panels.

LARSS Report

Allowing the abstract to be an integral portion of this report, I will not redescribe Ms. Canright's proposed distant learning center, but will instead, lead directly into my involvement with the center as a LARSS intern. My range of involvement covered several areas. To explain these, I will first list them, and then expand each one:

Design, collection of materials for, and construction of TV studio set.

Picture Book Science development:

- Propose topics that will align with NASA's research emphases along with the National Science Educational Standards curriculum guidelines.
- Create the first lesson- including the fundamental scientific concepts to be covered, a general lesson on the subject, as well as a list of activities demonstrating the principles.
- Integrate the scientific concepts into the children's story by writing the latter portion of the story.
- Visually create the nine characters in the story which Kenneth wrote.
- Illustrate 33 pictures for the children's story.

Studio Set Design and Construction:

The studio set design and construction involved several steps. The first step was establishing what the possible purposes of the set would be; the intended use would dictate the desired features as well as the constraints. The video equipment is currently being assembled in a studio located in the Office of Education's building. The capabilities will include being able to video a large television screen which can be fed by both video clips and computer images. Both prerecorded and live broadcasts will be developed. As part of my set design proposal I included this report:

Learning Laboratory Set Design Proposal July 5, 1995

The following video studio set design was created with the goal of meeting the Office of Education's diverse needs. By presenting a strong visual background that can easily be altered in both imagery and mood, the set will be useful for situations ranging from formal lectures on educational theory, to active demonstrations of scientific principles, to recorded conversations between two experts on a certain topic.

- Bold design adds a sense of sculpted space.

A backdrop should serve the purpose of defining a space for the lecturer, or group of people being recorded. It is important that the set reflect the content and purpose of the program, but that it not distract the audience from the information being presented. For this reason, I have designed a bold, interesting set of lines and spaces, but kept the overall picture uncluttered, free from permanent images and visual business.

The presented set's colors and spaces are designed to support a variety of topics and presentation styles

including:

- *outer space*, for lectures on space topics
- *the atmosphere*, for lectures on aeronautics or atmospheric sciences
- *abstract architectural setting*, for less formal discussion groups on various topics such as approaches to dissemination of scientific and technological information.

- Free standing panels.

The backdrop will be made of free standing panels. This allows for:

- mixing and matching of the panels to create desirable visual effects.
- portability of the set; it can be set up on stages in schools or other facilities such as the H.J. Reid Center.
- sizing of the overall set; two or three of the panels can be used to create a backdrop for presentations including live seminars or prerecorded narrated introductions to informational videos.

- For use with or without TV screen.

The TV screen can be used to show a stationary computer generated logo or image, used instead of a flip-chart or over-head projector, and can be used to show video clips during a presentation. The TV can show images loaded from the computer or the video equipment. However, when the TV is not desirable in a presentation, or the set is taken somewhere out of the studio, the panels are simply moved closer together.

- Modular Furniture for versatility.

Using light weight, interchangeable pieces, furniture such as display tables and benches, a podium, and a conference table will be easily built to suit the specific needs of each show produced in this studio.

- Multi-purpose studio set.

The topic of the video will be specified or emphasized by the imagery added to the set by hanging "cut-out" logos or images, projecting images on the TV screen, and displaying models or demonstration materials.

The intended purpose or mood of the video can be specified or emphasized by the geometry of the panels, as demonstrated below, the TV images, the cut-out images, the choice and positioning of furniture, as well as other set accessories such as plants or flags.

As described in the report, free-standing, interchangeable panels are what I proposed. As part of this proposal a complete set materials list and an estimated cost were included.

Upon acceptance, I consulted with a man from Engineering and Construction Services, Ralph Angel, who offered advice on the design of the panels as well as help in the construction of them. His help is greatly appreciated. After the panels were built, I proceeded to paint them. The furniture is still under construction but the materials are collected and the plans are drawn.

Picture Book Science Development:

Ms. Canright's Picture Book Science series was at the beginning of the design stage when I entered the project. All that was written is that the series would consist of eight half hour shows, each featuring a children's story, a science lesson, and an introduction of an activity which the children could pursue after the video at school or at home. This left a lot of room for creativity.

I spent the time during the first weeks of my LARSS internship brainstorming topic ideas and preparing the fundamental content that would be included in those. The following is a list of the topics I proposed:

TOPICS FOR PICTURE BOOK SCIENCE SERIES:

AERONAUTICS:

PROPULSION OF AIRPLANES:

- propellers: pushing on the air, (friction required)
- jets: expansion of compressed gases, (conservation of momentum)

LIFT & DRAG:

- forces involved in flying; discuss both flat plates and airfoils
- discuss similarities and differences
 - both deflect air downwards and conservation of momentum requires, then, that they go upwards.
 - they send air downwards by different methods.
 - flat plates: push air downwards from the bottom
 - airfoils: suction redirects air downwards by keeping it attached to the curved wing surface
- other possible features to include in lesson:
 - shape of wings, friction on wing, attached flow of air across wing, speed of air flow, pressure differential
 - conservation of energy, (how kinetic energy and rotational energy are both involved in lift)

CONTROL SURFACES and CENTER OF MASS:

- note historical challenge this posed to the development of flight
- discuss flaps, rudders, and other control surfaces
- discuss how the center of mass can change the pitch

HISTORY OF HUMAN FLIGHT:

- human fascination in flight throughout the world and history
 - myths, art work, folk lore
 - why humans can't strap on wings and fly (distribution of musculature of birds vs. humans)
 - first attempts at flight (balloons)
 - first attempts at heavier than air flight
 - first successes: Lilienthal, the Wright Brothers, Langley
 - how fast flight has taken off (grown in popularity and availability) compared to the time it took to get off the ground!

SPACE:

ROCKET PROPULSION (Expansion of mass vs. the use of friction):

- describe the physics of propellers, that they push on the air much as a tug boat pushes on water, or you push on the pavement when you run.
 - friction required for this type of thrust
- explain that in space there is no air to push on; there's nothing!
 - if rockets can't push on anything, how do they go forward?
 - have to burn fuel
 - the expansion of compressed gases sends them forward
 - actually relates to expansion of mass
 - this is conservation of momentum

GRAVITY and ORBIT:

- gravity as a force
 - relative factors
 - distance between objects
 - mass of each object
- orbit: (a balancing of the involved forces)
 - inertial tangential force vs. gravitational force

ATMOSPHERIC SCIENCE:

CLOUDS:

- what they're made of:
 - particles on which they form
 - water vapor
- effects on climate:
 - HUGE cooling effect:
 - reflecting sunlight back into space
 - (reflecting high energy radiation back to space)
 - HUGE heating effect:

- trapping heat given off by the earth
- (reflecting low energy radiation back to the earth)
- the NET effect is a SLIGHT cooling one
- effects of pollution on clouds:
 - spewing more dust particles into space allows more cloud droplets to form; (cooling effect)
 - particles also trap heat which causes evaporation of clouds; (heating effect)

HOW DO WE KNOW WHAT WE BREATHE? (Spectrometry)

- explain how tall the atmosphere is and that it is hard to collect samples going all the way up to space
- introduce a method used to collect information about our own atmosphere, spectrometry:
 - a device (spectrometer), from the ground, looks up into the sky and records the exact "color" (wavelengths) that it sees coming from the sun
 - an orbiting satellite with this same device also looks up into space and records the exact "color" that it sees coming from the sun
 - the two "colors" are compared
 - the difference is due to the gases in the earth's atmosphere
 - in labs, the color of gases can be recorded
 - then you can tell which exact gases and how much are in the air.

I focused my efforts on studying the fundamentals of lift, which would be the topic of the first book. I studied from Naval Aviator's Aeronautic Textbook as well as other books from Langley's technical library. I also discussed the principles at length with a NASA scientist, Geoffrey Considine.

Pulling out the fundamental ideas of something as complicated and subtle as lift proved to be the most difficult part of the process. I am now convinced that the reason lift is not taught until college level, and even then only a mathematically modeled version, is because the actual physics is so subtle. Explaining the *physics* in a manner that would reach even K-3 graders became my goal. Brainstorming for demonstrations accessible to all teachers and children was also a central part of this process.

Another part of the process of science lesson design, was to study the National Science Educational Standards. This book gave me a sense of what the children were capable of as well as what their teachers would be focusing on in their lessons. The goal for the videos should be to present different material but at an appropriate academic level.

In searching for the pre-published children's books that would lead into the science lessons by sparking the children's interests in flying, space, or clouds, we realized that none completely suited our needs. This led the other LARSS student, Kenneth Smith, and I to writing and illustrating our own. Kenneth wrote a story about eight children which brought up questions on the similarities and differences between kites and planes. I decided to write an ending to the story that would answer the questions on the mechanisms of both kite (flat plate) and plane (airfoil) lift.

I also illustrated story. The illustrations took me a large part of the summer as the eight children and their teacher were of widely varying ethnic backgrounds, which required some time learning to draw in an obviously differentiating manner. Upon visually creating the eight children and the teacher, I did 33 illustrations for the story. The drawings are black ink on white paper, a technique chosen for a several reasons. For one, the technique is relatively fast compared to such techniques as paints or pastels; children's books of this length would tend to take a year to illustrate if these more drawn out techniques were used. Also, the images can be easily scanned into the computer, which will be ideal for making a video out of them. The studio, with the silicon graphics computer, will have the capability of digitally editing the illustrations into the video. The

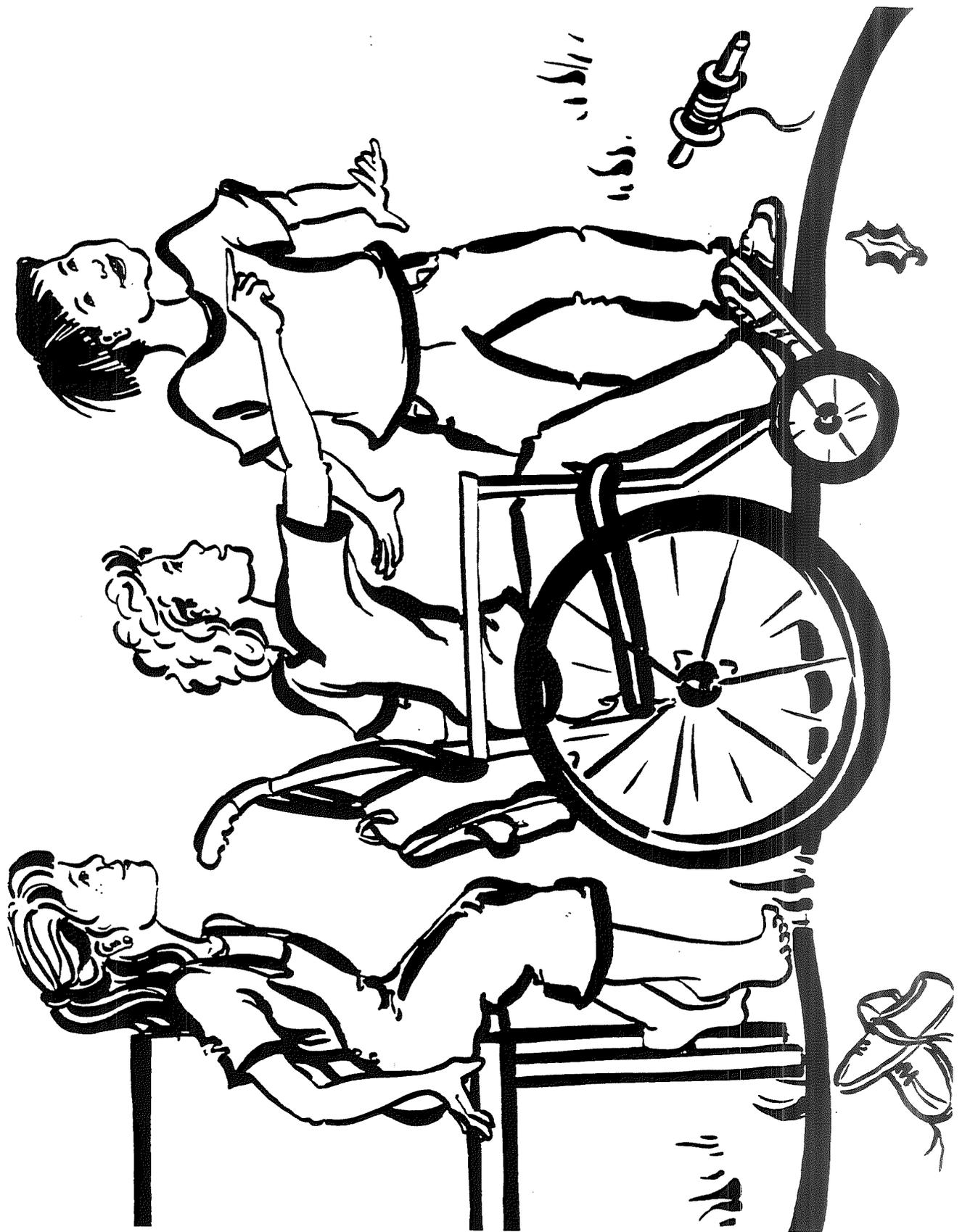
coloring of the illustrations also proves to be ideally done on the computer. To get extremely vivid colors, transparent ink is the best option. The visually smoothest way to apply ink is through a printer. By coloring the scanned black and white drawings with the computer, and then printing them, truly bold illustrations will be created if hard copies are desired. As I will mention further on in this report, publishing a book out of the story and including the science lesson as an insert or integral part of the book would allow teachers to create this lesson live in their classrooms, or more deeply instill the lesson by reviewing the material with the children multiple times. Examples of the black and white illustrations are included as an appendix.

The science lesson following the story will elaborate upon the ideas which were briefly explained in the story. Demonstrations of the principles will allow the children to relate the principles involved in such phenomena as lift to occurrences that are visible in their everyday lives; the demonstrations will help the children to assimilate the ideas. Also, activities which the children can pursue afterwards in school or at home will be presented and explained.

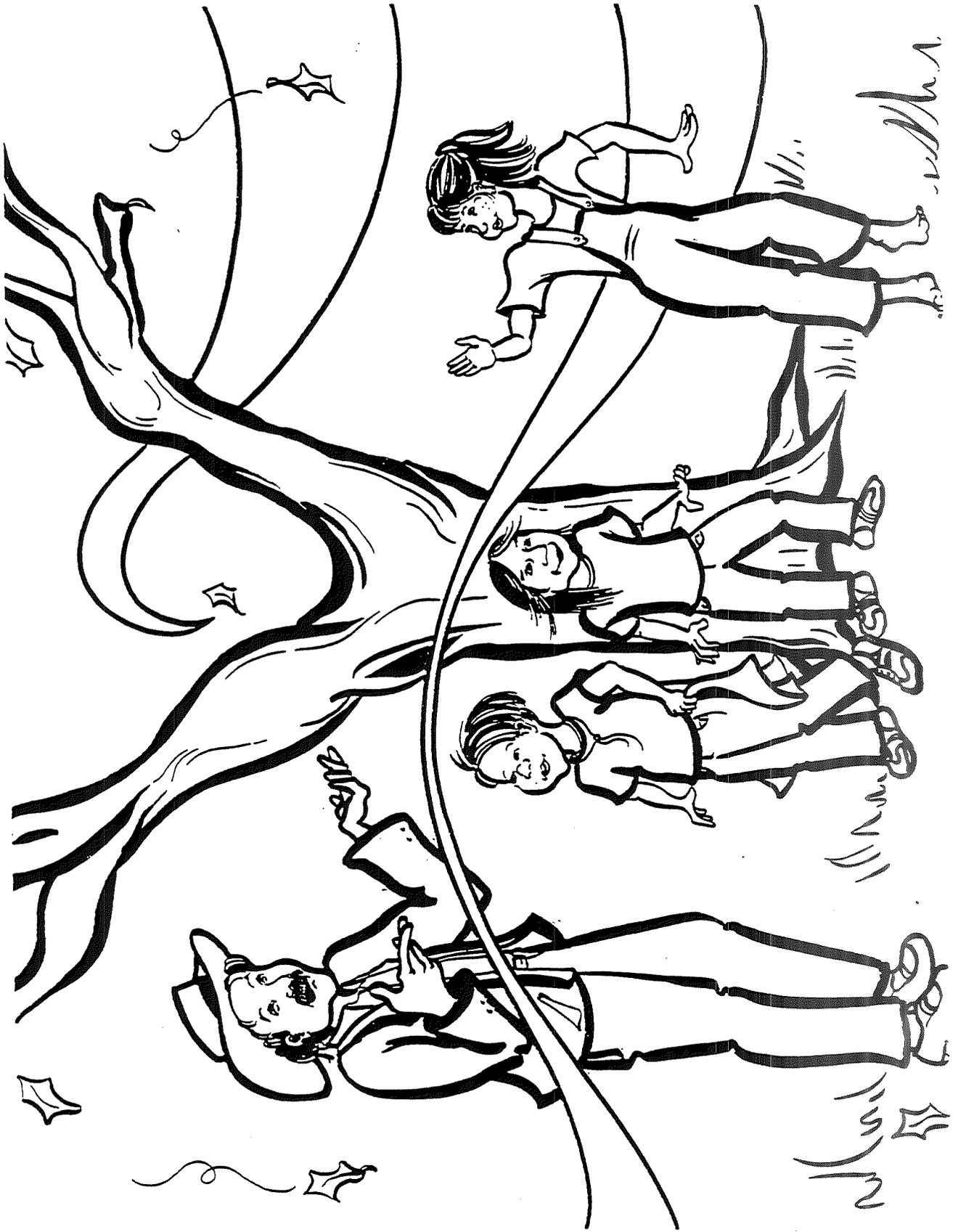
I have prepared a general lesson on the similarities and differences of lift between kites (flat plates) and planes (airfoils). The lesson still needs to be modified (simplified) for the use of it at the K-3 grade level. I have, however, already gathered ideas for the demonstrations of the principles of lift for airfoils and flat plates.

Now that the prototype for the Picture Book Science series is nearing the polishing stages of the content, I can see two other possible uses of the created material, uses that would align with the Office of Education's goals. For one, as mentioned, the story and illustrations could be published in book format with the corresponding expanded science lesson, demonstration ideas, and activity ideas included either as an insert or as an integral part of the book. Another use of the prepared material would be to share it with the teachers who visit Langley's Office of Education every summer as a way of preparing them to teach the material to their students.











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The OEOP Duties of Reasonable Accommodation

Angela Coppedge

Vivian Merritt

Office of Director/ Office of Equal Opportunity Programs

Abstract

1. I was fortunate enough to be assigned two assignments during my ten weeks here at NASA's Langley Research Center, in the Office of Equal Opportunity Programs (OEOP). One of my projects gave me the chance to gain experience in developing calculation formulas for the EXCEL computer system, while my second project gave me the chance to put my research skills and legal knowledge to use.

2. The function of the OEOP is to ensure the adherence to personnel policy and practices in the employment, development, advancement and treatment of federal employees and applicants for employment. This includes veterans and disabled as well. My initial project involved the research of hiring and promotion among the different minorities and females employed here at Langley.

3. The objective of my first project was to develop graphs that showed the number of promotions during the past five years for each minority group here on the Center. I also had to show the average number of years it took for each promotion. The objective of my second and main research project was to find and research cases regarding the reasonable accommodation of disabled workers. The research of these cases is to ensure that individuals with disabilities are provided the necessary accommodations that are essential to the function of their job.

Body

The data needed for the graphs was extracted from Personnel Data Runs. This data listed all the hirings and promotions from 1990 through 1994. Each employers' grade, race, and gender was also shown. My job was to calculate the average number of years needed for a promotion within each race/gender group. This was done by developing an EXCEL formula that would total up the number of promotions for each group, and then average the actual time experienced for each promotion. I then developed a graph, for each fiscal year, that detailed the number of yearly promotions and the average number of years it took for each promotion. Through trial and error, I discovered that the easiest way to develop the graphs was through Microsoft Word. With this system I was able to control the design of the graphs, and produce a more informative and effective linear representation.

The results of my work conclusively showed that the promotions of minorities and women are not compatible to their representation here at Langley. Most would argue that the disparity is due to a higher number of male employees, however I found that after women and minorities are hired they must wait twice as long as white males for promotions.

For my major research project I had to find and study court cases and information with relation to the reasonable accommodation of disabled workers. The facility used most often was the Chief Counsel Office in Building 1195. I used their law books to do preliminary research involving U. S. Acts and codes, and then pulled up recent court cases from the LEXIS, and PERSONNET computer systems. These systems can be used to obtain the background and decisions of either specific cases or cases regarding a certain subject matter. My main goal was to present new requirements and rulings that have become precedential setting due to the decisions of more recent court cases. Through my analysis, I was able to assist the OEOP in their perpetual efforts to assure reasonable accommodations to the disabled workers that they represent. They want to afford accommodations that provide an equal employment opportunity, however this accommodation can not create an "undue hardship." Therefore, the OEOP office must look at the difficulty of providing the accommodation, as well as the cost of the accommodation in relation to the employer's resources. This is of extreme importance when considering the financial strains that have been placed on NASA and its employees.

My final result was over 200 pages of information. This information includes 11 cases, and numerous acts and codes. With this project I was able to obtain knowledge about the legal aspect of the equal employment opportunities that not only affect disabled workers, but of which all workers are entitled.

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Validation of Global Climatologies of Trace Gases Using NASA Global Tropospheric Experiment (GTE) Data

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August 8, 1995

ABSTRACT

Methane is an important trace gas because it is a greenhouse gas that affects the oxidative capacity of the atmosphere. It is produced from biological and anthropogenic sources, and is increasing globally at a rate of approximately 0.6% per year [Climate Change 1992, IPCC]. By using National Oceanic and Atmospheric Administration/Climate Monitoring and Diagnostics Laboratory (NOAA/CMDL) ground station data, a global climatology of methane values was produced. Unfortunately, because the NOAA/CMDL ground stations are so sparse, the global climatology is low resolution. In order to compensate for this low resolution data, it was compared to in-situ flight data obtained from the NASA Global Tropospheric Experiment (GTE). The smoothed ground station data correlated well with the flight data. Thus, for the first time it is shown that the smoothing process used to make global contours of methane using the ground stations is a plausible way to approximate global atmospheric concentrations of the gas. These verified climatologies can be used for testing large-scale models of chemical production, destruction, and transport. This project develops the groundwork for further research in building global climatologies from sparse ground station data and studying the transport and distribution of trace gases.

INTRODUCTION

The concentration of methane (CH_4) in the atmosphere, an important greenhouse gas, is currently increasing at the rate of approximately 0.6% per year [Climate Change 1992, IPCC]. Table 1 shows the global sources of methane. Between 356 and 875 teragrams (Tg, 10^{12} grams) of methane are produced globally each year. Of this amount, as shown by the table, between 240 and 575 Tg are produced from anthropogenic sources. This amount constitutes 2/3 of all methane emissions globally. Because the concentration of methane is steadily increasing, and anthropogenic sources are such a large fraction of total production, it is important to understand man-kind's impact on the atmosphere. In order to aid in this understanding, it is shown that it is possible to determine global methane concentrations using sparse ground station data.

The basis of the project lies in methane measurements obtained from two sources. The first data source was the NASA Global Tropospheric Chemistry Program (GTCP), which was developed in recognition of the central role of tropospheric chemistry in global change. Its goal is to promote an understanding of the troposphere and to assess the susceptibility of the global atmosphere to chemical change. One component of the GTCP is the Global Tropospheric Experiment (GTE). Focusing on the study of the global troposphere, GTE consists of a series of airborne field experiments designed to (1) evaluate the capability of instrument techniques to measure concentrations of key chemical species in the atmosphere, and (2) systematically address tropospheric chemistry issues relevant to global change. The GTE project has encompassed four major airborne experiments: (1) the Chemical Instrumentation Test and Evaluation (CITE) experiments were conducted to evaluate the measurement techniques of some atmospheric gases; (2) the Atmospheric Boundary Layer Experiment (ABLE) explored the atmospheric boundary layer above major ecosystems that are known to influence global chemistry; (3) the Pacific Exploratory Mission-West (PEM-West) examined the impact of natural and anthropogenic emissions over the Pacific Ocean; and (4) the Transport and Chemistry near the Equator in the Atlantic (TRACE-A) investigated the distribution of trace gases over the tropical south Atlantic.

The second data source was the National Oceanic and Atmospheric Administration/Climate Monitoring and Diagnostics Laboratory (NOAA/CMDL). In April of 1983, NOAA/CMDL expanded its air flask sample analysis to include the collection and study of methane in the atmosphere. Globally, there are 27 permanent ground sites dedicated to this study. The Global Cooperative Air Sampling Network, which includes 44 total sites, collects samples approximately once per week (see Figure 1). All of these samples were analyzed for methane and referenced to a standard scale at the NOAA/CMDL laboratory in Boulder, Colorado. This data is now available via electronic archive.

The LARSS project involved data reduction and analysis of data from NOAA/CMDL and NASA/GTE. From a public database, NASA/GTE and NOAA/CMDL data were obtained. Using information about the ground stations and the measurements taken there, global contour plots of methane levels were constructed. The findings show that this low-resolution data can be smoothed and produce an accurate representation of global methane levels. The basis of the project lies in the verification of this contouring method. In order to verify the routine, NASA/GTE in-situ flight data was used, and its findings were compared to those generated by the contour plots. It is shown that good climatologies can be made using NOAA/CMDL ground station data, and that the high-accuracy and resolution in-situ aircraft data from the NASA/GTE missions can be used to validate the smoothing and contouring routine.

DESCRIPTION OF DATA

The average values for monthly methane levels were obtained from the NOAA/CMDL data archive for the years 1991-1993. A 72 by 36 array was used to represent a 5° by 5° global grid. Because the data was limited, many missing points needed to be replaced. To calculate these missing points, the program Spyglass Transform was used. This routine replaced the missing methane values with values interpolated from those that did exist. The weighted fill method was used to determine these missing data points. It replaced the missing data with a weighted average of the real data within a certain range (8). A spherical distribution model was used, in which the weight dropped off as the reciprocal of the distance squared ($1/d^2$) from the missing data value. The weighted fill was run twice more on the new arrays created, both with a range of 4. The defined data points were preserved so they would not be lost during this process. The final array created a global climatological map of methane with no missing data points. Some sample plots are shown as Figures 2-14, in which the low values of methane are indicated by blues, intermediate values are green to orange, and high values are red.

The data files for the various GTE missions were obtained by electronic means from the Distributed Active Archive Center (DAAC) at the NASA Langley Research Center. For each flight, methane levels were measured and recorded every five seconds. This high resolution data were then time correlated with flight navigational data, and the CH₄ measurements were separated into 5° by 5° blocks and the number of CH₄ samples taken in each block, their average, and their standard deviation was then calculated.

The key step in this process was to verify the validity of the smoothed contour plots. To do this, a correlation between the NOAA/CMDL ground station data and the in-situ GTE flight data needed to be found. Since there was no set program to make these comparisons, necessary IDL routines were developed on a DECstation 5000/200. The code produces graphs of each global area studied, comparing the flight data to the ground station measurements. This routine helped in making analyses for the objective.

DISCUSSION

Some measurements taken during some of the flights exhibited unexpected variations. During Flight 4 of the PEM-West A mission, which went from the Ames Research Center in California to Anchorage, Alaska, the methane measurements showed a sharp decrease at approximately 2100 GMT (see Figure 15). But at this same time the plane increased its altitude to over 35,000 ft., and a decrease was observed in some other trace gas species being measured. A significant increase in ozone concentration also occurred at this same time. This simultaneous increase in ozone, and a decrease in other trace gases indicates that the flight entered the tropopause and possibly the stratosphere. In this example, further evidence was provided by a temperature profile taken as the plane descended from an altitude of over 35,000 ft. to approximately 1500 ft. This profile showed a decrease in temperature with decreasing altitude from 35,000 ft to about 30,000 ft., which is characteristic of the stratosphere. Since data taken while the flight was not in the troposphere would not be representative of tropospheric methane levels, this data was excluded from the analysis and comparison with the globally contoured methane levels.

RESULTS

In general, the contours produced using the NOAA/CMDL ground station data compared favorably with the flight data from GTE. Figures 16-18 show some of these comparisons. The contour lines usually showed a 10-30 ppb higher methane concentration than the levels determined from the flight data. The contoured methane levels show the same trends seen in the flight measurements. In Figure 18, from PEM-West A Flight 4, it can be seen that methane levels increased by approximately 72 ppb during the flight and while the contour data show a 47 ppb change.

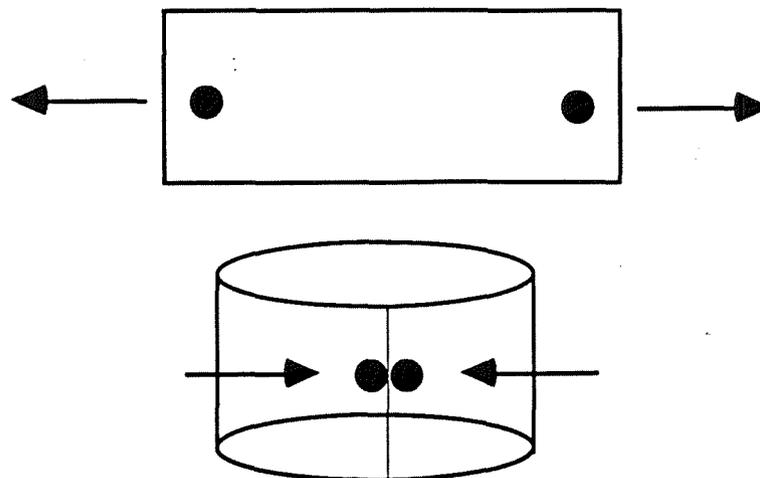
Figure 19 shows a plot of latitude versus the difference between the predicted and measured methane levels. It can be seen that the difference between the predicted contour and the measured flight data varies with latitude. At about 10°-15° N the average difference is approximately zero, while above and below this latitude the predicted levels are higher than the measured concentrations. In PEM-West A Flight 4, for example, the difference between the two methane values started out at approximately 35 ppb at the beginning of the flight and decreased to approximately 10 ppb at the end of the flight. A compilation of all the flight measurements taken showed that the average difference between measured and predicted values at the 40°-50° N latitude (the flight's starting point) was 23-33 ppb and that the average difference between the values at the 55°-65° N was 8-20 ppb.

One point to consider is the global variation of methane versus errors in calculation. On average, based on the actual values determined, there was a bias of 10%-20%. When looking at global variations of methane (see Figures 2-13), it is noted that there is a consistent concentration of 1650-1800 ppb. Therefore globally, there is an error of magnitude of approximately 20%. The average difference between the flight data and ground station data then becomes significant when considering global variations. For example, from season to season and from pole to pole, one can expect to see a maximum variation of approximately 200 ppb. Thus, if an error of over 20 ppb were found, one can deem the calculation inaccurate. If a constant bias of approximately 10-20 ppb were removed from all of the comparisons, this method of producing global climatologies and their verification using in-situ flight data becomes more accurate.

CONCLUSIONS

Several issues remain to be examined from the project. It is noted in Figure 4 that the difference between the contours and the measured flight data varied with latitude. The graph shows a "double-hump" distribution of values, with a minimum value at 10°-20° N. The cause of this "double-hump" can be explained by examining both Figures 1 and 19. At 10°-20° N, there are virtually no ground stations. Therefore, one can predict that measurements in that area obtained from the smoothing process will be somewhat inaccurate. In order to compensate for this, it would be beneficial to place further ground stations in Africa, South America, and northern and central Australia. This would dramatically improve the resolution quality of contouring using ground station data.

The contouring routine treated the globe as a cylinder, and not a flat plane. As shown below, this was necessary to do this in order to connect data points that are at opposite ends of a map that are actually beside each other.



However, with limited software, it was difficult to treat the globe as a sphere. Because of this, the predicted values in the high latitudes may be suspect. Therefore, it may be beneficial to construct a spherical contouring routine to examine what changes became evident using this new method. It must also be mentioned that only the northern and central pacific regions, the United States, and the equatorial Atlantic regions during the months of September and October were examined. Greater validity could be lent to the contouring method if other areas and times of the year were be examined.

The capacity to validate global climatologies is significant for chain studies. Since methane has a long lifetime in the atmosphere, and is therefore well-mixed, it is not practical to use global climatologies to determine the sources of the gas. Instead, these climatologies can be used to examine seasonal trends of methane, as seen in Figures 2-14. The work can be further expanded to compare these seasonal cycles to estimated sources from biomass burning. The methods used for this project can also be used to contour other trace gases, such as carbon dioxide (CO_2) and nitrous oxide (N_2O). In conclusion, the project shows that using aircraft data, especially if globally distributed, is a good method to validate global climatologies produced from sparse ground station data. It lays the groundwork for further research in building global climatologies from sparse ground station data and studying the transport and distribution of trace gases.

REFERENCES

1. Houghton, J.T., B.A. Callander, and S.K. Varney (Eds), 1992: *Climate Change 1992: The Supplementary Report to the IPCC Scientific Assessment*. WMO/UNEP/IPPC, Cambridge University Press, pp35.

Estimated Sources and Sinks of Methane
(Tg méthane per year)

Sources		
<i>Natural</i>		
• Wetlands	115	(100-200)
• Termites †	20	(10-50)
• Ocean	10	(5-20)
• Freshwater	5	(1-25)
• CH ₄ Hydrate	5	(0-5)
<i>Anthropogenic</i>		
• Coal Mining, Natural Gas & Pet. Industry †	100	(70-120)
• Rice Paddies †	60	(20-150)
• Enteric Fermentation	80	(65-100)
• Animal Wastes †	25	(20-30)
• Domestic Sewage Treatment †	25	?
• Landfills †	30	(20-70)
• Biomass burning	40	(20-80)
Sinks		
Atmospheric (tropospheric + stratospheric) removal †	470	(420-520)
Removal by soils	30	(15-45)
Atmospheric Increase	32	(28-37)

† indicates revised estimates since IPCC 1990

Houghton, J.T., B.A. Challander, and S.K. Varney (Eds),
1992: Climate Change 1992: The Supplementary Report
to the IPCC Scientific Assessment. WMO/UNEP/IPCC,
Cambridge University Press, pp35.

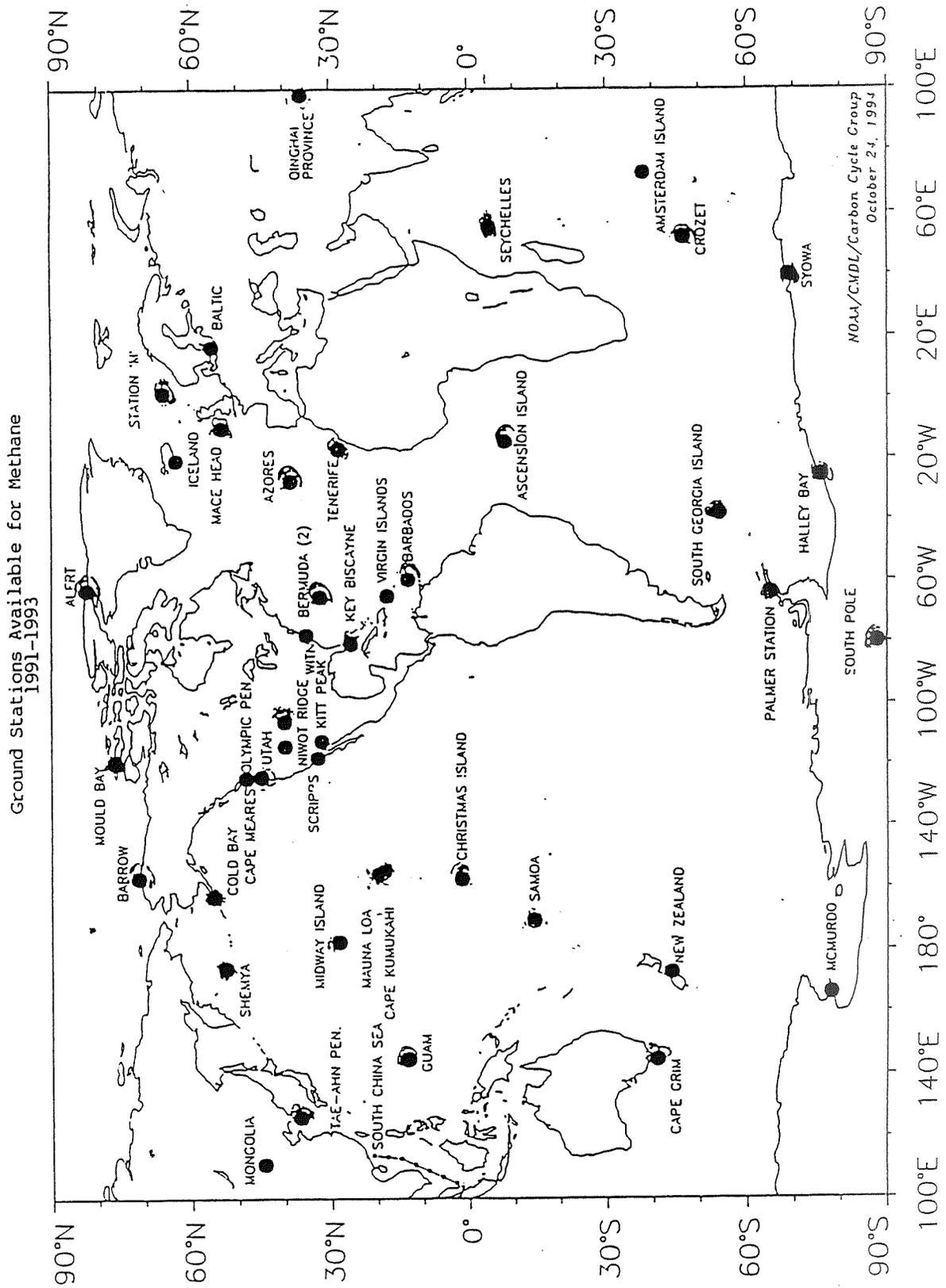
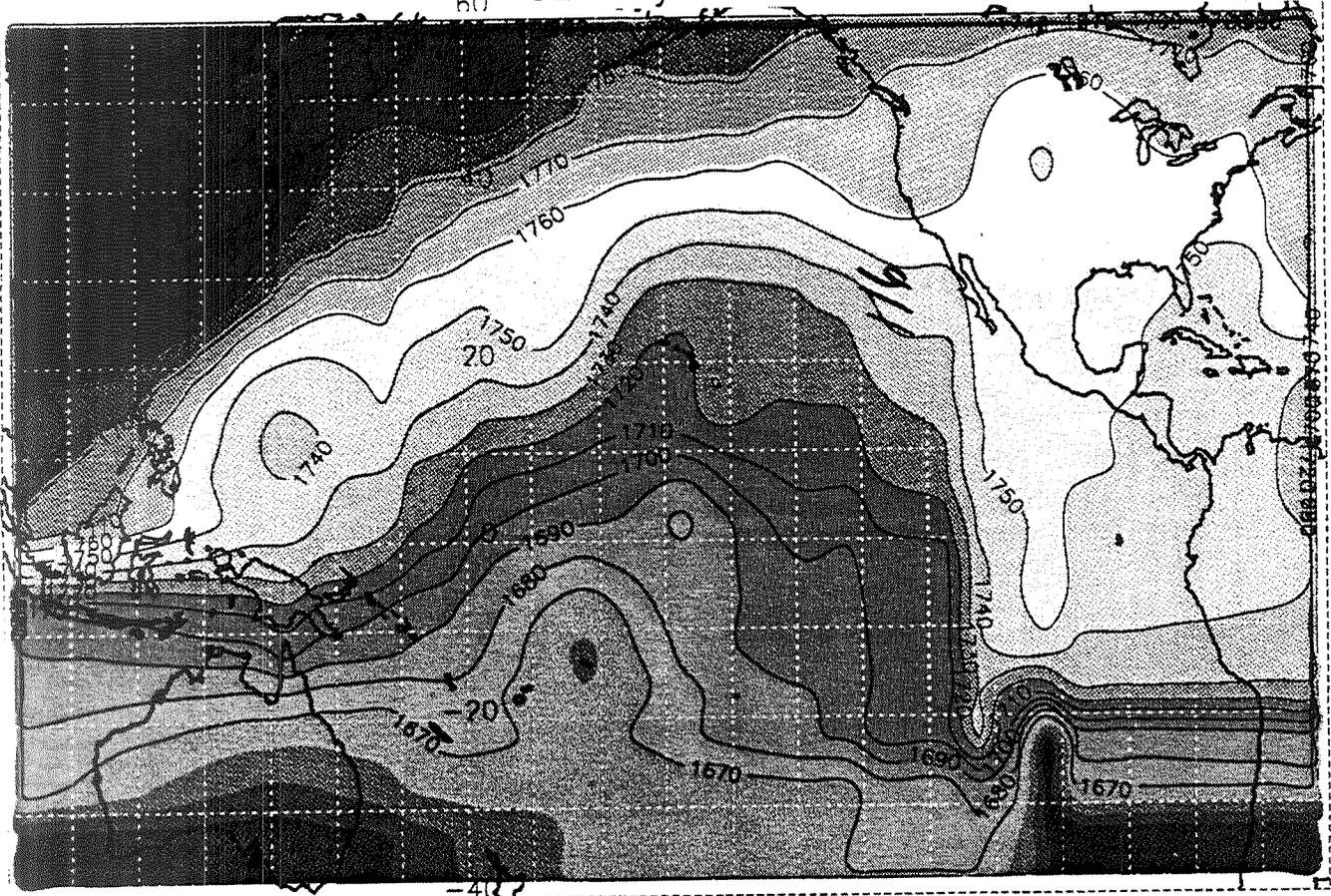


Figure 1

60 January 1991

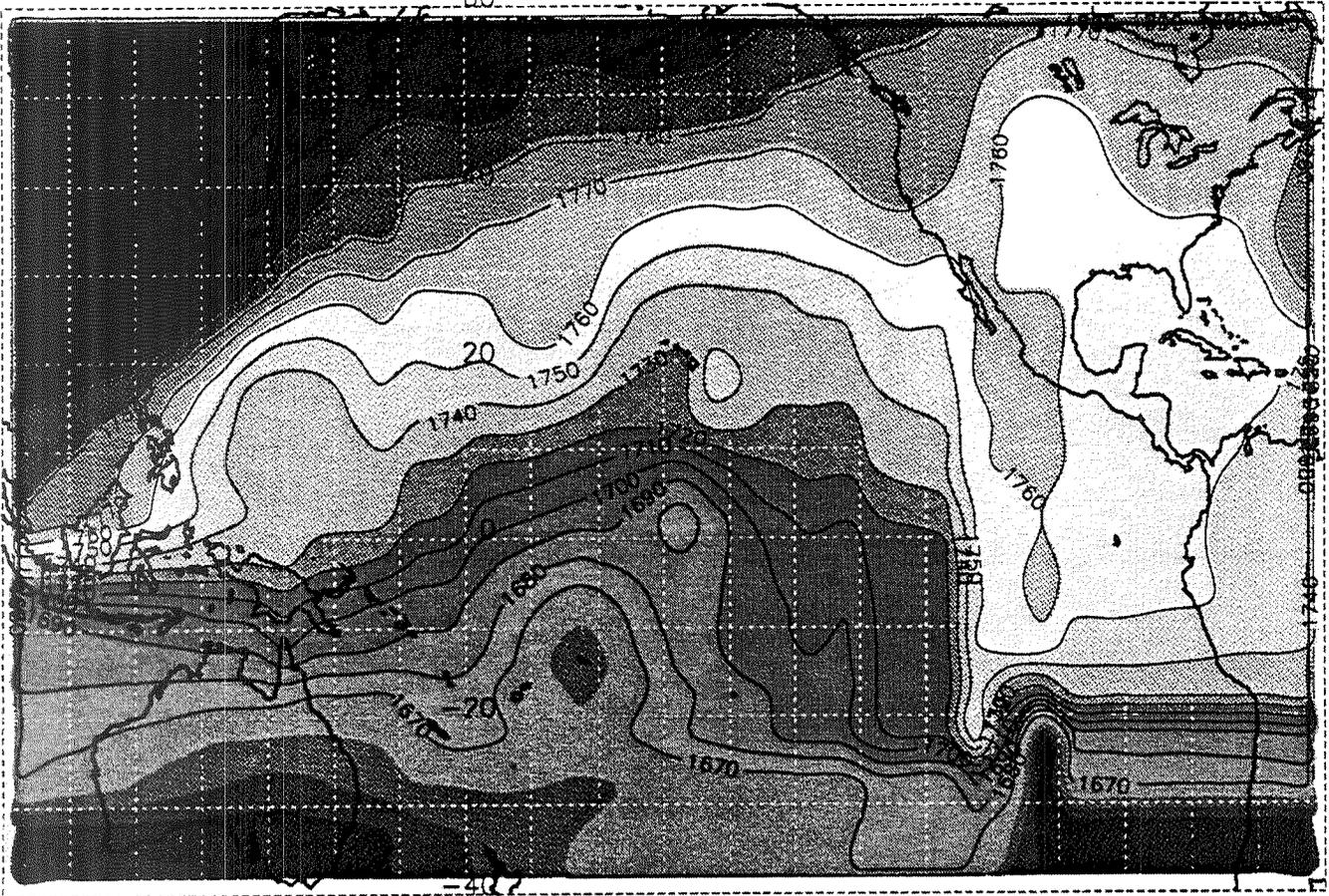


100 120 140 160 180 -160 -140 -120 -100 -80 -60

Figure 2

March 1991

60



100 120 140 160 180 -160 -140 -120 -100 -80 -60

Figure 4

April 1991

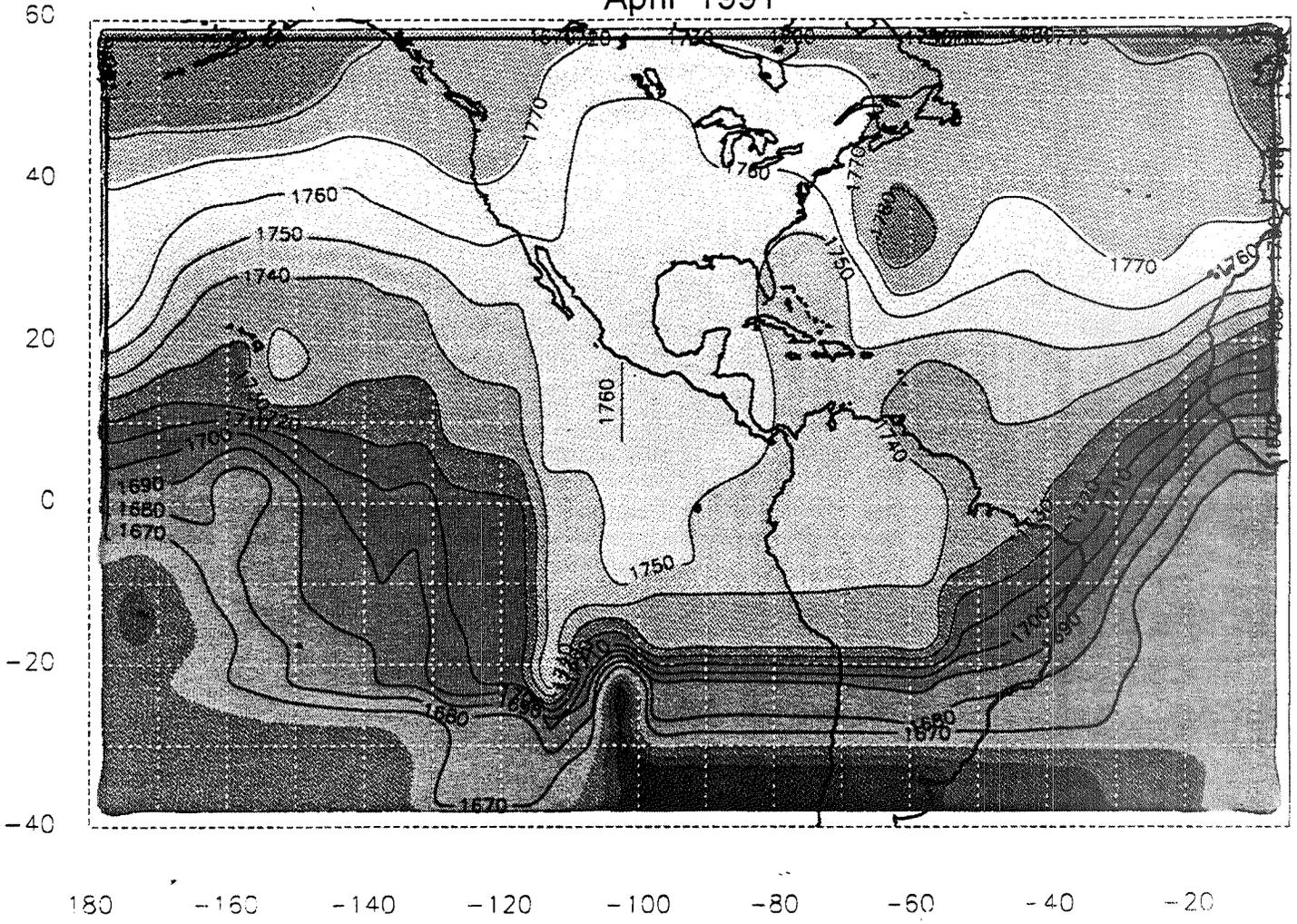
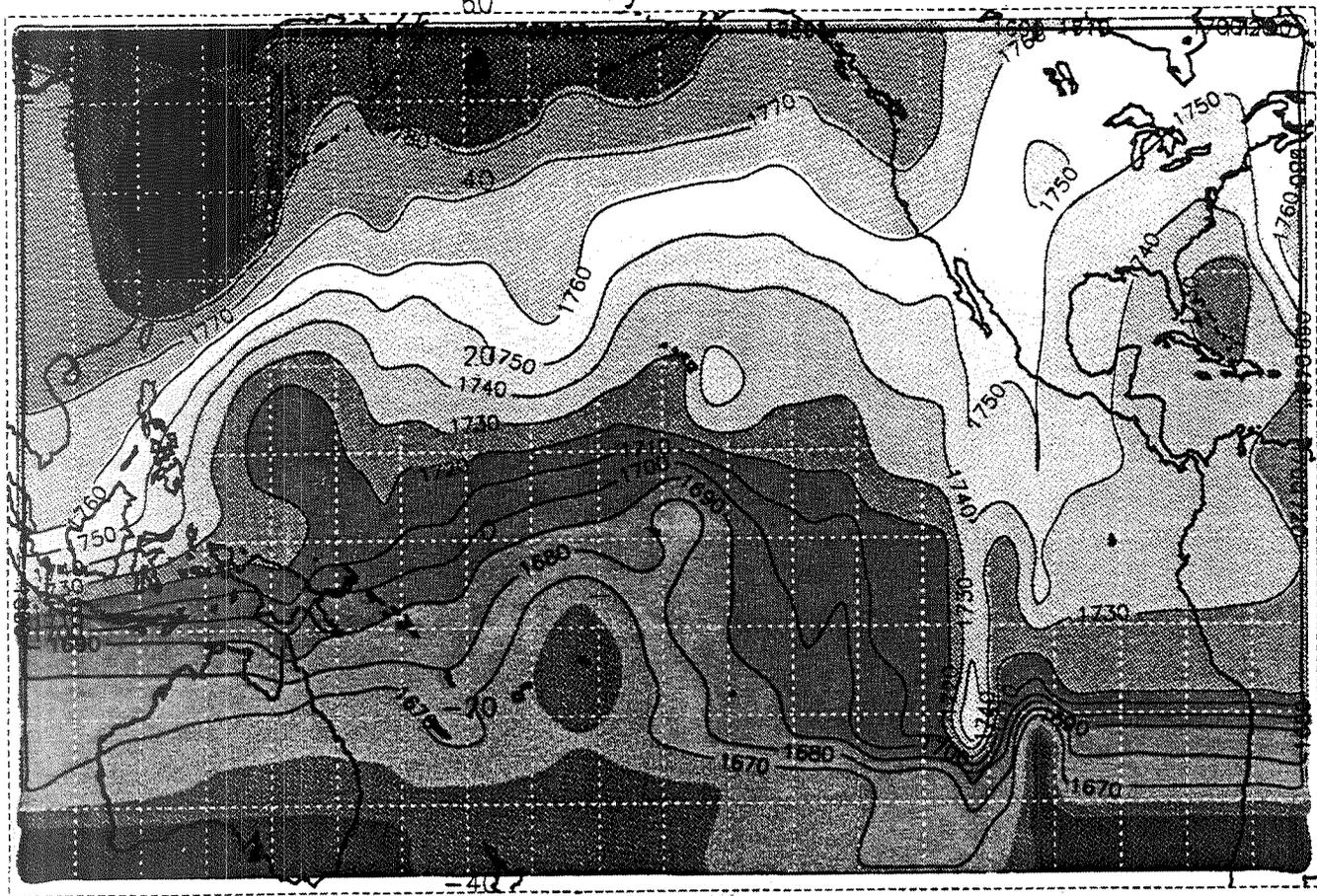


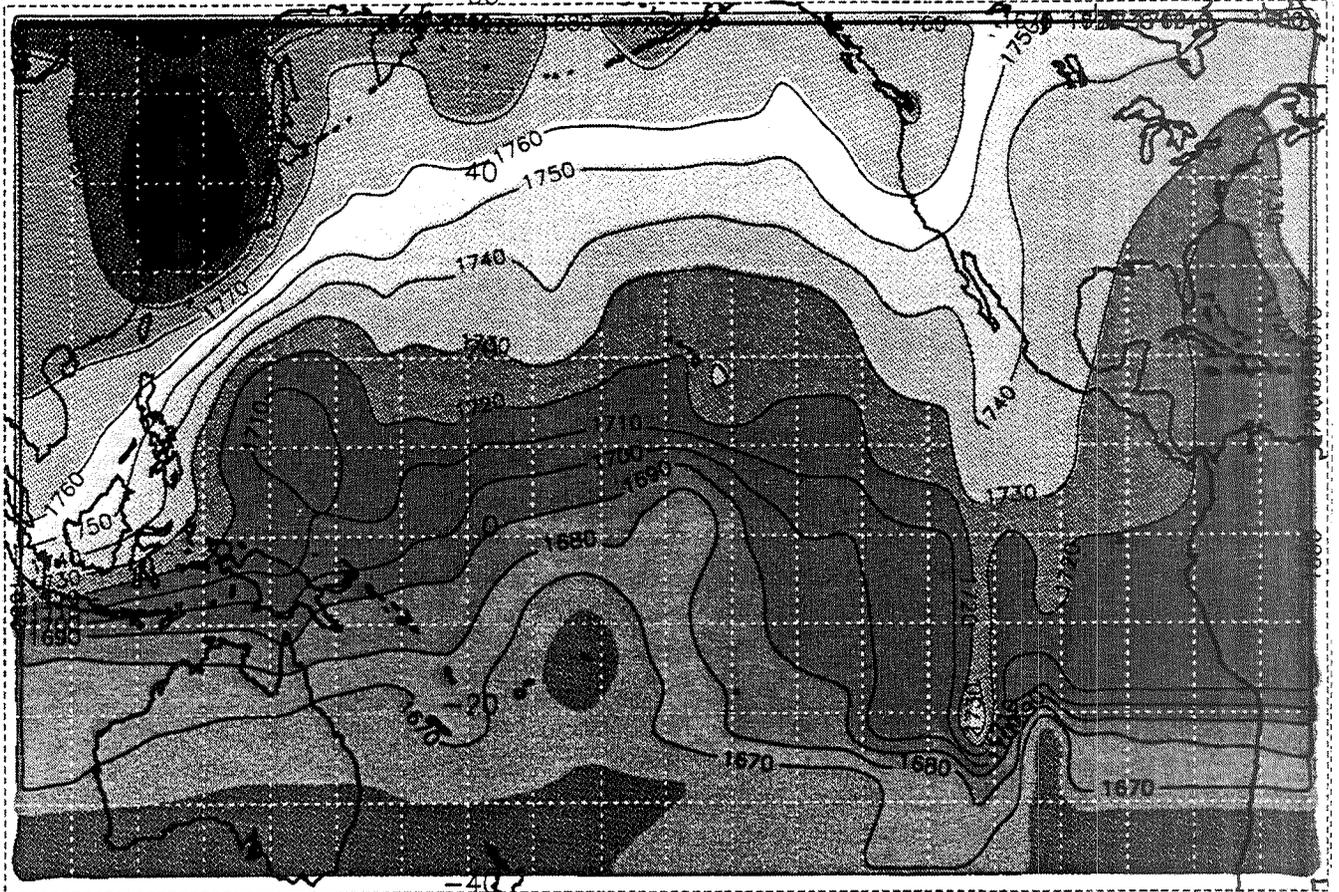
Figure 5

May 1991



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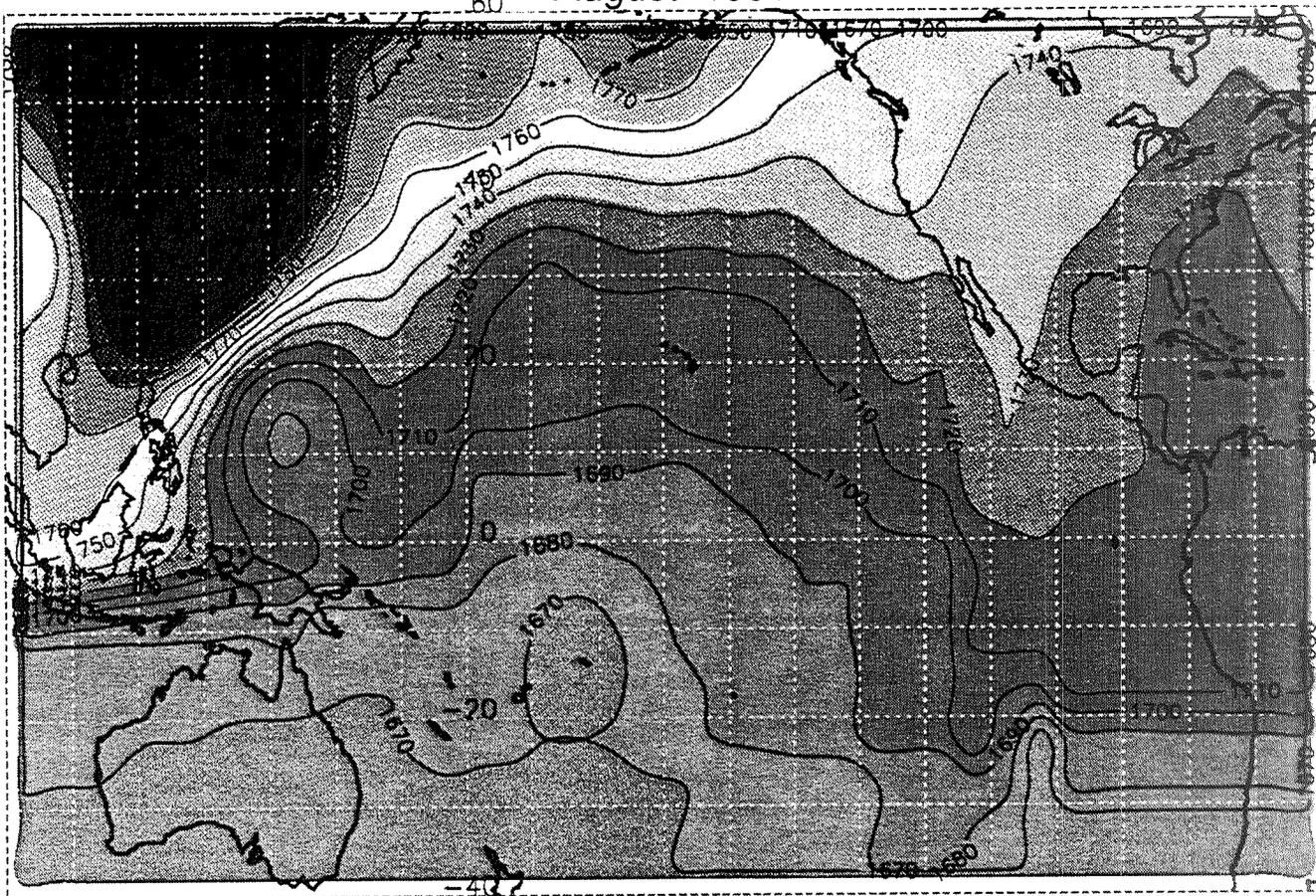
June 1991



100 120 140 160 180 -160 -140 -120 -100 -80 -60

Figure 7

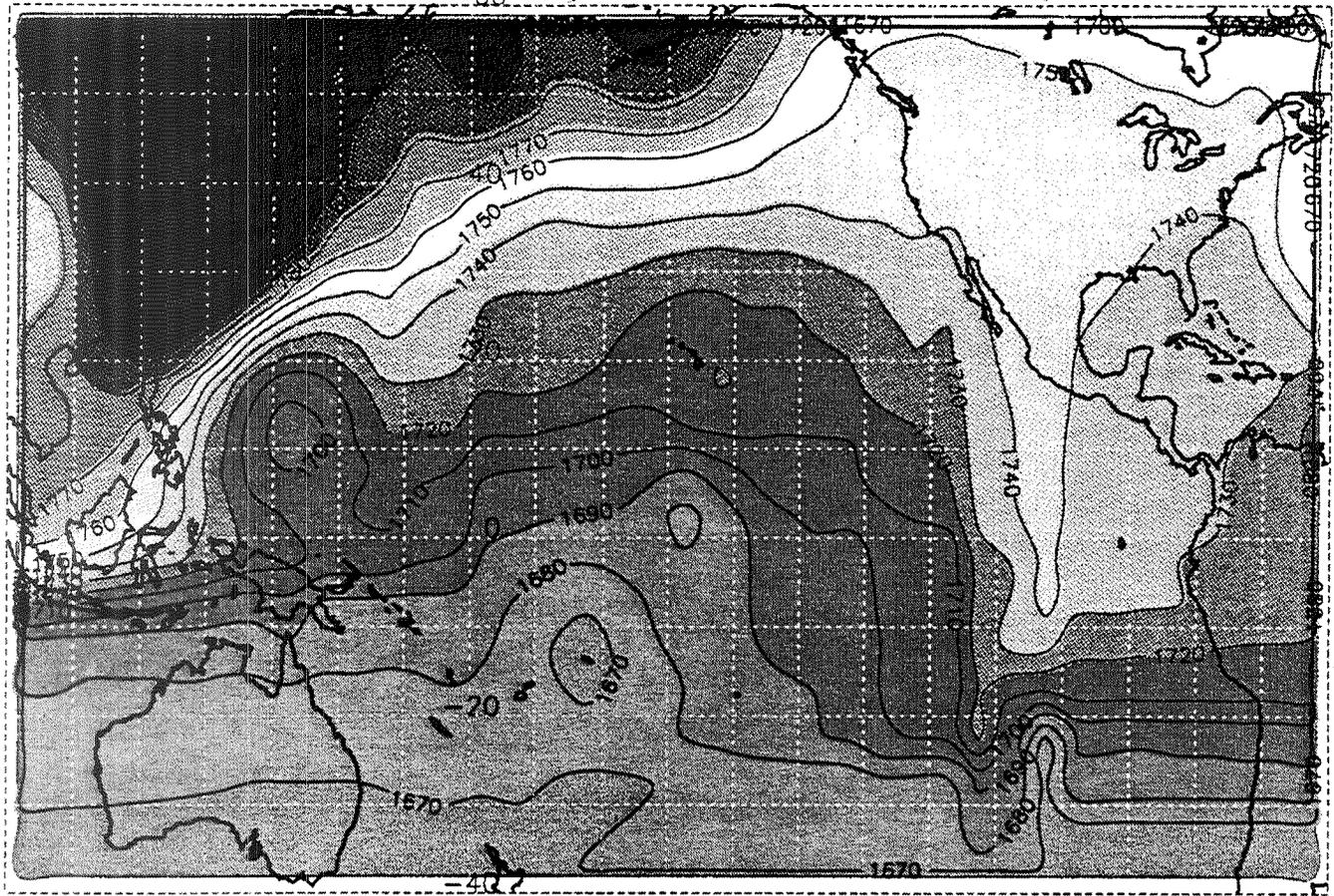
August 1991



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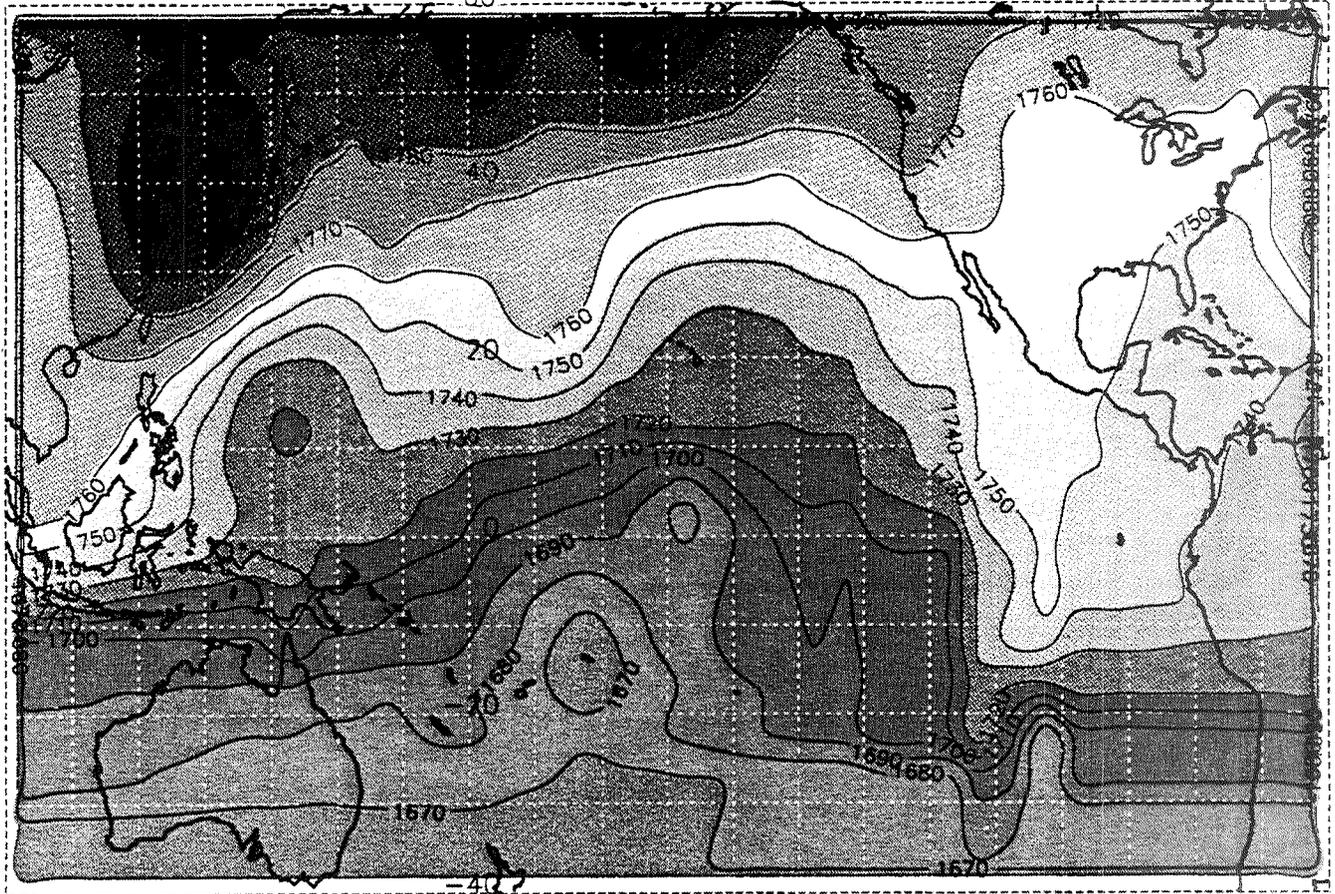
Figure 9

60 September 1991



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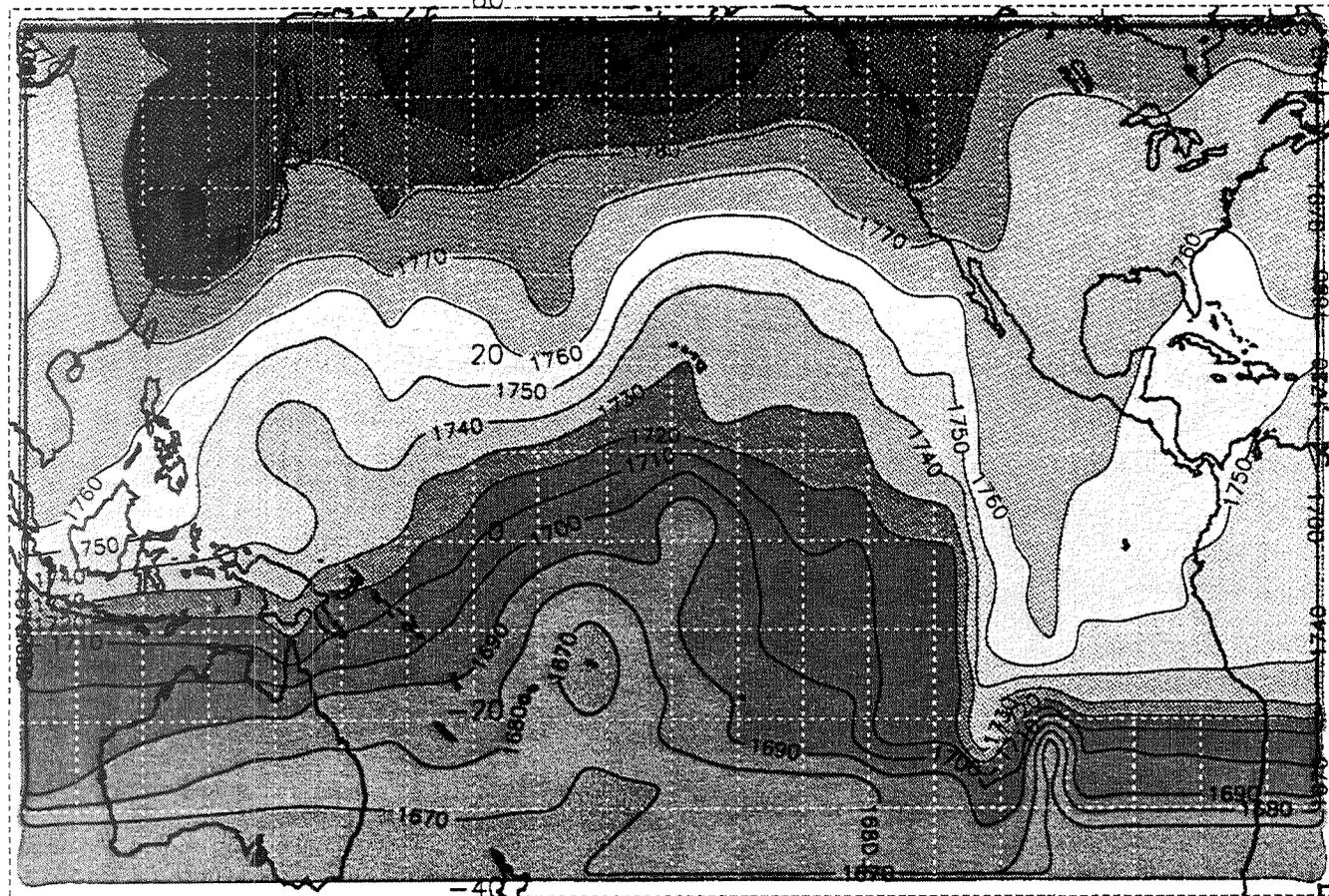
October 1991



180 160 140 120 100 80 60

Figure 11

60 November 1991



100 120 140 160 180 -160 -140 -120 -100 -80 -60

Figure 12

60 December 1991

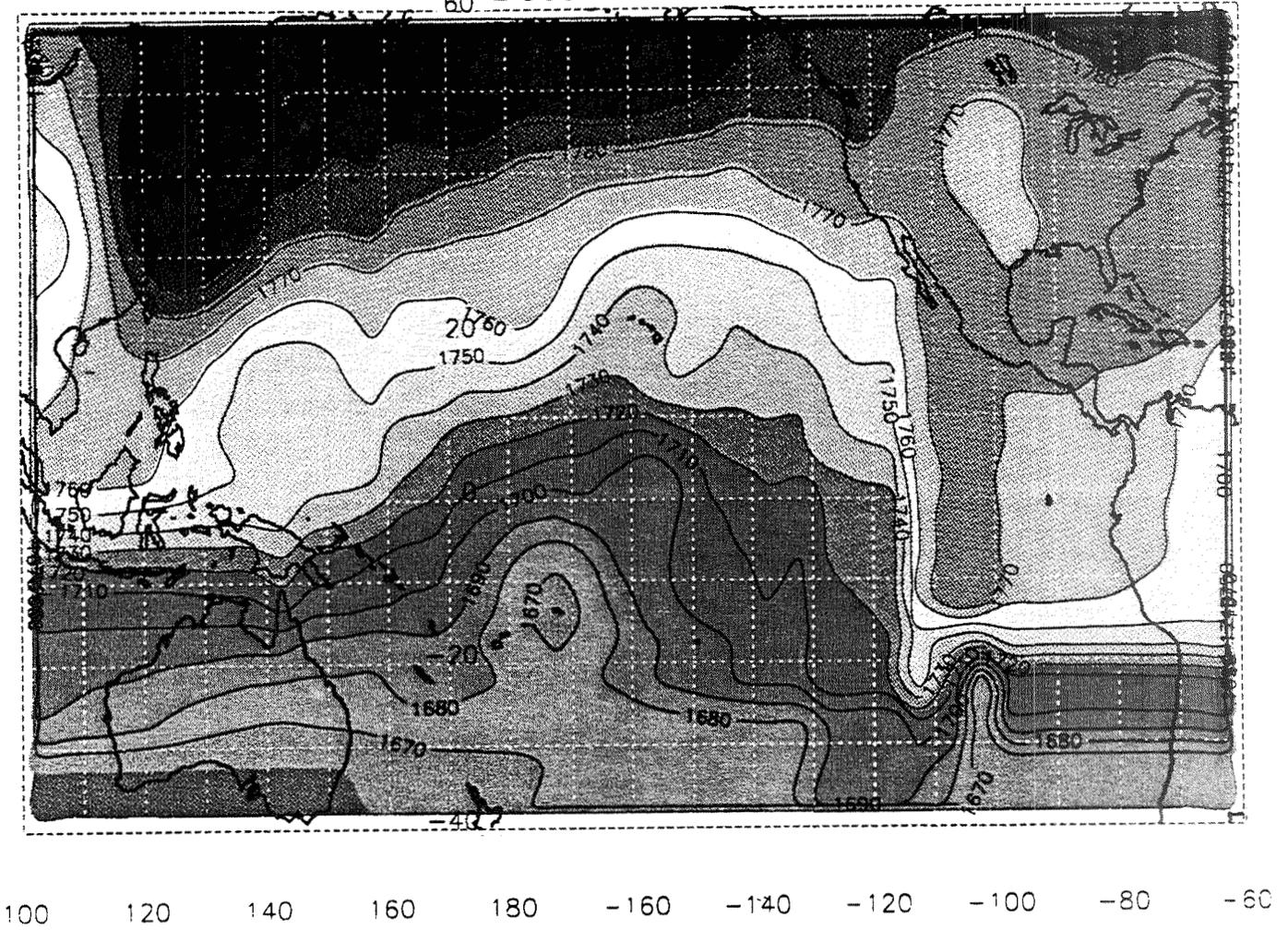


figure 13

PEM-West A Mission Flight 4

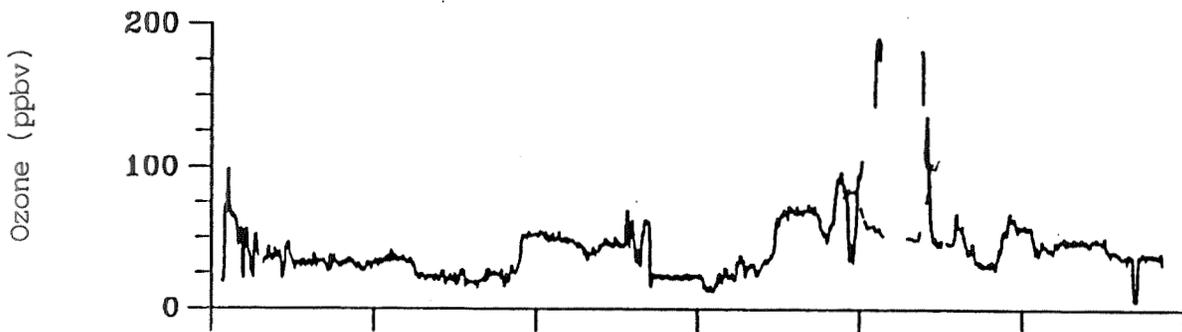
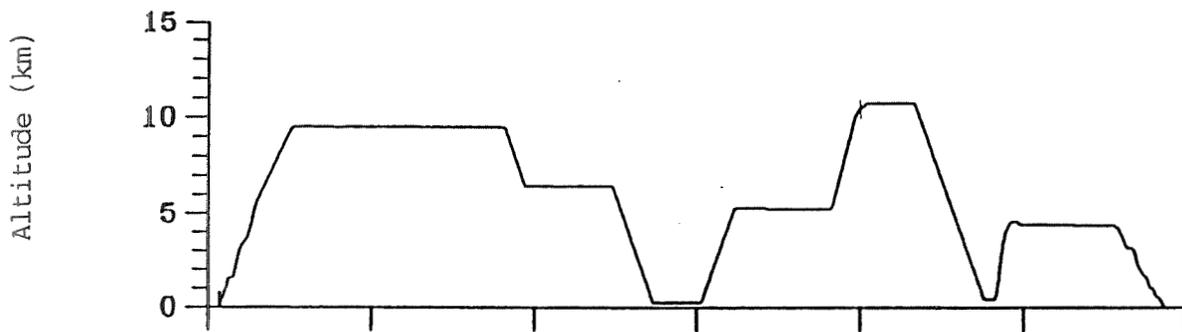
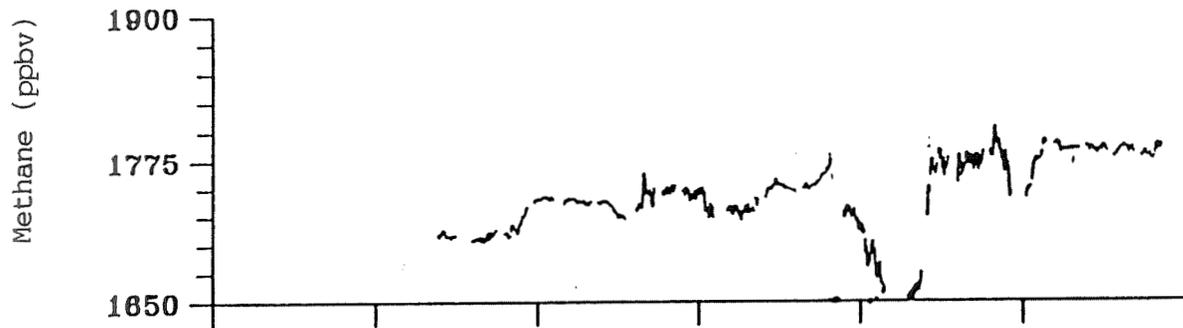
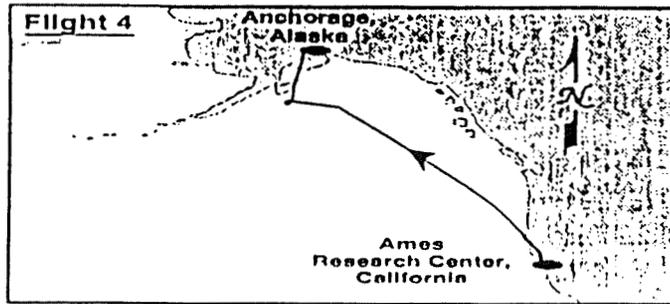


Figure 14

TRACE A Flight 19

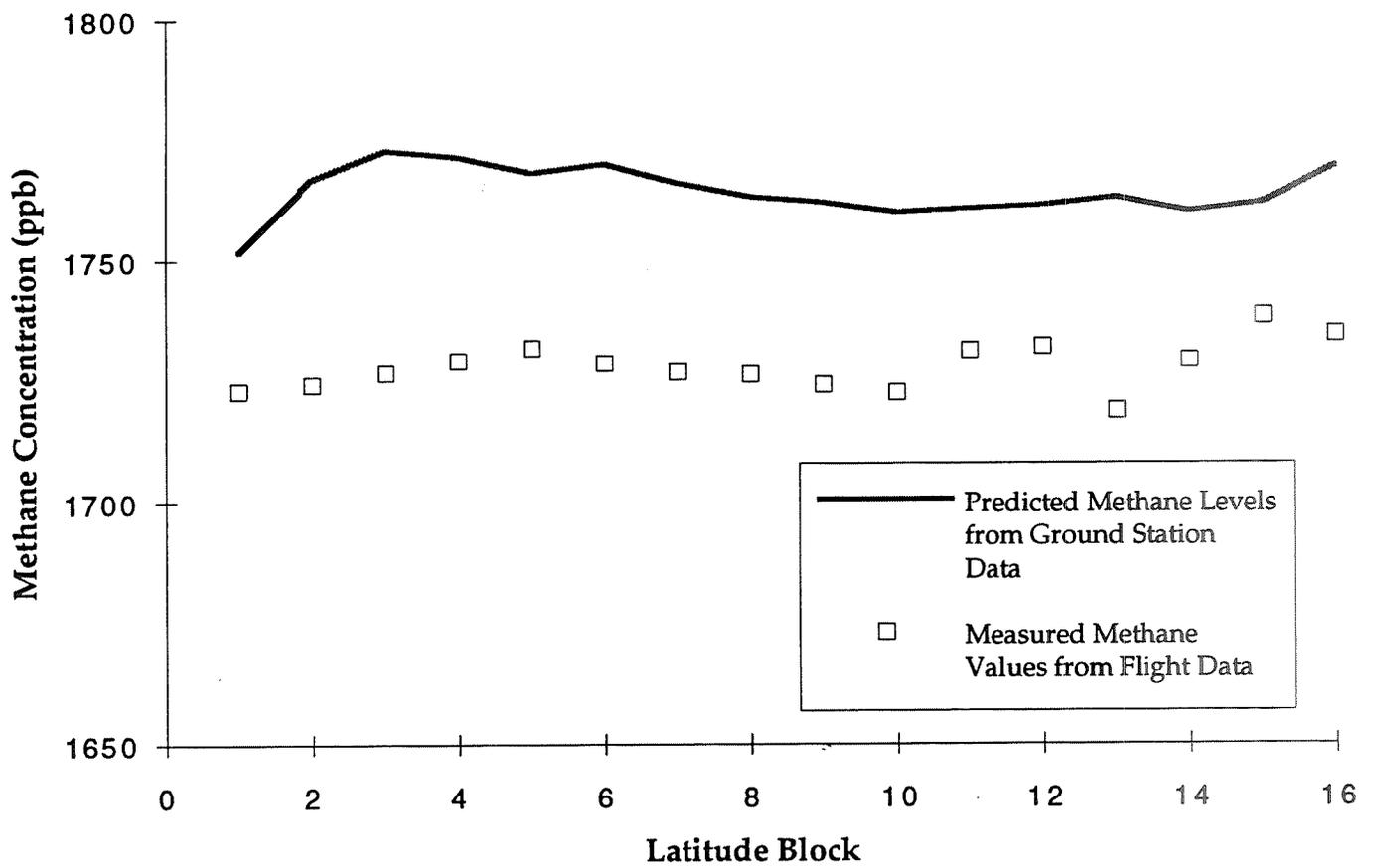
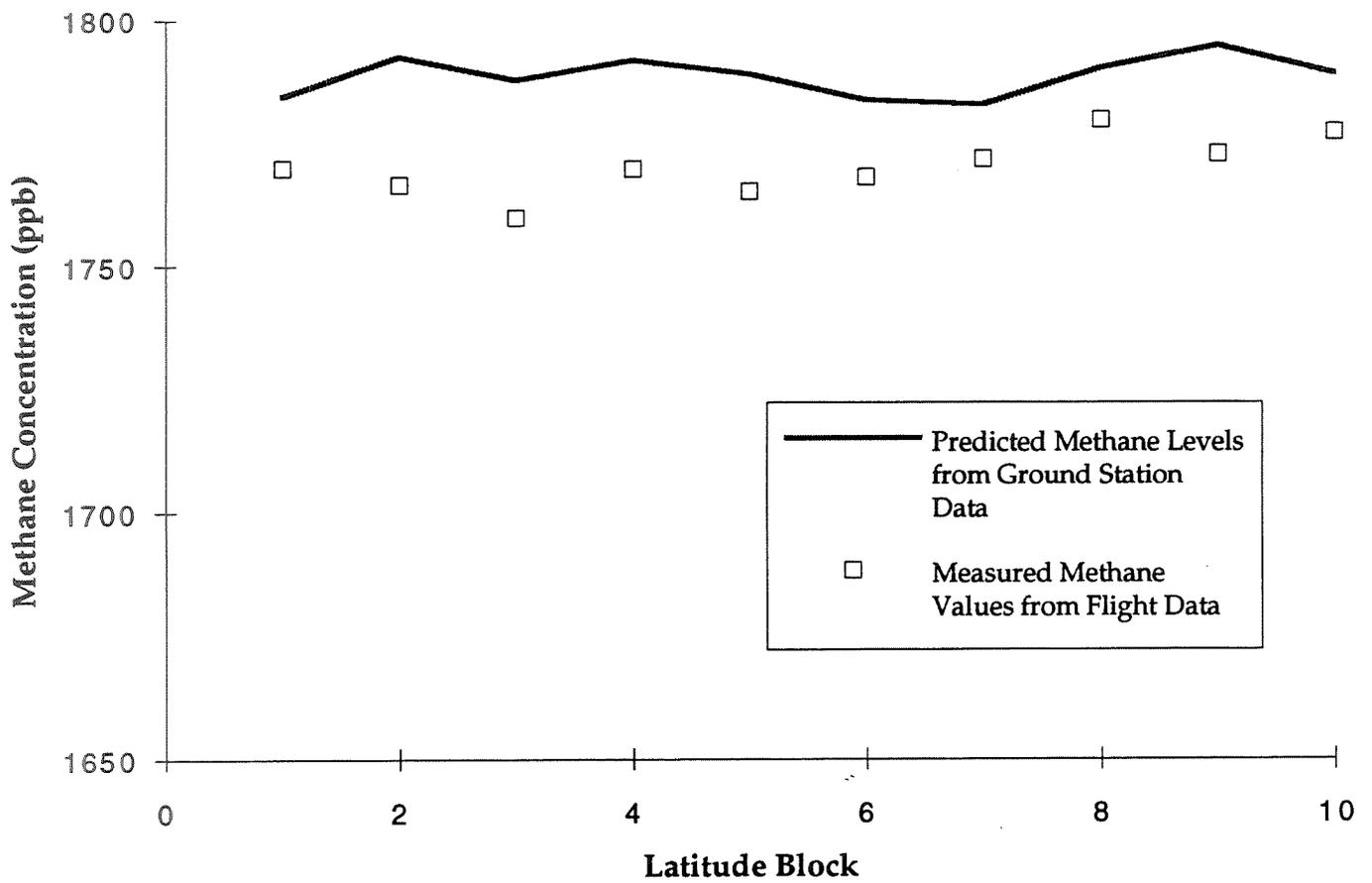


Figure 15

PEM-West A Flight 5



PEM-West A Flight 4

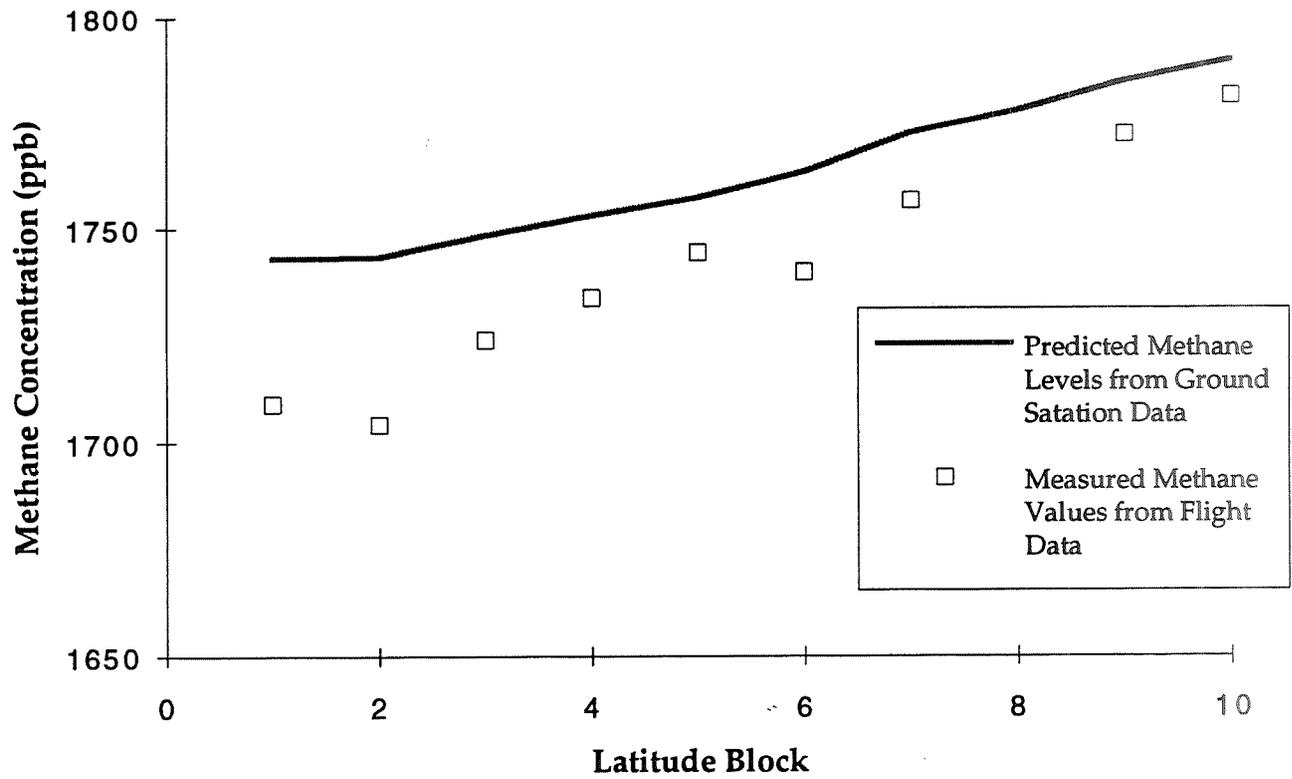
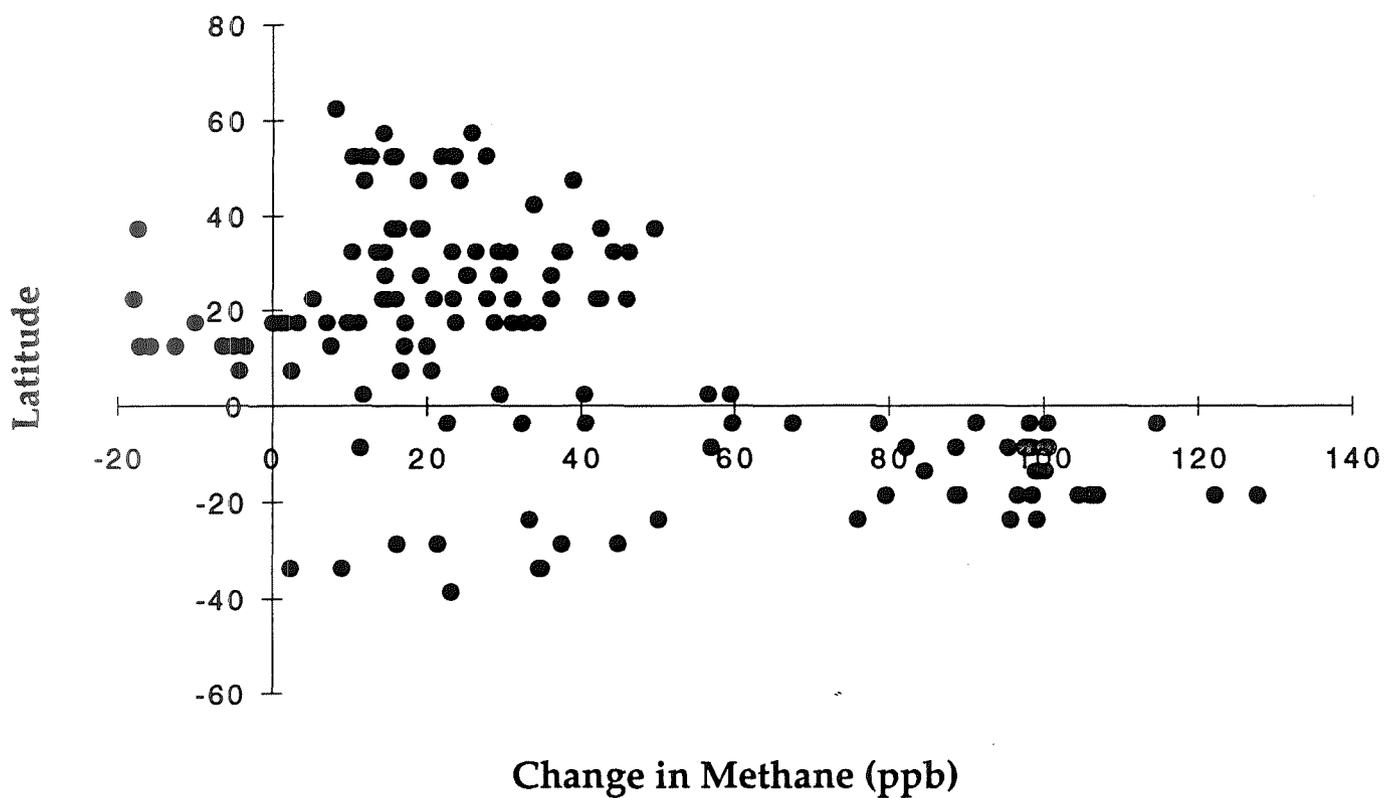


Figure 17

Difference Between the Predicted and In-Situ Methane Values (ppb)



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**User Interface on the World Wide Web:
How to Implement a Multi-Level Program Online**

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Abstract

The objective of this Langley Aerospace Research Summer Scholars (LARSS) research project was to write a user interface that utilizes current World Wide Web (WWW) technologies for an existing computer program written in C, entitled LaRCRisk. The project entailed researching data presentation and script execution on the WWW and then writing input/output procedures for the database management portion of LaRCRisk.

Introduction/Background Information

A few years ago, Robert M. Baker wrote a risk assessment program in DBase IV called TeamRisk that evaluated the security of computer systems at NASA Langley Research Center (LaRC) by comparing a branch's implemented protective measures against a database of NASA and LaRC guidelines. Realizing that other NASA Research Centers might benefit by using such a program to assess their computer security, he then wrote CentRisk, a program which allows a center to create its own database of guideline protective measures.

However, because DBase is a DOS-based software package, both CentRisk and TeamRisk, which together are known as LaRCRisk, were limited in use and availability to IBM PC-compatibles. Consequently, last year Mr. Baker asked Jerry W. Park to write a version of LaRCRisk in C so that it would be portable to various computer platforms (e.g., UNIX, DOS, Macintosh, etc.). Considering that most of the larger computer networks at LaRC are UNIX-based, Mr. Park first concentrated on developing a version of LaRCRisk for a UNIX environment, intending to develop versions for other platforms at a later time. Also, since LaRC's guideline database had already been defined, he decided to focus on the TeamRisk module of LaRCRisk before converting the CentRisk module.

In writing the program, however, he was limited to a crude user interface called "curses" because it was the only C language library available on most other computer platforms. Once the program was completed, he realized that different software packages did not have to be developed for other computer platforms; a user on a platform other than UNIX could simply hook up to the UNIX machine running LaRCRisk via a network connection. Nonetheless, Mr. Baker and Mr. Park decided that the most efficient way to use LaRCRisk, due to the awkwardness of the interface, was to have the branch wanting to do a risk assessment fill out worksheets describing the relevant computer systems and other necessary parameters for the program. Mr. Park could then personally enter the data from the worksheets and run LaRCRisk, generating reports to return to the branch requesting the risk assessment. Until a more efficient system could be created, conversion of CentRisk into C was indefinitely postponed.

This LARSS research project was to create such a system, i.e., if possible, to modify LaRCRisk so that it would run off the World Wide Web portion of the Internet. The advantages of putting LaRCRisk "on the Web" are as follows:

1. user-friendliness.
2. LaRCRisk can be stored on a single machine and still allow the user to enter data from a local computer.
3. Many users can access and use the same guidelines database.

The specific objectives of this project were therefore to 1) determine whether putting a multi-level program such as LaRCRisk on the Web was feasible or not, 2) learn how to manipulate the user interface provided by Web browsers (e.g., Netscape, Mosaic, Lynx, etc.), and 3) using Mr. Park's original code, write an appropriate user interface.

Summary

Before a determination could be made concerning the feasibility of putting LaRCRisk on the Web, more information had to be gathered concerning data presentation and script execution. Data presentation is controlled by Hypertext Markup Language (HTML), which consists of tags of different types embedded into the text of a WWW document; these tags control how the document appears on the screen of a Web browser. Included in HTML is the capability of obtaining input from a user online via a "fill-out form"; browsers which support this feature allow the user to submit the form to a WWW server, which processes the data and generates a document to return to the user as output. How the Web server processes that data and what kind of document it returns are controlled by a "script," a type of computer program. Scripts utilize the Common Gateway Interface (CGI) in communicating with the Web server.

After researching HTML and the CGI and downloading some CGI codes from the National Center for Supercomputing Applications at the University of Illinois at Urbana-Champaign (NCSA), a trial program entitled LaRCRiskII was written to discover whether or not a multi-level C program could be implemented on the Web. Upon the successful execution of LaRCRiskII and the accompanying conclusion that this research project was indeed feasible, Mr. Baker and Mr. Park were consulted as to the most efficient way to implement LaRCRisk. A modular approach was then adopted: as LaRCRisk was composed of several levels, each of which obtained a certain amount of data from the user and processed it, each level of LaRCRisk would become an individual module, with each module being called in succession. These modules would be scripts separate and distinct from each other that would accept input from the user via a form, save appropriate data into files for later use, and generate a document (usually another form) to return to the user. Using this modular approach, input/output procedures were written for each module as it was converted to CGI format.

LaRC equipment and facilities used in this research project include a SunOS workstation, computer time and space on two separate UNIX network servers, office space, and the technical advice of several employees.

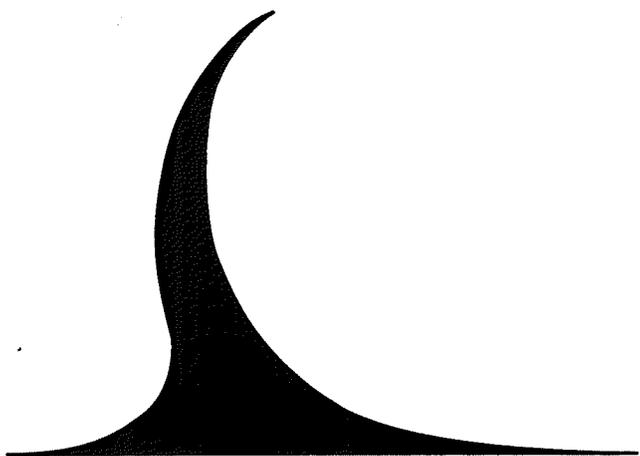
The results were excellent; not only does the WWW user interface add user-friendliness, but members of the same risk assessment team for the branch conducting the risk assessment can run LaRCRisk in the comfort of their own offices. With the necessary documentation, LaRCRisk is self-supporting; it can be implemented so that risk assessments are done without the full-time mediation of a contact person (though one will probably still be necessary to provide user support). Furthermore, the Web version of LaRCRisk (which at this time only includes the TeamRisk portion of the program) provides the necessary environment for the future conversion of CentRisk into C, or another CGI language.

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OFFICE OF EDUCATION GUIDE TO GRAPHIC ARTS SOFTWARE

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Office of Education

1995 LARSS Technical Report Abstract

Objectives:

During my summer experience in the LARSS program, I created a performance support system showing the techniques of creating text in Quark XPress, I then placed the text into Adobe Illustrator along with scanned images, signatures and art work partially created in Adobe Photoshop. The purpose of my project was to familiarize the Office of Education Staff with Graphic Arts and the computer skills utilized to typeset and design certificates, brochures, cover pages, manuals, etc.

During my summer experience in the LARSS program, I created logos, brochures, cover pages, manuals and certificates using Quark XPress, Adobe Photoshop and Adobe Illustrator. By incorporating scanned images and photographs from Photoshop into Illustrator along with text from XPress, I utilized all the aspects of typesetting and design. With over 60 projects completed this summer, my skills as a graphic artist have been used by the Office of Education extensively. That is why, as my final project, I am creating a step by step guide for typesetting text, scanning signatures and photographs and designing page layouts.

To give you an idea of the role of each graphics program, I will show you it's function. XPress was used to typeset this portion of my paper. I also created the LARSS/ASEE banquet program in XPress. It has typographical functions that allow total control over leading, x-height, letter spacing, word spacing and so on. Mainly, it has a spell checker. That is it's best typesetting function. My title page was created in Illustrator along with all the viewgraphs I did this summer. Illustrator's design functions allow text and art to be manipulated, moved and adjusted with ease. Text from XPress and photographs and line art from Photoshop can be imported directly into Illustrator for quick and easy page layout. Photoshop not only allows total manipulation of photographs, but it is also the connection to our ColorOneScanner. This program captures signatures, photographs and line art to be exported to other programs for incorporation into page layout designs or simply to be printed directly from Photoshop after being cleaned up.

I will explain the operation of the scanner first. **Here are the basics for opening Photoshop and scanner with the ColorOneScanner:**

1. First, turn on the ColorOneScanner & *then start* the Macintosh.
2. Double click on the Hard drive to open the hard drive window.
3. Open the Applications window and open the Photoshop window.
4. Double click on the Photoshop icon to launch the program. It will take a few seconds to open the program.

5. Go to File menu, scroll down to Acquire and move cursor over to OneScanner. The scanner dialog box appears.
6. Select the scan parameter. ie. 300 dpi, color or grayscale.
7. Click the preview box. The scanner previews your selection.
8. In the image field, select the area to be scanned by clicking, holding down & dragging the cursor to select all of the image area you want scanned.
9. Click on Scan to capture the image.

The image is now scanned and ready for manipulation. First and foremost, SAVE the file. It is most frustrating to lose a large scan simply because you did not save it directly after scanning. Also, remember to save the image on the hard drive in a folder designated for your work. You do not want to search for files that have been saved haphazardly.

Here are some tips for scanned signatures.

1. After scanning as a grayscale image and saving, choose the pointer tool and select the desired area by clicking at one corner of the image and dragging to the opposite corner.
2. Go to the Edit menu to Crop, release and the image is cropped to your specifications.
3. Use the magnification tool to enlarge the scan to a view of 1:1.
4. Go to the Image menu to Adjust to Brightness/Contrast. The Brightness/Contrast dialog box appears. Slide the brightness bar to the right to brighten the background of the scan and the contrast bar to the right to darken the name in the scan. Hit OK.
You want a solid white background with a consistently black signature.
5. Make any further adjustments necessary for a quality image.
6. Go to the Mode menu to Bitmap and hit OK, OK.
7. Save the file by using the File menu, Save As option. Under Format, save as an EPS file. Replace the image and be sure the Transparent Whites option is clicked on.

When scanning a photograph, use the same guidelines but feel free to adjust the image

using any of the adjustment tools and filters Photoshop offers with assistance from the Adobe Photoshop User Guide.

Just as Photoshop has specific functions relevant to the graphic arts, so does Quark XPress. XPress offers typographical freedom and expression. Creating text in XPress is simple and allows multiple pages, importing of text and graphics from other programs and spell checking. Although XPress does not allow for the diversity available in Adobe Illustrator, it is a valuable tool for the graphic artist.

Below are the steps for entering text into XPress.

1. Turn on the Macintosh.
2. Double click on the Hard drive to open the hard drive window.
3. Open the Applications window and open the Quark XPress window.
4. Double click on the Quark XPress icon to launch the program. It will take a few seconds to open the program.
5. Go to the File menu, select New and choose a Document format. Specify size, columns, and margin specifications and hit OK. Be sure the Automatic Text Box is clicked on.
6. Select the type/scroll tool, click in the Text Box on the page and begin typing.
7. Use the text bar at the bottom of the page or use the Style menu to change fonts, point size, leading, alignment and word/letter spacing.

Any number of changes can be made to text in XPress; so be creative, remember to save often and use the Quark XPress Reference Manual if you become lost or for suggestions to creating a typographical masterpiece.

With Photoshop and XPress having such specific graphic art qualities, it would be expected for Adobe Illustrator to be just as specialized as well. But it is not. Illustrator will perform many of the functions of the other two programs, just not as specialized. Illustrator does text as well as XPress, only Illustrator does not have a spell checker and has memory problems after

using the Tab function. (So *NEVER* do Tabs in Illustrator!!) And Illustrator even goes farther than XPress in it's capability to "play" with text. You can type on a curve, in a box, rotate text, skew text, have access to millions of colors not only for text but also for artwork. You can create artwork and manipulate that artwork in Illustrator just as you can photographs in Photoshop. Basically, Illustrator is the medium to bring all the other art elements together in. Much like a canvas for a painter or a rock for a sculptor. Illustrator's diversity allows many functions to be available in one program and allows a document to be accurate typographically, visually and artistically.

Listed below are the basics to opening Illustrator to create a certificate.

1. Turn on the Macintosh.
2. Double click on the Hard drive to open the hard drive window.
3. Open the Applications window and open the Adobe Illustrator window.
4. Double click on the Adobe Illustrator icon to launch the program. It will take a few seconds to open the program.
5. Illustrator automatically gives you an 8.5 x 11 page setup. For 11 x 8.5 certificates, go to the File menu, to Page Setup and the Page Setup dialog box appears. Click on the 11 x 8.5 page orientation picture.
6. Go to the bottom right corner where the rulers cross and drag the crosshair to the edge of the page. This resets the rulers to correspond with the new page orientation.
7. Select the Text Tool Icon in the Toolbox, click on the page where you want the text to begin and begin typing. Use the ruler as a guideline for centering text or graphics.
8. After entering text, use the Font & Type menus to change fonts, point size, leading, alignment and word/letter spacing.
9. Go to the File menu to Import Text to import any text needed from XPress.
10. Choose the Pointer Icon from the Toolbox.
11. Go to the File menu to Place Art. A dialog box appears. Go to Desktop,

Macintosh HD, Logos!Etc., Logos and select the desired logo. Click OK. Repeat with other logos, signatures, and/or scanned images from Photoshop.

12. Click and drag on the placed image to move it around on the page.

Remember that at anytime you choose a drawing tool, whether it be the pen, oval, box, paintbrush or freehand tool, you must stroke and/or fill the object. **Here is how to use the Paint Style dialog box:**

1. Click on the object to be stroked/filled. (Click on the baseline of text to select it with the pointer tool or triple-click on text with the text tool.)
2. Go to the Object menu to Paint Style.
3. The Paint Style dialog box appears. If you want to fill an object, click on fill and select a color. Repeat for to stroke an object. (Always fill text with color, never stroke.)

You can re-size an object or a place image by selecting the Scale Tool from the toolbox, clicking on the corner of the image to be re-sized and dragging the image. Remember that holding down the shift key while dragging will keep the object's dimensions in proportion. Always use the shift key when re-sizing a signature, scan or logo. If you goof, go the Edit menu to Undo or hit the command and z keys together. You can study the toolbox dialog box on page 7 of the Adobe Illustrator User Guide to learn the names and functions of each of the toolbox icons, as well as other useful tips.

Not only does Photoshop, XPress and Illustrator incorporate all the elements of graphic arts software into an easy and fun package, but they also provide concise, professional features that allow the artist to present a total image. Learning typography and design as an art is fulfilling and rewarding, not only on a professional level but also on an amateur one. As you learn how to use the Mac and it's various software "tools", you gain a respect and admiration for the art of graphics.

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**The Development and Use of a Flight Optimization System Model
of a C-130E Transport Aircraft**

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Abstract

The Systems Analysis Branch at NASA Langley Research Center conducts a variety of aircraft design and analyses studies. These studies include the prediction of characteristics of a particular conceptual design, analyses of designs that already exist, and assessments of the impact of technology on current and future aircraft.

The Flight Optimization System (FLOPS) [Ref. 1] is a tool used for aircraft systems analysis and design. A baseline input model of a Lockheed C-130E was generated for the Flight Optimization System. This FLOPS model can be used to conduct design trade studies and technology impact assessments. The input model was generated using standard input data such as basic geometries and mission specifications. All of the other data needed to determine the airplane performance is computed internally by FLOPS. The model was then calibrated to reproduce the actual airplane performance from flight test data. This allows a systems analyzer to change a specific item of geometry or mission definition in the FLOPS input file and evaluate the resulting change in performance from the output file.

The baseline model of the C-130E was used to analyze the effects of implementing upper wing surface blowing on the airplane. This involved removing the turboprop engines that were on the C-130E and replacing them with turbofan engines. An investigation of the improvements in airplane performance with the new engines could be conducted within the Flight Optimization System. Although a thorough analysis was not completed, the impact of this change on basic mission performance was investigated.

Introduction

The Systems Analysis Branch at NASA Langley Research Center is involved in the design and analysis of new aircraft concepts and the assessment of technology impacts on existing and future aircraft. One of the resources used in these studies is a library of computer models, or specifically Flight Optimization System (FLOPS) models, of existing aircraft. These models are used by engineers to evaluate new ideas and theories for improving aircraft performance through the use of existing aircraft. This method produces reasonably accurate results in a timely and cost effective manner which can be used to identify areas for future in-depth research such as flight tests.

A FLOPS baseline model of a Lockheed C-130E was generated as an addition to an existing library of aircraft models in the Systems Analysis Branch. The model can be used to evaluate changes in basic mission sizing and performance resulting from changes in the airplane configuration, weights, aerodynamics, or propulsion system. The model consists of a series of input and output files, compatible with the Flight Optimization System, that closely reproduce the actual airplane characteristics. FLOPS baseline development and associated derivative studies were performed using the X-Windows based X-FLOPS tool found on the Systems Analysis Branch's Silicon Graphics workstations.

The C-130E baseline model was also used to conduct some limited design trade studies and technology impact assessments through the implementation of an upper surface blowing concept. The idea was to use turbofan engines to augment the air flowing over the upper surface of the wing thereby increasing lift. This concept would decrease the runway length required by this airplane for takeoff and landing and improve its low speed flight characteristics. Unfortunately, no detailed data was obtained for takeoff and landing for the actual C-130E. For that reason, only the basic improvements in mission performance with the new engines and upper surface blowing concept could be investigated.

Approach and Methodology

The C-130E is a special operations military transport powered by four Allison T56 turboprop engines. The baseline model for the airplane was compiled by using available data on the existing C-130E. The sources of airplane information included the Standard Aircraft Characteristics Chart [Ref. 2], a MIL-STD-1374 Group Weight Statement [Ref. 3], Jane's All the World Aircraft [Ref. 4], the Propulsion Summary Characteristics Chart for the Allison T56 turboprop engines [Ref. 5], and other existing aerodynamic and thrust data for the airplane.

The source data was broken into four categories before it was put into the input file. These categories were geometry, weights, aerodynamics, and propulsion performance, also referred to as the engine deck. All of the known information from these categories except aerodynamics was used to put together the input file for the initial model. It was intended that, using this information, FLOPS would compute the aerodynamics internally. Initial FLOPS executions were made to determine how the output for the model would compare with the real data. The FLOPS model was then calibrated to reproduce the actual airplane mission performance and other performance constraints. Comparisons were made between the internally

computed aerodynamic data and the existing aerodynamic data to ensure that the FLOPS model was reasonable. After the model was calibrated, the real weight data was taken out of the input file. The model was then recalibrated so that FLOPS generated all of the weights and aerodynamics internally given the specific C-130E airplane geometry and engine deck. This calibrated model along with the output made up the baseline model.

The concept behind the baseline model is that most of the airplane data is generated internally within the FLOPS program driven by key aspects of the airplane design. If design changes are made, the program will automatically account for all of the corresponding changes due to the initial design change. This feature is what allows the engineer to investigate the impacts of new ideas and technology on the performance of an existing airplane. Other derivatives of the baseline model were also made to allow investigations involving more isolated changes such as replacing the current engines with more efficient ones. With the original baseline model, changing the engines would change the design of the wings and many other components on the airplane. These results would not properly reflect the design change made since it was not intended to change the wing and other equipment just because the engines were changed. Derivative models allow for changing specific airplane components while leaving all of the other components untouched.

Both design trade studies and technology impact assessments were conducted for the implementation of the upper surface blowing concept on the baseline model. The implementation of this concept involved an engine change as described in the paragraph above. The approach taken was to change just the engines on the airplane without changing any other aircraft structure or systems. High by-pass ratio turbofan engines with approximately the same static thrust rating as the Allison T56 turboprops were selected for this investigation. The engines selected were the General Electric TF34 engines rated at 9000 pounds sea level static thrust. Since only limited data was available for takeoff, landing, and other low speed flight characteristics for the C-130E, only the major impacts of the new engines on basic mission performance--range, speeds, and altitudes--were examined. This investigation would be considered a design trade study.

The General Electric TF34 engines chosen for the upper surface blowing concept were relatively old engines. New technology, if implemented on these engines, could reduce fuel consumption and increase thrust. Using the new derivative model, the effects of the newer technology on the performance of the engines were also investigated. The change in engine performance directly affected the airplane performance. This would be an example of a technology impact assessment.

Results

The baseline model was validated using a number of performance constraints and parameters describing the basic design mission. These parameters were limited to a deviation of 5% from the actual value. These parameters along with their actual values and FLOPS baseline model values are shown in Table 1.

Table 1: Validation of the FLOPS Baseline Model

Aircraft Parameter	C-130E (Actual)	FLOPS Baseline Model
Gross Weight for 2000 n.m. range	152,914 lb	152,723 lb
Rate of Climb at S.L.	1630 fpm	1659 fpm
Rate of Climb at S.L. OEI	1000 fpm	951 fpm
Average Cruising Speed	287 kts	279 kts
Initial Cruising Altitude	21,200 ft	22,300 ft
Final Cruising Altitude	37,700 ft	37,000 ft
First Landing Weight	134,766 lb	132,706 lb
Total Mission Time	7.2 hrs	7.37 hrs
Max Velocity at Combat Weight (90087)	325 kts	319 kts
Combat Speed	301 kts	303 kts
Combat Ceiling	34,100 ft	34,400 ft
Service Ceiling at Combat Weight	36,750 ft	36,400 ft
Service Ceiling OEI at Combat Weight	30,400 ft	31,900 ft

The baseline model can be further validated by examining Figures 1 and 2. Figure 1 shows a comparison of the actual C-130E drag polars and the drag polars computed internally with the FLOPS model. These drag polars reflect the best available for constraint matching. The maximum error between the two curves is 9%. This was the smallest overall error achieved between the two polars while maintaining the 5% error constraint on performance. There may be an inaccuracy in the engine deck which might have caused the discrepancy between the performance matching and the drag polars matching. It was considered more important that the performance results match than the drag polars in generating the baseline model; therefore, the error in the drag polars was accepted. Figure 2 shows the payload-range diagram for both the actual C-130E and the baseline model. These diagrams match very closely, indicating that the model performance very closely reproduced that of the real airplane.

The results of the implementation of the upper surface blowing concept indicated a small overall improvement in performance. This was the expected result, but without the necessary takeoff, landing, and low speed flight characteristics data for the C-130E, the total impact of upper surface blowing on the airplane could not be determined at this time. With the replacement of the turboprop engines with turbofans, an increase in speed and altitude and subsequent operational mission improvement was observed. A summary of the improvements in performance with the addition of the upper surface blowing is presented in Table 2.

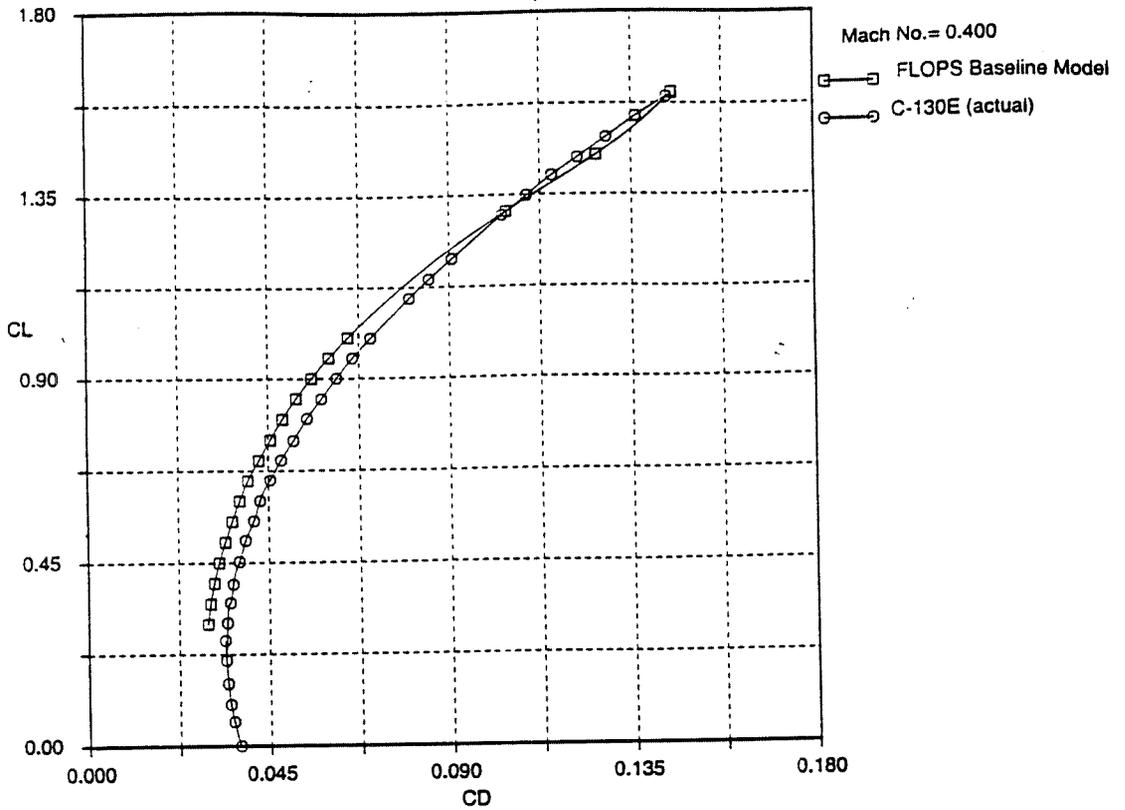


Figure 1: C-130E AERO POLAR PLOT - ALTITUDE = 0

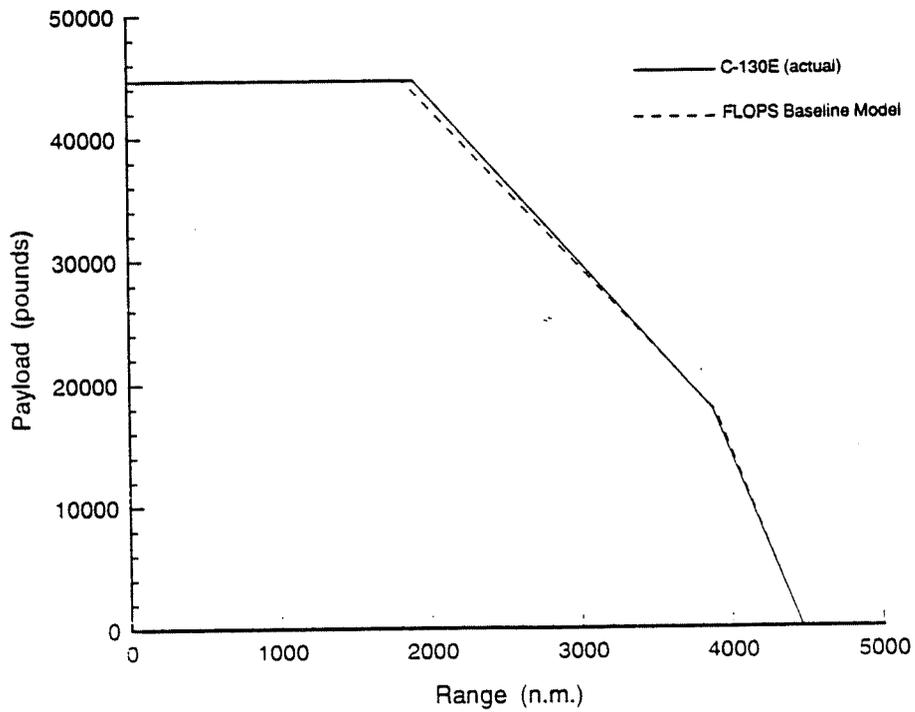


Figure 2: Payload-Range Diagram

Table 2: Improvements in Performance with Upper Surface Blowing

Airplane Performance Parameter	Change in Performance
Total Mission Time (2000 n.m. range)	-42 min
Max Rate of Climb at S.L.	+300 fpm
Max Rate of Climb at S.L.	+360 fpm
Max Velocity at 18,000 ft	+34 kts
Combat Velocity at 34,600 ft	+39 kts
Combat Rate of Climb at 34,600 ft	+215 fpm
Service Ceiling	+4000 ft
Combat Rate of Climb at S.L.	+740 fpm
Cruise Altitude (average)	+4000 ft
Cruise Velocity (average)	+29 kts
Operating Weight Empty	-8700 lb
Fuel Consumed	+6000 lb

The results above were computed using the baseline reference gross weight to obtain a meaningful comparison. The total mission time was based on a gross weight sized for a range of 2000 n.m with the GE TF34 engines. It is evident that the turbofans showed some marked points of improvement in airplane performance. The turbofans did consume more fuel which had a significant impact on range. The range improved slightly for heavy payload weights due to the decrease in operating empty weight. As the payload weight went down, the range did not grow as fast as with the Allison T56 engines due to the increased fuel consumption. This trend can be seen in the payload-range diagram contained in Figure 3.

Since the General Electric TF34 engine was designed in 1972, two decades of significant engine technology improvements would make the engine more efficient and powerful. Assessing the impact newer technology would have on the engine/aircraft performance, the FLOPS model with the TF34 engines was used to investigate higher engine thrust ratings and lower fuel consumptions. Figure 3 shows the payload-range diagrams for several conditions. The conditions include the baseline C-130E model and the derivative model with the TF34 engines at their original thrust rating and thrust rating increases. It can be seen that increasing the power output of the engines, or increasing thrust, does not have a significant effect on the airplane range. The airplane performance otherwise did increase with higher thrust.

Figure 4 shows the effects of reducing the engine fuel consumption. Reduction in fuel consumption does have a significant effect on range. The reduction in fuel flow did not make any significant improvements in other aspects of airplane performance, though. This figure also shows the possible effects of year 2005 technology. Improvements in materials and manufacturing will allow not only large fuel consumption reductions, but also significant reductions in thrust-to-weight ratios. This 2005 technology is represented in Figure 4 by a 50% reduction in fuel flow and 15% increase in thrust-to-weight ratio.

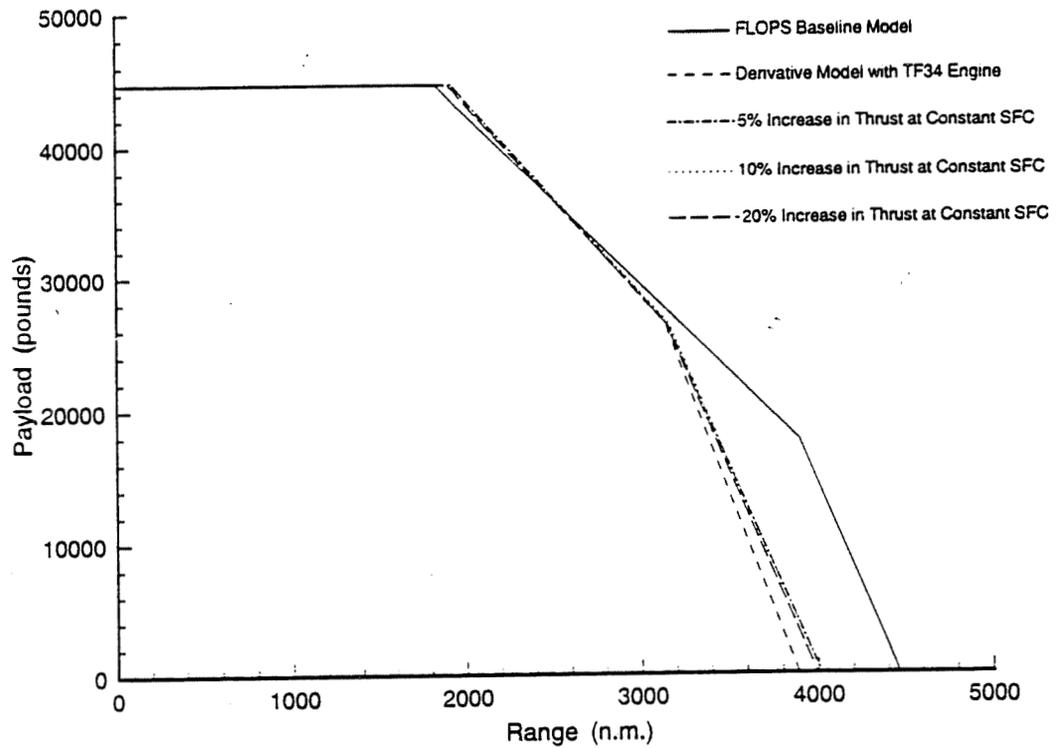


Figure 3: Payload-Range Diagram for Increased Thrust with the TF34 Engine

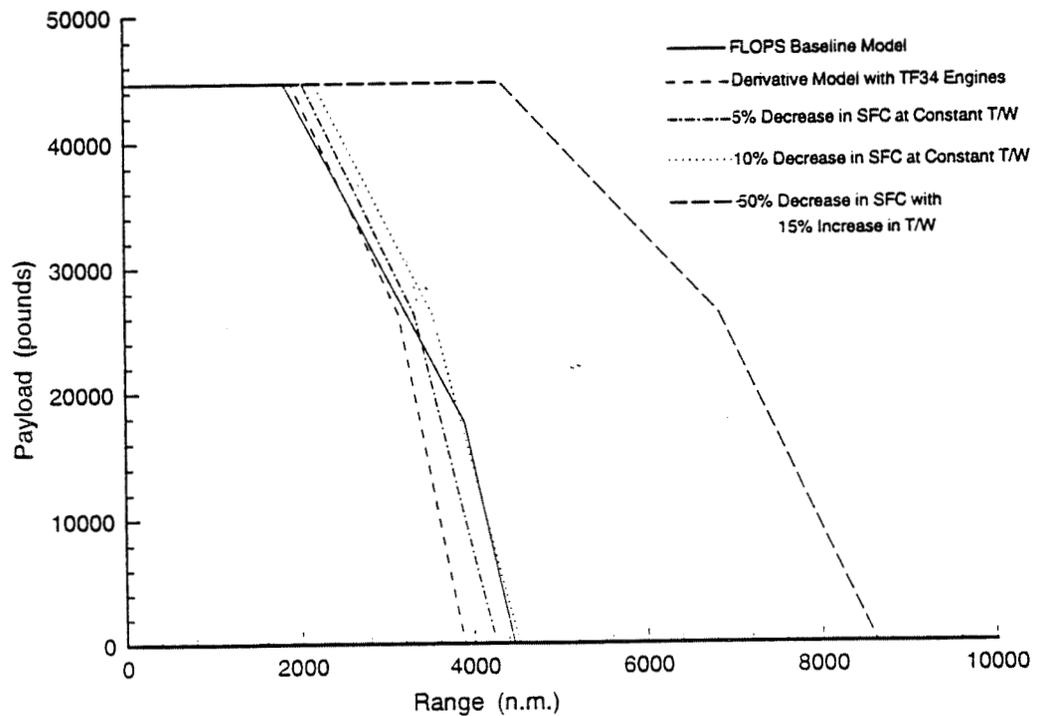


Figure 4: Payload-Range Diagram for Decreased Fuel Flows with the TF34 Engine

Conclusions

The baseline performance model of the C-130E was created for the Flight Optimization System. The model was calibrated against known data to reproduce the actual airplane performance. Variations of the baseline model were used to examine the implementation of an upper wing surface blowing concept using high by-pass ratio turbofan engines. Variations of the baseline model were also used to examine the impact of new technology on the engine/aircraft performance.

The upper surface blowing concept had mixed benefits to basic mission performance. The addition of turbofan engines to the aircraft increased cruising speeds and altitudes and reduced the airplane empty weight. Unfortunately, the turbofan engines also consumed more fuel. For full cargo missions, the range increased slightly due to the advantage of the lighter operating empty weight. As cargo weights went down and range increased, the higher fuel consumption negated the benefit of the reduction in empty weight and range performance decreased significantly. The application of technology to increase engine thrust did little to affect airplane range, although it did improve other performance characteristics. Technology to reduce fuel consumption had a significant impact on aircraft range while leaving other aircraft performance characteristics basically unchanged.

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**CURATION OF FEDERALLY OWNED
ARCHEOLOGICAL COLLECTIONS
AT NASA LANGLEY RESEARCH CENTER**

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**John Mouring, mentor
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ABSTRACT

As a federal agency, NASA has a moral and legal obligation to the public to manage the archeological heritage resources under its control. Archeological sites are unique, nonrenewable resources that must be preserved so that future generations may experience and interpret the material remains of the past. These sites are protected by a wide array of federal regulations including the Antiquities Act of 1906 (P.L. 59-209, 16 U.S.C. 431-433), the Historic Sites Act of 1935 (P.L. 74-292, 16 U.S.C. 461-467), the National Historic Preservation Act of 1966 (P.L. 95-515)(P.L. 102-575, 16 U.S.C. 470-470t), and the Archeological Resources Protection Act of 1979 (P.L. 86-95, 16 U.S.C. 470aa-470ll). These regulations are intended to ensure that our nation's cultural heritage is preserved for the study and enjoyment of future generations.

Once a site has been excavated, all that remains of it are the artifacts and associated records which, taken together, allow researchers to reconstruct the past. With the contextual information provided by associated records such as field notes, maps and photographs, archeological collections can provide important information about life in the past. An integral component of the federal archeology program is the curation of these databases so that qualified scholars will have access to them in years to come. Standards for the maintenance of archeological collections have been codified by various professional organizations and by the federal government. These guidelines focus on providing secure, climate-controlled archival storage conditions for the collections and an adequate study area in which researchers can examine the artifacts and documents.

In the 1970's and early 1980's, a group of NASA employees formed the LRC Historical and Archeological Society (LRCHAS) in order to pursue studies of the colonial plantations that had been displaced by Langley Research Center (LaRC). They collected data on family histories and land ownership as well as conducting archeological surveys and excavations at two important 17th-20th century plantation sites in LaRC, Cloverdale and Chesterville. The excavations produced a wealth of information in the form of artifacts, photographs, maps and other documents. Unfortunately, interest on the part of the LRCHAS membership waned before a report was written, and since 1982 the artifacts have moldered in a flimsy trailer with no climate controls, which had once served as a field laboratory but which threatened to become a tomb for the collection. A recent analysis of Langley's cultural resources by Gray & Pape, Inc. recommended that the collection be organized, cataloged, and placed in a proper curation facility in accordance with federal regulations.

My project for the LARSS program was to research curation standards, organize the collection, catalog it, and prepare it for transfer to a facility which could provide adequate long-term curation conditions for the artifacts and documents. The first phase was to organize the artifacts, which were lying about the lab in various stages of cleaning, analysis, and conservation. Once all of the artifacts from the various excavation units and levels had been regrouped, they were cleaned and/or repackaged in archivally-stable materials. A basic catalog was prepared which will provide interested parties with a rough idea of what we have and where it can be found. Another aspect of my project was to organize the records left by the LRCHAS. Bundles of papers, photographs, and field data found in every corner and drawer of the laboratory trailer were put into order and, where appropriate, copies were made on acid-free Permabond paper for longterm storage. Finally, the entire collection and most of the lab equipment was transferred into a secure, climate controlled room which will serve as an archive and study space for qualified scholars interested in exploring LaRC's rich historical heritage.

INTRODUCTION

Archeology provides us with a unique opportunity to study the past through the examination of actual objects used by people in the past. Archeological sites constitute a finite, nonrenewable resource of important information which cannot be duplicated or supplanted by standard historical sources. The act of excavation effectively destroys a site, leaving only the artifacts and associated records to tell its story. An important component of the federal archeology program is the curation of archeological collections for the benefit of future scholars. Curation is often given low priority in archeological circles, being considered less glamorous than field excavation, but any archeologist who has had to work with previously excavated materials can attest to the importance of proper storage and maintenance of artifacts and especially the related records. These records can include field notes, maps, photographs, historical records, and any other materials which provide information on the people whose remains are being excavated or on the excavation process itself. Artifacts without records are like paragraphs cut randomly from the pages of a book: interesting bits of information with no relation to any unifying whole.

Recognizing its role as steward for the shared cultural heritage embodied in archeological resources, the federal government has established guidelines for the curation of federally-owned archeological collections to ensure their preservation for future generations. These regulations are spelled out in 36 C.F.R. Part 79 "Curation of Federally Owned and Administered Archeological Collections" (see Appendix B). In a nutshell, these guidelines require that artifacts and records be stored together in a secure, fireproof facility with stable climatic controls providing optimal archival storage conditions for their long-term preservation. The Society for Historical Archeology's "Standards and Guidelines for the Curation of Archaeological Collections" (see Appendix A) expands on the federal guidelines, specifying optimal methods and materials for labelling, packaging, and storing these materials.

Ideally, an archeologist in the year 2095 should be able to come to Langley, sit down with our collection, and find everything necessary to be able to make sense of it. As more and more sites are destroyed by development or excavation, archeologists will increasingly come to rely on previously excavated collections to conduct their research.

ARCHEOLOGY AT LANGLEY RESEARCH CENTER

The study of the history and archeological resources at Langley Research Center can be traced to the mid-1950's, when two events occurred in the West Area that sparked the interest of NASA employees. One was the 1955 demolition of Cloverdale, the last surviving colonial house in this part of Hampton, which had stood where the bandstand is now located next to Reid Conference Center for almost 300 years. The other was the construction in 1956 of the hydraulic test track near Brick Kiln Creek, when a 17th century stone house foundation and colonial artifacts were exposed by grading equipment. It had long been known that this area and the nearby brick house ruin had once been the property of George Wythe, the famous colonial legislator, law professor, and signer of the Declaration of Independence. A NASA employee, Lyman Stilley, saved some artifacts which had been exposed in the track bed between the remains of the two houses, thus forming the nucleus of NASA-Langley's present archeological collection.

In 1970, a group of NASA employees organized and formed the LRC Historical and Archeological Society (LRCHAS) as an avocational pastime, with the goal of studying the people and properties that had preceded NASA in occupying this section of Hampton. Some members focused on historical issues, researching state and county records offices for family histories, wills, land patents, and deeds in order to document the human history and changing patterns of land ownership in the region. Other members opted to study the material remains of the past, and after consultation with the state archeologist and NASA officials, commenced the

first instructional archeological excavation in Fall 1973 at the site of Cloverdale plantation. They soon encountered a large trash pit which eventually yielded hundreds of artifacts dating from the mid-17th through the early 20th century.

In 1971, the LRCHAS prepared the documentation necessary to have Chesterville plantation, the birthplace and home of George Wythe, declared a National Historic Landmark. The site included the 17th century stone house foundation and the remains of a brick house which was built c. 1772 and burned in 1911. In the fall of 1974, they initiated a systematic shovel test survey of the main area around the two house ruins in order to establish the site boundaries, discovering an 18th century brick kiln and several possible outbuildings in the process. The site was duly accorded NHL status, and the 13-acre site is protected as such to this day.

In 1975, the LRCHAS initiated extensive excavation of the older stone house foundation in order to further assess its archeological deposits and to prepare an exhibit for the upcoming bicentennial celebration. The entire foundation was exposed through the excavation of thirteen 10-foot squares, of which two were selected for deeper excavation. Tens of thousands of artifacts were recovered in the course of this project. In addition, the group constructed the historical site markers which still dot Langley's landscape and prepared a drive-through historical tour which became one of the Visitor's Center's most popular attractions. Excavations continued on and off through 1981, by which time the bicentennial spirit had waned and with it the enthusiasm of society members. Laboratory curation and analysis had been neglected for some time, and by the mid 1980's the entire project had been essentially abandoned.

THE PRESENT PROJECT

When examined in early June 1995, the situation appeared hopeless. The last excavation unit had never been backfilled, and a small tree had sprouted from the exposed site floor. In the lab, artifacts were piled on every flat surface in sight: shelves, desks, worktables, the draining board of the sink, and the floor. They were stored in every conceivable kind of container: cigar boxes, Dixie cups, paper bags, cardboard boxes, plastic boxes, and sometimes just in open piles on a desk. Artifacts from the two different sites were often found on the same shelf together, and most had never been cleaned after excavation. Paper bags had sat in the non-climate controlled environment of the trailer for so long that in some cases the provenience information on the bag had faded beyond the point of legibility, and in many cases the bags were so dried out that they crumbled when touched. Field records, drawings, maps, photographs, and artifact inventory sheets were found to be in a similar state of disorganization, lying in drawers, on shelves, and in piles on the floor. Photographs were faded and crumbling, written records that had lain exposed to sunlight had faded, and evidence of rodent activity was everywhere. The laboratory building itself was a flimsy three-room trailer with a door that could be opened with a screwdriver in less than ten seconds. The structure was deteriorating, and stood a very real chance of being destroyed by a strong windstorm.

Before dealing with the artifacts themselves, the files of the LRCHAS were organized in order to get a feel for the operation of the society and to gain some idea of what could be expected to exist in the collection. Minutes of meetings, memos, correspondence, field notes, photographs, and other research materials were organized as best as possible. As the project progressed it was often possible to label uncaptioned photographs or to determine the provenience of unlabelled artifacts based on information gleaned from drawings and field notes. Wherever possible, information from several sources was cross-referenced. For example, an artifact found in the lab which had lost its identification tag was later identified, using a labelled photograph and an entry on an artifact inventory sheet. In another case, a labelled stratigraphic profile drawing of the site's basement wall provided the key to understanding a series of dozens of photographs, an interpretation which was later borne out by a careful rereading of the field

notes . Often, an obscure reference noted in this initial stage of the project would suddenly make sense weeks later when a corresponding piece of data was uncovered. It was quite a detective story at times, and in the end it was possible to learn a great deal about George Wythe, his family and property from what had seemed like a hopeless mess eight weeks before.

The artifact collection itself is especially rich, and together with the associated records, forms a valuable resource for a variety of inquiries into this period of the past. Major functional artifact classes represented in Langley's collection include the following:

<u>Functional category</u>	<u>Related artifact types</u>
Food storage / preparation / consumption	ceramics, glassware, iron kettles and stove parts, utensils of pewter, iron & bone
Architectural materials	brick, nails, mortar, stone, shell, plaster, window glass, lead window comes, iron hinges
Clothing and furniture	Buttons, upholstery tacks, brass pins, thimbles, buckles
Dietary remains	bone and shell
Hunting /defense	gunflint, bullets, gun parts, sword parts
Leisure activities	pipes, marbles, porcelain dolls, bone dominoes.

These items of material culture, along with the contextual information gleaned from geneology and documentary research, provide us with a window into the life of one of our founding fathers, as well as his neighbors and successors in the region. Archeologists have developed a wide array of analytical and interpretive approaches to material culture in recent years, enabling deeper and more humanistically satisfying recovery of meaning from archeological remains. Significant advances in archeological method and theory have occurred even since the Chesterville excavations were abandoned in 1981, and these interpretive capabilities can only be expected to increase in years to come.

The most basic step in archeological curation is to wash the soil from all artifacts, except in rare cases where such action may damage residues of food or blood that could prove useful for future analysis. After drying, the artifacts were placed in plastic ziploc-type bags, grouped by provenience. Where practical, the artifacts from a particular provenience were separated into artifact classes such as ceramics, glass, bone, etc., then all of those bags were placed in one large bag and assigned a lot number for the entire provenience.

For the benefit of the uninitiated, provenience refers to the location in which an artifact was found. This context is crucial in understanding the relationships between all the artifacts from a site. The provenience, then, is the artifact's position in three-dimensional space. The excavation unit, usually identified with an Excavation Record number (E.R. #), marks the horizontal location, while the level, usually identified with an upper case letter, marks the vertical position within the unit. The LRCHAS excavators worked in ten-foot squares based on U.T.M. coordinates found on the NASA-LaRC grid map, so the horizontal position of the excavation units can be precisely established. Following a practice common at the time, they left narrow walls known as bulks to separate the squares; these bulks were later excavated in some cases, and the artifact bags marked accordingly. The units were excavated in natural levels following visible changes in soil color and composition, occasionally denoting sublevels if only a minor change was noted. Thus, provenience 6AAA would have been above 6B, which was above 6BB, 6C, and so on. The only problem with using natural levels is that accurate detailed records must be kept which describe the differentiating characteristics of each level (soil color, composition, and artifact content) as well as its depth and thickness. Without these descriptions, there is no way of knowing exactly where in vertical space an artifact was found, only its position relative to the other levels within that unit. Unfortunately, this information does not appear to have been recorded by the LRCHAS excavators. A few stratigraphic profile drawings have been found

which might provide this information, but time constraints in the current project precluded this level of analysis.

Once all of the artifacts had been grouped with others from the same provenience, the cataloging process commenced. Every provenience was assigned a lot number, and if a bulk wall or feature within a level was excavated separately from the other artifacts in that level, it was assigned a separate lot number (examples: 4B, 4B-West Bulk, 4B-South Bulk, 6C, 6C-SE pit, 6C-NW pit, etc.). All artifacts from the same provenience should be cataloged under the same lot number, and any deviations from this standard should be noted in the artifact catalog. In the present case, rubble (consisting of brick, mortar, plaster, shell and stone) was cataloged separately from artifacts (such as ceramics, glass, etc.) for packaging purposes, so as to prevent fragile artifacts from being crushed by the bulkier rubble. The rubble was cataloged in numerical order from E.R. # 1 through E.R. # 13, followed by E.R. # 101, followed by the artifacts from E.R. #1 through E.R. #13. Occasional deviations from this system occurred if, for instance, a stray bag of artifacts was discovered after the rest of that provenience had already been cataloged and packaged.

Artifacts were occasionally found with no provenience information, whether the container had never been labelled in the first place or the label had simply faded over the years. These artifacts were labelled "No Provenience" and each such group was assigned its own lot number. Artifacts with no provenience have no analytical value, but are useful for a study collection or for display purposes.

Ideally, every artifact should be permanently labelled with the site number and provenience, so that if any become separated from the rest of the lot, they can later be returned to their proper place. Many of the unique or most interesting artifacts from the Chesterville site were pulled from the collection for displays and lectures, and the list of their proveniences has been lost, so they are stuck in a display collection limbo. Anytime an artifact is pulled from its lot, a note to that effect should be placed with the remaining artifacts and a separate list of "pulled artifacts" should be maintained to provide double indemnity against information loss. When the pulled artifact is returned to its proper place, the note can be removed from the lot bag and the entry checked off from the list.

Once all artifacts had been organized, bagged, and cataloged, they were placed in standard-sized acid-free archival quality Hollinger storage boxes. These are the archival industry standard and should be used whenever possible for the long-term storage of archeological collections. They are sturdy, they last much longer than any ordinary cardboard box, and they look nice lining the shelves. They are expensive (about \$4 per box), but well worth it.

The artifact catalog sheet lists the lot numbers, proveniences, contents, of each lot, and the number of the box in which it is stored. This system facilitates a variety of collections management tasks. A quick scan of the list can tell where all of the artifacts from a particular provenience can be found, which lots are in a particular box, and give an approximate idea of the quantity of a particular lot. For instance, lot 143 consists of 24 bags of rubble from provenience 6BBB, and is stored in boxes 18, 19, 20, and 21. On the other hand, box 45 contains all of the artifacts (except rubble) from all of the levels in excavation units 1, 2, 3, and 4, comprising lot #'s 208-246.

The organization, cleaning, cataloging, and packing of the collection was carried out in the trailer that had served as the laboratory and storage facility. Meanwhile, back at the Facilities Planning and Development Office, LaRCs Master Planner (who also serves as Historic Preservation Officer) was trying to find a new home on the Center for the collection. A variety of choices were presented and rejected for a variety of reasons - too small, no climate controls, inadequate security - until, finally a room that met the basic requirements was found. It will have room for the present collection to be stored on shelves, with additional space for work benches, a

desk, and storage space for the tools and equipment left behind by the LRCHAS. Photographs, maps, field records, historical background materials, and other research materials will be stored along with the artifacts in a room that can be used by qualified researchers who wish to study the material. In theory, the collection should never have to leave that room, except for exhibits, as long as the building stands. The Historic Preservation Officer will have authority over access to the collection, which will be much closer to compliance with the guidelines of 36 C.F.R. 79.

Another alternative is to finish cataloging the collection and submit it to the Virginia Department of Historic Resources (VDHR) for permanent curation. The Chief Curator for VDHR, Beth Acuff, has indicated that that would ultimately be the best avenue to take. VDHR has the staff, facilities, and resources to properly care for the collection in perpetuity and to make it available to scholars in a central location along with other collections from throughout the state. A one-time fee of \$75 per box is charged for this service, and since LaRC's collection currently includes 72 boxes, this would cost a total of \$5625. This outlay may seem high at first, but it would remove a great burden of responsibility from NASA's shoulders. In addition to storage, VDHR takes responsibility for any future conservation needs or exhibit preparations that may become necessary.

In either case, much work remains to be done before this phase of the project can be said to be complete. The collection needs to be more thoroughly inventoried, and this information added to the site files at VDHR. The Chesterville site, by virtue of its association with George Wythe as well as its sheer richness, is an important resource for the region and the archaeological community at large, and the results of its excavation must be disseminated to the public. It would be feasible to write a report, perhaps to be published in the Quarterly Bulletin of the Archeological Society of Virginia or a similar journal, based on the information at hand. The existing records are spotty, but many of the original excavators are still employed at LaRC and have indicated a willingness to assist in such an undertaking. Prompt reporting of archeological investigation is an accepted standard in the profession; it fulfills our obligation to share information with the public that funds much of our work. To excavate an archeological site without publishing a report is irresponsible at best, and borders on treasure hunting at worst. Either way, at least the basic site data must be published for the sake of interested scholars.

In all fairness, it should be noted that had it not been for the hard work and dedication of the LRCHAS members, working on their own time with no reward except the thrill of discovery, we would know nothing about any of these sites or about the people who lived here before the arrival of NASA. While history and archaeology are not within the realm of NASA's mission, the agency had done nothing to save or interpret the national heritage lying beneath its feet. On the contrary, the Chesterville site was very nearly destroyed by facility construction before the efforts of LRCHAS members led to its listing on the National Register of Historic Places and the subsequent archaeological investigations. In spite of any shortcomings in their methods or reporting, the members of the LRC Historical and Archeological Society deserve to be commended for their research and hard work.

Historian David Lowenthal has referred to the past as "a foreign country" which can be more fully interpreted through the preservation and analysis of historic artifacts and sites. It is hoped that the present archaeological curation program at Langley Research Center can bring us closer to recovering the multiple meanings that the past held for the people that lived here before the arrival of NASA.

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NASA LaRC HAZARDOUS MATERIAL PHARMACY

81.

Student: Remy Esquenet

Mentor: Robert D. Brown

Office of Safety, Environment, and Mission Assurance

Office of Environmental Engineering

ABSTRACT

This report outlines the steps taken in the research and design of a pilot hazardous material pharmacy at NASA LaRC. The purpose of the hazardous material pharmacy is to reduce hazardous material procurement costs and hazardous waste disposal costs through the collection and reissue of excess hazardous material. The results of this research show that a hazardous materials reuse facility is feasible and potentially beneficial to LaRC.

INTRODUCTION

In 1993-1994 the Office of Environmental Engineering contracted SAIC to develop NASA Langley's Pollution Prevention (P2) Program. One of the priority projects identified in this contract was the development of a hazardous waste minimization (HAZMIN)/ hazardous materials reutilization (HAZMART) program in the form of a Hazardous Materials Pharmacy. As my LARSS project I was tasked with beginning the development of the Hazardous Materials Pharmacy.

A hazardous materials pharmacy is designed to reduce hazardous material procurement costs and hazardous waste disposal costs. This is accomplished through the collection and reissue of excess hazardous material. Currently, a rarely used hazardous material may be stored in a shop area, unused, until it passes its expiration date. The material is then usually disposed of as a hazardous waste, often at a greater expense than the original cost of the material. While this material was on the shelf expiring, other shop areas may have ordered new supplies of the same material.

The hazardous material pharmacy would act as a clearinghouse for such materials. Material that is not going to be used would be turned in to the pharmacy. Other users could then be issued this material free of charge, thereby reducing procurement costs. The use of this material by another shop prevents it from expiring, thereby reducing hazardous waste disposal costs.

APPROACH

Research on the project began by doing a literature search and by visiting some operational Hazardous Materials Pharmacies in southeastern Virginia. The original contractor, SAIC, supplied two documents from The Air Force Center for Environmental Excellence. These documents are called "Hazardous Material Pharmacy: Commanders 'How-To Guide'" and "Facility Planning and Design Guide: Hazardous Material Pharmacy." The operational pharmacies that were visited were at Fort Eustis and at the Norfolk Naval Base.

The available literature and visits to operational pharmacies pointed out that hazardous material pharmacies are usually involved in the supply of new hazardous materials as well as the reuse of excess materials. NASA LaRC supply was contacted but they did not see the benefit of such a project. Because of lack of support from supply it was decided that the hazardous material pharmacy was only going to be a hazardous material reuse facility.

Putting a full scale reuse facility into affect immediately would be very difficult so a pilot program was chosen for development. This would allow for the collection, storage, and distribution mechanisms to be established while the pharmacy was still small and manageable. A pilot program dealing with Operations and Maintenance at LaRC was deemed the best option. Operations and Maintenance at LaRC is handled by a contractor called EG&G. EG&G was chosen for several reasons. EG&G has demonstrated exceptional awareness of environmental responsibilities and is an active participant in other pollution projects. EG&G has excellent accountability procedures for issuance, use and disposal of hazardous materials. EG&G is

divided into many trades covering the entire center. Each trade uses hazardous materials and could benefit from a hazardous material reuse facility.

EG&G's environmental coordinator was contacted and the project was discussed. The various trade shops were visited to evaluate their potential for participation in the reuse facility. A letter was sent to the contract specialist in charge of EG&G's contract, requesting EG&G's official involvement in the project. (See Appendix A) Copies of this letter were sent to key LaRC and EG&G personnel. OEE and EG&G representatives then met to discuss EG&G's participation in the pharmacy.

After an agreement was reached between OEE and EG&G a meeting was held to inform representatives of all of the EG&G trade groups that this pharmacy project would be moving forward. A list of excess hazardous materials was requested from each of the trades.

Research was also conducted to determine a location for the pharmacy. Property management personnel at the Logistics Management Division (LMD) were contacted to discuss the use of existing structures at LaRC. The use of prefabricated environmentally controlled hazardous material storage units was also considered.

EQUIPMENT AND FACILITIES

NASA LaRC vehicles were used for travel to the Hazardous Materials Pharmacies at Norfolk Naval Base and Fort Eustis. LaRC bicycles were used to visit various EG&G trade shops and potential locations for the pharmacy. Training was received at the NASA LaRC Computer Lab in Microsoft Excel. Microsoft Word was used extensively to generate reports and letters.

RESULTS

A temporary site for the pharmacy has been established. While in its preliminary stage it will be operated out of the EG&G warehouse. Buildings 1270 B,C,D had been considered as a permanent location for the pharmacy because they are currently being used for chemical storage and are scheduled to be closed in October. After reviewing the structures they were determined to be unacceptable because they do not meet safety requirements for hazardous material storage. The best option for a permanent location was determined to be a prefabricated structure designed for hazardous material storage. A suitable unit has been priced and funds have been allotted in next year's budget. (See Appendix B) The final location of this structure has not been definitively established. One possible location is adjacent to the EG&G warehouse, building 1187. Another possible location is behind the new pollution prevention building that is currently under construction.

Lists of excess materials have been received from each of the EG&G trade offices. (See Appendix C) These materials will be collected when suitable storage lockers have been placed into the EG&G warehouse.

OEE and EG&G personnel have agreed that EG&G personnel will run the daily operations of the hazardous materials pharmacy while it is in its preliminary stage. During this preliminary stage no additional manpower will be needed and no amendments will be made to the EG&G contract. A list of available materials will be distributed to all of the trades on a bi-weekly basis. Any trade will be able to take any material that is listed on the pharmacy inventory if they can show that the material is needed for a specific work order. The material can then be issued free of charge.

The success of the program will be determined by tracking the material that passes through the pharmacy. The value of the materials that are distributed can be totaled to estimate the reduction in procurement costs for EG&G. The potential disposal costs of these materials can also be totaled to estimate the reduction in hazardous waste disposal costs. The sum of these two figures will provide an estimate of the total savings benefit resulting from pharmacy operations.

If this pilot project proves successful it can be expanded to incorporate other areas at NASA LaRC. Other areas that have been identified, through analysis of hazardous waste disposal records, are the Operations Support Division, the Fabrication Division and Flight Dynamics.

429/RMEsquet

National Aeronautics and
Space Administration
Langley Research Center
Hampton, VA 23681-0001

APPENDIX A



Reply to Attn of: 429

June 30, 1995

TO: 126/David Jones, Contract Specialist, EG&G Contract NAS1-20243, Supply,
Construction, and ADP Contracts Branch, AD

FROM: 429/Head, Office of Environmental Engineering, OSEMA

SUBJECT: Establishment of Hazardous Materials Pharmacy

The Office of Environmental Engineering (OEE) is in the preliminary stage of developing a hazardous materials pharmacy program. OEE proposes EG&G participate in establishing a Center pilot project.

A hazardous materials pharmacy is designed to reduce both hazardous material procurement costs and hazardous waste disposal costs. This is accomplished through hazardous material collection and reissue. Currently, a rarely used hazardous material may be stored in a shop area, unused, until it has passed its expiration date. The material is then usually disposed of as hazardous waste, often at a greater expense than the material originally cost. While this material was on a shelf expiring, other shop areas ordered new supplies of the same material.

The hazardous materials pharmacy would act as a clearinghouse for such materials. Material that is not going to be used would be turned in to the pharmacy. Other users could then be issued this material free of charge, thereby reducing procurement costs. The use of this material by another shop prevents it from expiring, thereby reducing hazardous waste disposal costs.

If successful, the pharmacy concept could be expanded to include the entire Center. EG&G is uniquely qualified to participate for several reasons. EG&G has demonstrated exceptional awareness of environmental responsibilities and is an active participant in pollution prevention projects. EG&G has excellent accountability procedures for issuance, use, and disposal of hazardous materials. The Centerwide operations and maintenance activities conducted by EG&G are eminently suitable for hazardous materials pharmacy operations. Successful pharmacies based on similar operations have been established at the Norfolk Naval Base and at Fort Eustis, VA. OEE would not expect any modifications or additional tasking to the EG&G contract for its participation.

We would like to meet with you and an EG&G representative to discuss this project. The OEE point of contact for this activity is Leslie Holland at extension 48690. Please contact her to set up a meeting or if you need additional information. Thank you for your time and consideration.

John W. Lee
43342

cc:
134/AD
481/OSD
485/J. R. Carbonneau
485/J. L. Kirby
421/OSEMA
429/OEE
429/L. H. Holland

429/RMEsquet:edd UFI:8800 (48690)

APPENDIX B

The following unit is suitable for use as an exterior containment unit for hazardous materials. It measures 16' long, 9'9" deep and 8'8" high. It has a storage capacity of 28 - 55 gallon drums. Two entrances are located on the 16' side of the unit. The interior of the unit is divided into two halves by a fire rated separation wall. One side is suitable for the storage of hazardous materials, and the other side is suitable for storage of corrosives. Separate secondary containment and sumps are built into each side of the unit in the event of a leak or spill. The unit is fitted with explosion relief and dry chemical fire suppression systems. The unit is also air conditioned and insulated.

Safety Storage Model 30

Feature	Cost
Base Unit - Model 30	\$13,000
Air Conditioning 2,800 BTU	\$ 2,800
Explosion Relief	\$ 750
Fire Rated Separation Wall	\$ 750
Dry Chemical Fire Suppression	\$ 1,775
Separate Sumps	\$ 155
Insulation	\$ 1,330
Explosion-proof Lighting	\$ 1,055
Corrosive Materials Liner	\$ 600
TOTAL	\$22,215.00

Manufacturer Information

Safety Storage, Inc. Northeast
341 Willowbrook Lane
West Chester, PA 19382
Representative: Art Fad
Telephone: (610) 692-9151
Fax: (610) 692-9156

APPENDIX C

August 01, 1995

EG&G's inventory of materials to be placed into NASA's Hazardous Materials Pharmacy Reuse facility.

PIPE / WELDING SECTION

Selig's Super Freee-All
Drain cleaner, contains sodium hydroxide.
poison / corrosive
1 ea. 5 gal. can

ELECTRICAL SECTION

Glyptal Inc.
74010 hardener
flammable liquid
5 ea. 1 gal. cans

Paint, aluminum, heat resisting, 1200 deg. F
flammable liquid
1 ea. 1 gal. can

Glyptal Inc.
74004 buff epoxy enamel
flammable liquid
2 ea. 1 gal. can

A/C, SHEETMETAL SECTION

Ethylene Glycol
6 ea. 1 gal. cans

Selig's spray & wipe, Clean Up II
aerosol detergent, disinfectant
11 ea. 19 oz. aerosol cans

Paint aluminum, heat resisting, 1200 deg. F
NSN 8010-00-815-2692
1 ea. 1 gal. can

Selig's Formula 0-88
organic cleaner and degreaser
combustible liquid
1 ea. 5 gal. can

MECHANICAL SECTION

Dupont Axarel 6100
cleaning agent
combustible liquid
1 ea. 5 gal. can

Dupont Axarel 2200
cleaning agent
combustible liquid
1 ea. 5 gal. can

BUILDING TRADES SECTION

Paint Enamel, interior, semi-gloss
4 ea. 1 gal. cans

Glidden Latex paint
6 ea. 1 gal. cans

Pittsburgh Paints
DTM enamel / 100% acrylic
2 ea. 1 gal. cans

Bix spray-on stripper
paint remover
poison
1 ea 1 gal. can

Pittsburgh off white
block filler / latex
1 ea. 5 gal. can

Pittsburgh pitt-guard
polyamide-epoxy coating
part A, 3 ea. 1 gal. cans
part B, 3 ea. 1 gal. cans

Plasite (white)
cold-set coating
flammable
3 ea. 1 gal. kits

Devcon "Z"
cold galvanizing compound
3 ea. 24 lb. cans

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14e

Assessment of Electromagnetic Fields
at
NASA Langley Research Center

Carter B. Ficklen, Student
Alan H. Phillips, Mentor

Office of Director
Office of Safety, Environment, and Mission Assurance
Office of Safety and Facility Assurance

ABSTRACT

This report presents the results of an assessment of electromagnetic fields completed at NASA Langley Research Center as part of the Langley Aerospace Research Summer Scholars Program. This project was performed to determine levels of electromagnetic fields, determine the significance of the levels present, and determine a plan to reduce electromagnetic field exposure, if necessary. This report also describes the properties of electromagnetic fields and their interaction with humans. The results of three major occupational epidemiological studies is presented to determine risks posed to humans by EMF exposure. The data for this report came from peer-reviewed journal articles and government publications pertaining to the health effects of electromagnetic fields.

INTRODUCTION

Recently, a great deal of attention has been given to the possibility of detrimental health effects resulting from exposure to Extremely Low Frequency (ELF) Electromagnetic Fields (EMF). The first reports of the possibility of health effects resulting from EMF exposure originated in the 1960's from the Soviet Union. Researchers in the Soviet Union reported a number of varied health problems in persons working in high-voltage power switch yards. In 1977, the United States Department of Energy began researching EMF in response to concerns raised about the safety of utility workers. Wertheimer and Leeper performed a study in 1979 that showed a slightly increased risk of leukemia in children living near power lines in the Denver area. The results of the Wertheimer and Leeper study were not replicated. Since the Wertheimer and Leeper study, numerous epidemiological and biological studies have been performed to determine if EMF poses a significant threat to human health, but to date no concrete evidence has been presented to prove or disprove the possibility of detrimental health effects being caused by EMF.

Electromagnetic fields are virtually ubiquitous in our environment. NASA Langley Research Center has numerous varied work environments which correspond to varying levels of worker exposure to EMF. The purpose of this assessment is to present a review of existing studies of EMF health effects, present the results of a survey of EMF levels at LaRC, and present ideas to help in reducing EMF exposure at LaRC.

ELECTROMAGNETIC FIELD BASICS

Extremely Low Frequency (ELF) Electromagnetic Fields (EMF) are present wherever electricity is being generated, transmitted, or used. The electromagnetic spectrum is divided into ionizing and non-ionizing regions. Ionizing radiation includes gamma rays and X-rays. Non-ionizing radiation sources include visible light, infrared light, radio frequency and extremely low frequency.

Non-ionizing and ionizing radiations are different from one another in how they are produced, how they propagate, how they react with matter, and how they produce biologic and health effects. Non-ionizing radiation is not strong enough to break chemical bonds in molecules and form ions. The higher the frequency (expressed in hertz), the shorter the distance between one wave and the next, and the greater the amount of energy in the field. A comparison between the wavelengths of a microwave oven and power lines illustrate this phenomenon. A power line operating at a frequency of 60 hertz has a wavelength of 3100 miles, while a microwave oven operating at 2450 megahertz (one megahertz = one million hertz) has a wavelength of 4.8 inches. Extremely low frequency electromagnetic fields include frequencies below 3000 hertz.

Magnetic fields are measured in units called gauss which express the magnetic flux density. A unit called the tesla has been agreed upon as an international standard, but the gauss is used more often by the general public. The material presented in this discussion will be given in gauss with distances expressed in inches and feet.

Conversion Between Magnetic Flux Density Units

1 gauss (G) = 1000 milligauss (mG)

1 milligauss (mG) = 0.1 micro tesla

In the United States, electrical power alternates at a rate of 60 cycles per second (hertz). This alternating current (AC) behaves differently than direct current (DC). Direct current flows directly from batteries to the device being powered while alternating current flows back and forth. The earth produces its own DC electrical energy through thunderstorms and currents deep within the earth's core. The DC magnetic field from the currents in the earth's core averages 500 milligauss (mG) which is higher than the magnetic field levels resulting from AC electrical power.

The earth's magnetic field has virtually no effect on human health because DC fields are not able to create currents in objects in the manner that AC fields from electrical power do. AC fields induce weak electric currents when they come into contact with humans, and have been the focus of research pertaining to human health effects resulting from EMF exposure.

Electromagnetic fields are made up of both electric and magnetic fields. Electric and magnetic fields behave very differently from one another even though they both result from the same source, electrical power. Electric fields are produced by voltage. When an appliance is plugged into an electrical outlet, an electric field is given off, even if the appliance is turned off. Magnetic fields are produced by current, so an appliance must be plugged in and turned on to give off a magnetic field. Electric fields can be shielded easily by conducting objects such as buildings. Magnetic fields can only be effectively shielded by using nonferromagnetic, high-conductive copper.

ELECTROMAGNETIC FIELD INTERACTION WITH HUMANS

Electromagnetic fields contact humans through the outer surface of the body. The fields then induce weak electric currents that flow through the body. Electromagnetic fields are not capable of penetrating cell membranes, they can only flow between cells. The human body has electrical activity of its own from the heart and brain. The currents from extremely low frequency electromagnetic fields are much weaker than the natural currents of the human body. The effects that electromagnetic fields have on the natural currents within the body are not well understood. The confusion lies in determining the exact mechanism by which electromagnetic fields interact with cells.

Electromagnetic fields are not capable of causing any tissue heating because the frequencies of ELF electromagnetic fields have frequencies 12 orders of magnitude less than very weak ionizing radiation.

Acute Physiological Effects

In 1991, research was performed at the Midwest Research Institute to determine the effects of EMF on human heart function. Healthy human volunteers were intermittently exposed to electric and magnetic fields. The results showed a statistically significant slowing of the heart rate. Exposure to the magnetic field (200 mG in strength) had a much greater effect than the electric field. Significant variation occurred in the responses of each individual. The variation in response was largely due to blood pressure and heart rate prior to exposure.

The researchers believe the change in heart rate was caused by interaction of the magnetic field with the nervous system which exercises control over heart rate and function. While the heart

rate variations were statistically significant, they fall within the range of normal physiological variations.

Such effects would only be of concern if they have negative effects on human performance that might enhance the risk of accidents, produce a much stronger interaction with other stress factors, or give rise to more extreme effects in individuals with pre-existing heart problems. Currently, there is no evidence that the slight alteration in heart function caused by magnetic fields constitutes a health hazard.

The pineal gland acts as a biological timekeeper for the human body. In a process known as the circadian cycle the pineal gland secretes a hormone called melatonin. One of the major effects of EMF to be discovered is that high level EMF can suppress the normal nocturnal rise of melatonin in animals, and is believed to do the same in humans. In a study performed by Wilson et al. rats exposed to 60 hertz EMF had reduced levels of melatonin production which disrupted basic biological functions, behavior, and immune system response.

Several additional studies performed on pineal function show a significant effect to pineal gland output, but they can't be replicated for unknown reasons. The replication problems may be due to the sensitivity of pineal function. The pineal gland quickly responds to stress, light exposure, temperature, and diet. The individual response of each organism being studied makes it difficult to prove or disprove that a definite effect on pineal function is caused by EMF. Studies performed to determine if EMF disrupts the human biological timeclock have been inconclusive.

Recently, a great deal of attention has been focused on the role of melatonin in cancer, particularly breast cancer in women. Melatonin acts as a growth inhibitor of some types of cancer cells and improves the efficiency of the immune system which can indirectly help the body fight cancer cells. If EMF can inhibit melatonin production, it is possible that EMF can be thought of as a potential promoter of cancer cells, but this will be extremely difficult to prove because of the numerous variables that effect melatonin production

Effects on Cardiac Pacemakers

A number of studies performed in the early 1980's reported that electromagnetic interference can effect pacemaker function by altering pacemaker impulse formation, causing a reduction in pacemaker rate, or changing pacemaker operation from a need-based mode to a fixed-rate mode. In 1986 J.C. Griffin assessed what is required to put a pacemaker at risk from electromagnetic interference. In order for pacemaker function to be altered the user must have one of the few unipolar models that is affected by EMF, be completely dependent on the pacemaker at the time of interference, and experience the effects long enough to lose consciousness (at least 5 - 10 seconds). Only 10 - 20 percent of unipolar models are susceptible and only 20 - 25 percent of pacemaker users are totally dependent, so risk levels of cardiac malfunction from electromagnetic interference are relatively low. It has been suggested that standardization of pacemakers to resist electromagnetic interference would be the preferred mode of protection.

EPIDEMIOLOGICAL STUDIES

Epidemiology is the study of disease and its pattern of occurrence in human populations. Results of epidemiological studies are reported in terms of statistical association between various factors and disease. Epidemiology is an observational science, not an experimental science.

Principles of Epidemiology

Epidemiology is complicated by the difficulty of determining whether the results of a study indicate a true causal association because of the effects of other factors not included in the scope of the study known as confounding variables. A finding from a study is said to be statistically significant if researchers are 95 percent confident that an association exists. A statistically significant finding does not necessarily prove a causal association.

In most epidemiological studies pertaining to EMF researchers try to establish an association between the occurrence of a particular health related outcome and exposure to EMF. Two groups are assembled in an epidemiological study, the cases and the controls. The cases are the group with a particular disease (such as leukemia). The controls are the group who do not have the disease, but possess characteristics similar to those of the cases. This type of study is referred to as a case-control study. The next step is to estimate the exposure of the cases and controls to EMF. After exposure estimation, a calculation can be used to determine the relative risk (odds ratio).

$$\text{Relative Risk} = \frac{\text{Incidence rate among exposed}}{\text{Incidence rate among unexposed}}$$

The higher the value for the relative risk, the more likely it is that a particular factor (EMF) is capable of causing disease.

Review of Occupational Epidemiological Studies

Research into occupational exposure to EMF was launched in 1982 when Samuel Wilhelm, an epidemiologist at the Washington State Department of Social and Health Services found elevated leukemia rates in 10 of 11 occupations involving exposure to EMF. Numerous studies have been reported since this study, but no conclusive evidence has been found. Many studies conflict one another or find relative risk values so small they are inconclusive.

The conflicting nature of the studies may largely be due to the fact that most studies infer exposure assessment by job title instead of taking actual field measurements to determine worker exposure. This paper will review three recent occupational epidemiological studies. These studies were chosen because they have a large number of subjects, they are based on actual measurements of EMF in the workplace, they are well designed, and they have been thoroughly peer reviewed.

In 1994, Gilles Theriault published an occupational epidemiological study on EMF. The study focused on cancer risk among electricity workers at Ontario Hydro, Hydro-Quebec, and Electricite de France. The main priority of the study was to assess risk for leukemia, brain cancer, and skin melanoma, but risks for all other cancers were also assessed. Large numbers of people

were included, an extended measurement campaign was performed, and a comprehensive assessment of exposure to other cancer risk factors was included. Assessment of exposure to other cancer risk factors included looking at past exposure to 47 toxic chemicals and cigarette smoke.

The research team looked at 223,292 utility workers. Exposure estimation was aided by workers wearing a personal exposure meter (dosimeter) for a full working week at various times of the year. A total of 10,330 days of worker exposure measurements were obtained. The data obtained from the worker measurements were combined with knowledge of present and historical working environments (dating back to 1945) encountered by the workers being studied to formulate an exposure estimation for each worker.

The median exposure to the workers was 31 mG-years. Workers whose exposure exceeded the median had a statistically significant relative risk of 3.2 at the 95 percent confidence interval for developing acute myeloid leukemia. No other associations were found for 29 other types of cancer when the data were analyzed. Theriault assessed the significance of his study by stating that even though he and his research team utilized all available means for exposure assessment and collected an immense amount of data, the results were imprecise because no clear dose-response was established.

Despite the fact that no concrete evidence to prove or disprove the theory that EMF can cause cancer, this study is the largest and most comprehensive study performed to date.

In 1993, Sahl, Kelsh, and Greenland studied 36,221 electrical utility workers at the Southern California Edison Company. The researchers assessed the risk of death in workers from leukemia, brain cancer, or lymphoma from 1960 to 1988. The researchers combined personal dosimetry with job histories to construct an exposure assessment for each employee.

Ten controls were used for each case of leukemia, brain cancer, and lymphoma. The cohort (a group of persons who share a common experience within the same time period) was made up of all persons who worked at Southern California Edison for at least one year. The mean duration of employment was 13 years. No association between magnetic field exposure and deaths from leukemia, brain cancer, or lymphoma, as well as all other cancers was observed.

Matonoski et al. conducted a study of retired American Telephone and Telegraph lineworkers. A total of 124 leukemia cases were identified from the mortality records of AT&T. Three controls were selected for each case. Worker exposure was assessed through employment histories and actual EMF exposure monitoring of lineworkers and non-lineworkers under present working conditions. Each worker in the study was assigned a lifetime exposure score. For workers with a lifetime exposure score above the median, a doubling in leukemia risk was observed. Individuals who held jobs with intermittent peak exposures had a slightly higher risk of developing leukemia than workers with a constant exposure level. Cable splicers had the highest estimated mean exposure (4.3 mG), central office technicians had an intermediate mean exposure level of 2.5 mG, and installers had a mean exposure level of 1.7 mG which was the lowest.

Summary of Findings From Epidemiologic Data

While the studies presented in this report represent a significant improvement in design and methodology over past studies, they have provided no conclusive evidence that an effect from EMF exposure exists or does not exist. Theriault reported a slightly increased risk in acute myeloid leukemia, but was skeptical that his findings were inconclusive. Sahl et al. found no evidence of an association between EMF and cancer. Matanoski et al. reported an association between levels and duration of EMF exposure and cancer, but stated that

Problems will always exist in designing epidemiological studies pertaining to EMF due to the retrospective nature of EMF studies, confounding variables, and the difficulty in finding a truly unexposed population to act as controls. Interpretation of results will remain a problem until a dose-response relationship between EMF and detrimental health effects is demonstrated.

RESULTS OF EMF SURVEY

Research to assess exposure to EMF in occupations other than electrical power workers is still in its infancy. NASA-Langley Research Center has a diverse range of working environments and occupations. This survey was performed to characterize the magnetic field strengths in facilities at LaRC.

Methods

Measurements of magnetic field strengths were made at approximately 20 LaRC facilities. Magnetic fields were chosen over electric fields because magnetic fields are believed to be the more hazardous component of EMFs. Facilities were chosen after consulting with electrical safety personnel according to the level of electrical power consumption. Electrical substations and power lines were also included in the survey.

Area, point-in-time magnetic field measurements, often referred to as "spot" measurements were made during a walk through survey at each facility. Efforts were made to cover all areas of each facility. A significant level was considered to be above 1.0 mG. During the walk through, levels were continuously monitored while walking at a slow pace. When a significant reading registered on the display, it was recorded and the surroundings were assessed to determine the source of the field. Often, the facility coordinator or safety head would aid in the survey process by identifying areas that would be of potential concern in their facility. Every effort was made to perform surveys at a time when equipment pertinent to the task of each facility was in operation.

Instrumentation

All measurements were made using a handheld ELF gaussmeter (Model PLM-100WB) manufactured by Macintyre Electronic Design Associates (Herndon, Virginia). The PLM-100WB is a general purpose, single axis AC gaussmeter which measures the root-mean-square (RMS) value of ELF magnetic fields. The survey was performed using the wideband mode where the meter covers the bandwidth of 12Hz to 50 kHz to account for the harmonics often present in ELF fields. The PLM-100WB has a probe (4.8" long x 0.8" diameter) separate from the unit to allow for determination of the orientation of the field. Measurements were made holding the probe approximately four feet above the floor, an arms length from the surveyor.

Results

The results of the survey will be presented by describing the data gathered at each facility.

1205 - Fatigue and Fracture Research Lab

Measurements taken throughout the first and second floor indicated background levels of less than 1 mG. The test area (Room 114) has various instrument test strength machines that produced levels ranging from 2 - 4 mG two feet away while the machines were in operation. The electrical panels in room 114 had levels of 3 - 4 mG at a distance of two feet.

1208 - Aircraft Noise Reduction Laboratory

The survey of this facility indicated all background levels to be less than 1 mG. Levels found were typical for any office environment. Elevated levels (under 20 mG) were measured in close proximity to computers, clocks, and desk lamps, but levels fell off to less than 1 mG at a distance of 1 foot from the source.

1212 (B,C,D) - Subsonic Tunnels

A measurement outside of room number 101 indicated a level of 1.3 mG. Investigation revealed that the measurement was taken below the intake for the air conditioning system. All other background levels in office areas were less than 1 mG. Room 139, an electrical panel room had readings ranging from 4 - 16 mG, but no work stations were in the area of these levels so worker exposure in this area is limited. Readings taken in the vicinity of the 14x22 foot Subsonic Tunnel while in operation ranged from 1.2 to 5.1 mG. The substation located in room 107 in 1212C had levels ranging from <1 mG to 3.5 mG. The high speed 7x10 foot Tunnel was not in operation at the time of the survey.

1220 - Air Lab, Simulation Research Facility, Transport Simulator, and Visual Landing Display System, Automation Technology

Measurements taken throughout the first and second floor indicated background levels of less than 1 mG with the exception of two areas in front of room 109 with electrical panels where levels ranged from 1.5 to 2.6 mG. The electromagnetics research area was not in operation at the time of the survey, but a large computer drive was in operation in this area. Six inches from the side of the drive, a level of 66 mG was recorded, but three feet from the drive the level dropped to 3.5 mG.

1227 - Substation DL

Measurements were taken at the fence surrounding the substation. Eight measurements were taken at this substation with a minimum of 0.3 mG and a maximum of 5.4 mG.

1233 - Stratton Road Substation

This substation receives power directly from the two sets of overhead power lines entering LaRC. Measurements taken at the four corners of the fence at the substation indicate levels of less than 1 mG. The power lines were measured at ground level, three feet from the ground, and six feet from the ground at the point where they entered the substation. The levels measured at six feet were the highest, ranging from 13.1 - 16.0 mG. The measurements taken at the edge of the right-of-way the power lines ranged from 1 to 2.5 mG.

1236 - National Transonic Facility

A survey of the facility was conducted while the tunnel was in operation. Readings were taken in the control room for the tunnel and in the area where the induction motors were located. The control room had numerous computers and video display terminals, but no significant (>1 mG) measurements were recorded. The induction motors had levels ranging from 24 - 72 mG.

1238 - Electronics Technology Lab

No readings greater than 1 mG were recorded other than measurements from within two feet of video display terminals.

1247 - Hypersonic Facilities Complex

Readings taken in office areas were less than 1 mG with one significant exception. In 1247B the electrical panels in room 113 had readings of up to 140 mG. An office (room 114) was located directly in front of room 113. Readings in room 113 along the wall which divided the two rooms ranged from 6 - 12 mG. Readings were also taken while the Scramjet Tunnel was in operation, but no significant levels were observed. Measurements taken in all other working areas were not significant. The basement has a number of motors and electrical panels that ranged from 2.3 to 14.8

1251 - Unitary Wind Tunnel

All measurements taken in office areas and control rooms were less than 1 mG. Readings in the area of tunnel drive motors and compressors range from 30 - 80 mG.

1253 - Substation S2

Readings were taken at the fence surrounding the substation. Levels ranged from less than 1 mG to 4.1 mG.

1268(A and B) - Computer Complex

Readings taken in the basement range from less than 1 mG to 175 mG. The reading of 175 mG came from the electrical intake for the building. Office areas had no significant background levels. In 1268 B, the mechanical equipment room (room 1205) had several dehumidifying units with levels ranging from 24 to 57 mG. Room 1215 had large computer drives with fields ranging from less than 1 mG to 5.5 mG. The substation located behind building 1268A had levels ranging from 2.5 to 7 mG. On the second floor of building 1268, room 2086 had large central computers with levels ranging from 1 mG to 6.7 mG. Several areas could not be surveyed because of building renovations. The penthouse had field levels ranging from 1.5 - 9.7 mG.

1270 - Printed Circuit Lab

Measurements ranged from 1.1 mG to 1.3 mG.

1271 - Engineering Support Lab

Measurements ranged from less than 1 mG to 1.7 mG.

1290 - Substation UWT

Fields from the power lines entering the substation measured 2.4 mG. Readings taken around the perimeter of the substation ranged from less than 1 mG to 26.2 mG.

Discussion

The results of the EMF surveys at LaRC indicate a wide range of values, but the majority of the surveys yielded values of less than 1 mG. The levels observed are several orders of magnitude lower than the exposure guidelines of 5000 and 10000 mG issued by the International Radiation Protection Association and the American Conference of Governmental Industrial Hygienists,

respectively. Furthermore, the levels observed correspond to the average residential exposure which ranges from 0.6 to 2.5 mG.

Magnetic field measurements have a high level of spatial variability. Field strengths often change by a factor of 100 over a distance of three feet from the source of the field. A great temporal variability also exists in magnetic field measurements. The spot measurements made in this survey reflect instantaneous magnetic field levels, so levels may be higher or lower from the recorded values depending upon the power consuming equipment in operation at that point in time. Every effort was made to survey facilities at a time when they were in full operation (i.e. wind tunnels and laboratories).

Background levels (away from power consuming equipment) were lower than 1 mG. The low background levels occur because with the exception of the power lines entering LaRC that run to the Stratton Road substation, all power distribution is accomplished through underground wiring and all indoor wiring is adequately grounded.

No accepted protocol exists for magnetic field measurements. Spot measurements are valid to identify background field levels and equipment which produces significant fields, but they can't account for the total exposure a worker receives as he or she moves to different locations. Personal dosimetry is the ideal method for exposure assessment because it allows continuous monitoring of exposure levels for long periods, but dosimeters are expensive and are inconvenient to wear for extended periods.

REGULATORY GUIDELINES FOR EMF EXPOSURE

The American Conference of Governmental Industrial Hygienists (ACGIH) and the International Commission on Non-ionizing Radiation Protection (IRPA/INIRC) have issued guidelines for 60 hertz EMF exposure. These guidelines were based on known effects of EMF such as nerve stimulation, and do not correspond to the small field strengths found in typical occupational environments. These guidelines do not distinguish "safe" from "unsafe" levels because it is not known what levels of EMF exposure (if any) constitute a health hazard.

The ACGIH Threshold Limit Values for 60 hertz EMF exposure state that occupational exposure should not exceed 10 G (10000 mG) and workers with cardiac pacemakers should not be exposed to levels in excess of 1 G (1000 mG). These levels represent the Ceiling Threshold Limit Value which states that this level should not be exceeded during any part of the working exposure.

The IRPA/INIRC guidelines are as follows:

Occupational

Whole working day	5 G (5000 mG)
Short Term (< 2 hours per day)	50 G (50000 mG)
For limbs	250 G (250000 mG)

General Public

Up to 24 hours per day	1 G (1000 mG)
Few hours per day	10 G (10000 mG)

PRUDENT AVOIDANCE OF EMF EXPOSURE

Until the risks posed by EMF exposure are known, it is wise to attempt to reduce exposure to EMF. Prudent avoidance simply involves increasing the distance from a source of high fields or reducing the time spent in the fields. Prudent avoidance can be accomplished with little cost or inconvenience, and seems wiser than spending millions of dollars shielding magnetic field sources when there may not be a threat to human health

Ideas for prudent avoidance at LaRC include:

- Moving work stations away from electrical panels.
- Move small desktop clocks, fans, and all other appliances with small motors at least three feet from the work position.
- Workers should be advised to sit an arm's length (3 feet) away from their video display terminal (VDT) while it is in use. When the VDT is not in use it should be turned off. It is not necessary to re-boot to access data when the VDT is turned off.
- Work stations should not be in area surrounding drive motors, induction furnaces or other machinery with high electrical consumption
- All VDTs purchased should be shielded for magnetic field emissions

CONCLUSIONS

No biological or epidemiological studies have shown firm evidence of detrimental health effects resulting from exposure to extremely low frequency electromagnetic fields. Data from biological studies has been conflicting, and the studies that demonstrated evidence of significant effects have not been replicated. Epidemiological studies on EMF effects have suffered from inadequate exposure assessment and from problems in accounting for confounding variables.

The survey of magnetic field levels found that present levels are orders of magnitude lower than levels specified by current regulatory guidelines pertaining to EMF exposure.

At this point, the risks posed by occupational exposure to EMF are uncertain. The Department of Energy is coordinating the EMF RAPID (Electric and Magnetic Fields Research and Public Information Dissemination) Program in order to expand and accelerate ongoing EMF research efforts in the United States. The RAPID program is conducting research on possible health effects and addressing engineering-related issues such as exposure assessment and field management. The results of The RAPID program studies will provide adequate information for policy development at LaRC.

Until adequate information for policy development is available, a program for prudent avoidance will reduce EMF exposure with little cost or inconvenience.

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MARKETING NASA LANGLEY POLYMERIC MATERIALS
LARSS REPORT

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1 EXECUTIVE SUMMARY

A marketing tool was created to expand the knowledge of LaRC developed polymeric materials, in order to facilitate the technology transfer process and increase technology commercialization awareness among a “non-technical” audience. The created brochure features four materials, LaRC™-CP, LaRC™-RP46, LaRC™-SI, and LaRC™-IA, and highlights their competitive strengths in potential commercial applications. Excellent opportunities exist in the \$40 million per year microelectronics market and the \$6 billion adhesives market. It is hoped that the created brochure will generate inquiries regarding the use of the above materials in markets such as these.

2 INTRODUCTION

2.1 TAG Background

The Technology Applications Group (TAG) at NASA Langley Research Center (LaRC) was formed to facilitate the commercialization of LaRC developed inventions. TAG is subdivided into three business units:

- *The Patent Counsel Office*, who assist LaRC researchers in the completion of the patent application process to protect their inventions, and also provide information about LaRC patents to both NASA personnel and the American business community.
- *The Small Business Partnership Team*, who encourage and fund the development of innovative LaRC technologies through contracts with small (<500 employees) US-owned businesses.
- *The Technology Transfer Team*, who promote the transfer of LaRC developed technologies to the commercial sector, particularly for non-aerospace applications.

The project described in Section 2.3 was developed and supervised by a member of the Technology Transfer Team.

2.2 Composites and Polymers Branch Background

As a branch of the Materials Division, the Composites and Polymers Branch develops improved materials concepts for efficient aerospace structures, including polymeric materials to be used as matrices for fiber-reinforced composites, adhesives for bonding structures, and high-performance films for spacecraft. Currently, twenty-four scientists perform research activities for this branch. As of August 1995, these researchers had filed patents for one hundred and eighty-nine unique materials inventions, all of which are available for transfer to American industry.

2.3 Project Description

The efforts of the Technology Transfer Team are supported by a variety of publications detailing the advantages of utilizing a LaRC developed technology in industrial applications, available through both print and electronic media. However, these marketing tools are often too technical for a layman to understand. This causes an uneven disbursement of information, and can leave public policy-makers, financial decision-makers in companies, and the general public unaware of the benefits of technology transfer to American businesses.

The objective of the project undertaken was to create a multi-functional marketing tool, highlighting polymeric materials developed by researchers from LaRC's Composites and Materials Branch, to be used by the Technology Transfer Team to educate a wide-spread audience about general and specific benefits of the commercialization of these technologies. The end result of this project was to be a brochure, written in layman's terms, detailing the competitive advantages of several LaRC developed polymers, and describing potential non-aerospace industrial applications.

3 ANALYSIS

3.1 Project Methodology

Once the project was defined, a storyboard was created (Figure 1), from which a project methodology was designed.

LaRC material	Point of Contact	Competing Products	Similarities	LaRC Advantages	Applications	Sales Volumes
LaRC™-SI						
LaRC™-IA						
LaRC™-CP						
LaRC™-RP46						

Figure 1

The first step was to interview the points of contact within the Technology Transfer Team, to acquire a general background on the materials and current marketing efforts. After this, time was spent in the NASA Technical Library and the Patent Counsel Office, so that basic technical information on the materials and their competitors could be reviewed. Once this material had been collated, interviews with the researchers took place. During the interview process, the competitive strengths of the materials were discussed, as well as potential applications. After these interviews were completed, it was necessary to investigate market and sales volumes for the potential applications, requiring further research at the library and also interviews with outside contractors who have been involved in the technology transfer process with LaRC.

Once data collection efforts were completed, it was necessary to analyze the information gathered, and determine which materials and applications should be highlighted in the brochure. Materials which filled widespread, high potential market value applications were chosen to represent the Composites and Polymers Branch, since they could generate great interest from the industrial community. Upon completion of this analysis, brochure text was written, which then received feedback from both the researchers and members of the Technology Transfer Team. The results of these efforts are presented in Sections 3.3 through 3.5. After the text was finalized, a brochure layout was designed, graphics were selected, and the brochure was published.

3.2 Utilization of LaRC Resources

Through the course of the project, information was gathered from the following contacts:

- three Technology Transfer Team members
- two Patent Counsel Office members
- twelve Composites and Polymers Branch researchers
- two Research Triangle Institute (RTI) contractors
- one Graphics and Design Section member

The following facilities and physical resources were also used:

- NASA Technical Library, including STILAS and CD-ROM search capabilities
- WWW search facilities
- TAG publications
- RTI publications
- Composites and Materials Branch laboratories
- Graphics and Design section publishing facilities

Figure 2 details time allocations for project activities.

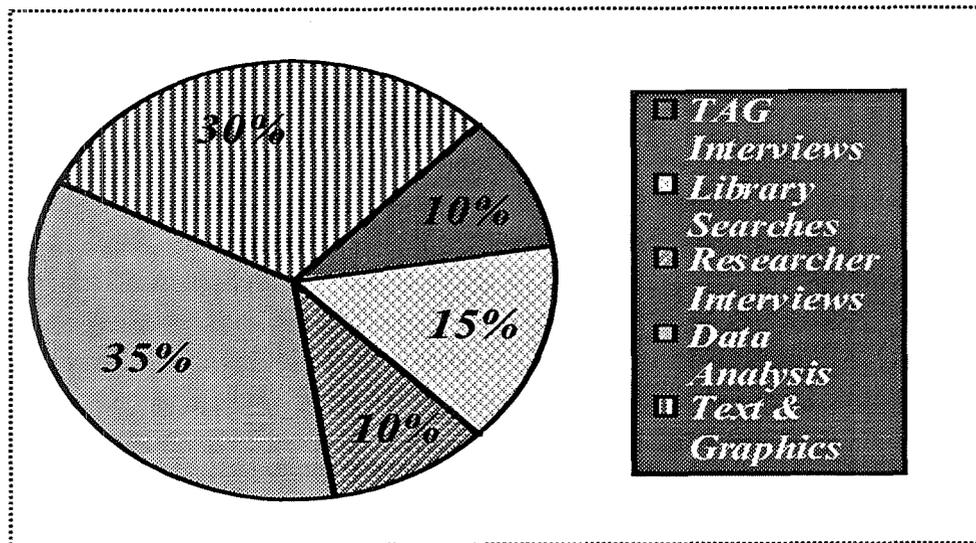


Figure 2

3.3 Competitive Advantages of LaRC Materials

The following table lists the competitive strengths of the LaRC polymers included in the brochure:

<i>Material</i>	<i>Strengths</i>
LaRC Colorless Polyimides (LaRC™-CP)	<ul style="list-style-type: none"> ▫ transparent ▫ soluble ▫ stable in high temperature environments ▫ low water absorption ▫ low dielectric constant ▫ excellent insulative abilities
LaRC™-RP46 Polyimide	<ul style="list-style-type: none"> ▫ lowest cost high temperature matrix resin ▫ non-carcinogenic ▫ twice as strong as competitors ▫ easy to use/process ▫ available in three forms
LaRC Soluble Polyimides (LaRC™-SI)	<ul style="list-style-type: none"> ▫ high strength and flexibility ▫ exceptional electrical insulation ▫ structural and thermal stability from -280°F to 400°F ▫ moisture and flame resistant ▫ chemical and environmental resistance ▫ excellent adhesive strength ▫ easy to process
LaRC Thermoplastic Polyimides (LaRC™-IA)	<ul style="list-style-type: none"> ▫ superior adhesive strength ▫ thermally stable ▫ recyclable ▫ solvent resistant ▫ high processability

3.4 Potential Applications for LaRC Materials

Based on the competitive strengths listed in Section 3.3, the following table lists the highest market value, non-aerospace applications of the LaRC polymers included in the brochure:

<i>Material</i>	<i>Applications</i>
LaRC Colorless Polyimides (LaRC™-CP)	<ul style="list-style-type: none"> ▫ LCD and other Flat Panel Displays ▫ Microelectronics, including Multi-Chip Modules and Flexible Printed Circuit Boards ▫ High Performance Wire Coatings
LaRC™-RP46 Polyimide	<ul style="list-style-type: none"> ▫ Printed Circuit Boards ▫ Automotive Engine Components ▫ Kitchen Ware ▫ Adhesives
LaRC Soluble Polyimides (LaRC™-SI)	<ul style="list-style-type: none"> ▫ Protective Coatings and Adhesives ▫ Electronics and Optics, particularly for Ultra-Thin Multilayer Flexible Circuits ▫ Fabrication of Mechanical Parts
LaRC Thermoplastic Polyimides (LaRC™-IA)	<ul style="list-style-type: none"> ▫ Fire Resistant Foams and Fibers, including use in Residences and Protective Fabrics ▫ Films and Coatings for Printed Circuit Boards and Wire Insulation ▫ Durable Moldings

Estimated 1995 market values for areas of applications are as follows:

- LCD and Flat Panel Displays ≈ \$20 million
- Microelectronics, including printed circuit boards ≈ \$40 million
- Wire Coatings ≈ \$37 million
- Adhesives ≈ \$6 billion

3.5 Competitive Disadvantages of LaRC Materials

There are two disadvantages to be overcome when marketing the LaRC developed materials. The first is a major obstacle for all of the above materials except LaRC™-RP46. Due to economies of scale, it is difficult for the LaRC materials to compete with commercial materials based on cost. Most commercialization opportunities will be based on performance advantages. However, the second disadvantage affects these opportunities. Because NASA funding comes from the public, including companies that produce competitive materials, direct comparisons can not be made between materials developed at LaRC and existing materials. It, therefore, can be difficult to effectively represent the performance advantages of LaRC developed materials, particularly when competing with technologies that are perceived as industry standards.

4 RECOMMENDATIONS & IMPLEMENTATION

4.1 Technology Pull Strategy

Much of the technology commercialization work done by the Technology Transfer Team follows “technology pull” techniques, where companies contact the TAG office regarding a technology which may fill a need of the organization. These inquiries are generated by a variety of stimuli, including the publication materials developed by the Technology Transfer Team. When an inquiry is received, the Technology Transfer Team should identify key non-technical decision makers within the company, and provide them with information that will ease the “pull” of the technology into the organization. The brochure created through this project is an example of the type of information that could be provided.

The brochure, as well as other marketing materials developed for the layman, should also be available to wide-spread audiences, so as to increase the level of awareness in the non-technical community, and possibly increase the number of inquiries regarding LaRC technologies. Distribution channels should include electronic media, as well as public displays. A further area of growth for this type of marketing tool is in non-technical journals and publications.

4.2 Technology Push Strategy

Because the Technology Transfer Team receives many inquiries through the technology pull strategy, LaRC contracts out much of the commercialization work involving “technology push” techniques, where individual companies are targeted for technology acquisition. A need is created within these companies for the benefits that a LaRC developed technology could provide. In instances where the Technology Transfer Team becomes involved with technology push methods, it will be important for them to receive support for the transfer throughout the company’s value chain.

For example, not only would the manufacturer of flexible printed circuit boards receive information regarding LaRC developed technologies, but the company who purchases the flexible circuit boards and the final consumer would also be provided with information. A brochure such as the one created would help these “indirect buyers” of the technology understand the advantages of having a LaRC developed technology within the final product. The acceptance created within these sectors will ease the “push” of the technology into lower layers of the value chain, and could be instrumental in unseating current technology leaders.

5 CONCLUSION

Examining the market values for potential applications for materials developed by LaRC's Composites and Polymers Branch shows that there is a lot to be gained from commercializing the LaRC technologies. Considering that American companies hold a minority market share in most of the applications, there is even more to be gained on an economic level, where international competitiveness and economic growth could be enhanced.

By creating marketing tools that reach a wide-spread audience and may be used in a variety of ways, the Technology Transfer Team can expand the number of opportunities and enhance the level of acceptance for LaRC technologies in commercial applications.

From Webster's Universal Dictionary:

cat's paw - one used by another as a dupe or a tool.

See also the official emblem of the great CLEMSON TIGERS!

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Controlling Air Traffic (Simulated) in the Presence of Automation (CATS PAu) 1995



**A study of measurement techniques
for Situation Awareness
in Air Traffic Control**

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Abstract

As automated systems proliferate in aviation systems, human operators are taking on less and less of an active role in the jobs they once performed, often reducing what should be important jobs to tasks barely more complex than monitoring machines. When operators are forced into these roles, they risk slipping into hazardous states of awareness, which can lead to reduced skills, lack of vigilance, and the inability to react quickly and competently when there is a machine failure. Using Air Traffic Control (ATC) as a model, the present study developed tools for conducting tests focusing on levels of automation as they relate to situation awareness. Subjects participated in a two-and-a-half hour experiment that consisted of a training period followed by a simulation of air traffic control similar to the system presently used by the FAA, then an additional simulation employing automated assistance. Through an iterative design process utilizing numerous revisions and three experimental sessions, several measures for situational awareness in a simulated Air Traffic Control System were developed and are prepared for use in future experiments.

Introduction and Background

Just as in the field of aviation, in which the technological advances that make aircraft safer and more reliable are the same ones that may have negative psychological effects on the flight crew (Burt, in press), the FAA's current efforts to upgrade and automate many of the tasks involved in Air Traffic Control may have detrimental psychological effects on controllers. As aviation situations become more automated, the amount of involvement required of operators tapers off, which can lead to dangerous states of awareness. In "monitoring tasks," (tasks requiring less active participation by the operator when the automated system performs most activities and requires a human operator only to monitor the system) mental engagement may drop to a level that precludes satisfactory performance (Pope et. al., 1994). Among the effects of decreased involvement are declined level of control or loss of skills (Endsley and Kiris, 1994); however, more dangerous is loss of vigilance and other symptoms of "boredom" that are not associated with fatigue, especially a decrease in situation awareness (Pope and Bogart, 1992). When this occurs, operators of automated systems become slower responding to errors, or may fail to notice system errors entirely. Additionally, as the decision-making process becomes increasingly facilitated by automated systems, the operator may slip from an active mode of information processing to a passive one. This, also, can lead to a dangerous decline in situation awareness and may have a drastic effect on performance (Endsley and Kiris, 1994).

In order to facilitate a study of these declines in performance using automated systems, Endsley and Kiris (1994) defined five specific levels of automation. The first level, incorporating no automation, leaves all decisions and actions to the operator. The second level, dubbed "decision support," calls upon the operator to make decisions and actions, while the automated system makes suggestions. In the third, or "consensual" level, the automated system makes the decisions and actions, but requires concurrence on the part of the operator. The fourth, "monitored" level, sees all decisions and actions made by the system, while the operator has only veto power. The fifth, fully automated level omits the human from the process entirely.

In Air Traffic Control today, most tasks reside in the first level. Currently, automation is rarely used for anything beyond transmitting information. Most often, even this process relies on outdated technology that Scientific American had dubbed "winking, blinking, aged hardware" that is "often less powerful than the personal computers used by agency secretaries for word processing" (1994).

In response to the rapid growth of air traffic that is quickly becoming too large to be serviced by existing ATC technology, the FAA has undertaken a wide-sweeping plan to update and upgrade, called Automated En Route Air Traffic Control (AERA). In addition to communicating the location of aircraft, the AERA computers will notify controllers of future conflicts, check for deviations, advise alternate routes, devise the most time- and fuel-efficient routes, and communicate directly with the airplane. In one textbook of air traffic control, the author tells us "as system capacity increases, and

confidence is gained in the computer's capability, the AERA system may be permitted to formulate alternative clearances, choose the most practical clearance, and transmit it directly to the aircraft without controller intervention. The air traffic controller will only be required to monitor system performance and to intercede in unusual conditions." (Nolan, 1994) Software has been designed at NASA Ames Research Center to help steer aircraft through traffic jams, advise the best sequencing for landing, and suggest landing maneuvers for individual airplanes (Scientific American, 1994).

However, in light of findings that warn of declining performance when decision-making processes become automated, extreme caution must be taken. Although numerous tests have been conducted on components of the new automated systems by NASA, and the FAA (Credeur et. al.), and international agencies (Beniot et. al.), none have been performed with an eye to the levels of automation as pertains to situation awareness.

So the question remains: What is the maximum level of automation that can be utilized to improve Air Traffic Control situations without exceeding the point at which controllers cease to be sufficiently involved and mentally engaged?

To answer this, an informal research project was conducted by this researcher in the summer of 1994. From that study, it was observed that a more in-depth and comprehensive means of data collection would need to be developed before the question posed above could be answered with any certainty. Since there is no definitive means for measurement of situation awareness in air traffic control, studies focusing on measurement of situation awareness and measurement of air traffic controllers were examined.

As early as 1980, David Hopkin discussed measurements of air traffic controllers at length in a special issue of *Human Factors* dedicated entirely to ATC. He cited several empirically proven techniques of testing air traffic controllers, from performance, errors, delays and omissions to physiological indices to interviews, discussions, questionnaires and case histories. One technique he favored was task performance as it pertains to workload and involvement, stating that, "All (ATC activities) do not have equal importance, and some, thought desirable, may often be postponed for awhile or omitted altogether," and that "measures of the least important activities of the controller may provide the most sensitive indices of the effects of high task loading." More recently, Hopkin (1994) has stated that, "Measures of errors, omissions, the time scale of decision, options considered and discarded, and tasks that are desirable rather than essential may all be more sensitive indices of the benefits of automation in air traffic control and of its other consequences than direct measures of core task performance," and that, "measures of performance that relate directly to these core tasks may therefore be insensitive to the effects of automation and computer assistance, whereas more peripheral activities may be changed greatly."

As recently as March 1995, Mica Endsley discussed measurement of situation awareness at length in a special issue of *Human Factors*. She began by establishing that the criteria for a measurement technique for situation awareness must measure the construct it claims to measure and not other processes, will provide the required insight in the form of sensitivity and diagnosticity, and will not interfere with the process being

tested. Beyond that, the technique should be able to predict performance and be sensitive to changes in workload and/or attention. Endsley then proceeds to analyze in detail physiological measures, performance measures, subjective techniques, and questionnaires. But the best measure of situation awareness, she concludes, is to freeze the simulation briefly to quiz the operator on his/her awareness of many different facets of the simulation and the information with which he/she should be familiar at all times.

To satisfy both sets of specifications as well as numerous others, a synergy of data collection techniques was developed and/or adopted for the CATSPAu experiment. Building on many of Hopkin's and Endsley's techniques, they are designed to test a subject's awareness of the air traffic control situation (See "Data Collection and Analysis" below, and Appendices for details).

The CATSPAu experimental task itself was also altered to reflect more realistically air traffic control situations that are in use/planned. A four-post system, which many air traffic controllers use to simplify their task by filtering all incoming aircraft through four main points on the radarscope (Erzberger and Nedell, 1993), was applied. Also, the timing of the automated system was altered to more closely emulate the Direct Course Error timer recommended as a part of the Final-Approach Spacing Aids, designed by LaRC researchers in 1993 (Creuder, et. al.)

Beyond that, conclusions from last summer's project were incorporated into CATSPAu. Based on the number of subjects from those experimental sessions who quickly lost patience with the automated system, additional instructions encouraged them to adhere to its recommendations. Further, the extended training session detailed below is reflective of last summer's conclusions as well.

Approach and Equipment

Equipment and Facilities: The Air Traffic Control simulation software TRACON, produced by Wesson Software, was run on an IBM PC with graphics capabilities. An additional IBM PC was used to run a program that simulated "automated assistance" written in quick basic by Dr. Ray Comstock. Additionally, a headset and a second monitor were used to aide a concealed confederate researcher to simulate higher levels of automation. Data was collected by pen-and-paper means. All facets of the experiment were conducted in the Human Engineering Methods offices and laboratory (Bldgs 1168 and 1268) at Langley Research Center.

Subjects: Three volunteer subjects, recruited from the pool of LARSS students and the researchers' personal contacts, were utilized. All three were male and ranged in age from 17 to 28. Subjects were screened to insure they had normal vision, had not been diagnosed with Attention Deficit Disorder (ADD) or Attention Deficit-Hyperactivity Disorder (ADHD), and had no prior experience with air traffic control.

Experimental Design: Subjects performed a task similar to that of Air Traffic Control by engaging in variations of TRACON, which realistically simulates the ATC radar scope and contains a computerized version of the paper strips used in Air Traffic Control (Wesson and Young, 1988). The experience of communicating with aircraft was simulated by having subjects speak into a headset, and their verbal commands were translated to TRACON keyboard commands by the concealed confederate.

From Endsley and Kiris' five levels of automation, the first two were selected and applied to ATC through TRACON:

Level 1: No automated decision-making aides. Subjects engaged in TRACON's ATC tasks with no automated assistance, much as in status quo ATC.

Level 2: Suggestions from automated system. Subjects engaged in TRACON while an automated assistant provided suggestions on the safest and most efficient commands, much like the proposed improvements to future ATC environments.

Subjects completed a 45 minute training session on the use of the simulation software and the philosophy behind ATC. Subjects then engaged in extended training sessions that were similar in duration and demand to data collection. The data collection sessions consisted of seventeen and a half minutes of TRACON at Level 1, and seventeen and a half minutes at Level 2.

Data collection and analysis: Several types of measurement techniques were designed and arrived at through an iterative process of testing and revision. A Freeze Technique Questionnaire, quizzing subjects on the location of aircraft, and their destinations and status (see Appendix A), was developed to administer to subjects at various intervals during the simulation in which the program was paused and the screen was covered. The Task Load Index (see Appendix B) developed and empirically proven by Hart and Staveland (1988), was also administered before the simulation resumed. Errors, in the form of missed approaches (aircraft that are not successfully prepared for landing at the airport), were counted during the simulation. Omissions less vital to the overall success of the task, in the form of hand-offs (aircraft that are not successfully passed on to the next controller), were counted as well. Finally, subjects were verbally de-briefed at the end of the simulation regarding their comfort and confidence with respect to the automated assistance they received.

Results and Discussion

Because only three subjects were run and conditions were altered for each subject through the process of iterative design, no cross-subject results can be derived. However, Table 1 illustrates a sampling of the types of data that would be available using the final form of the data collection techniques developed for CATSPAu. Data is organized by freeze number for each condition by subject. Comparisons among the number of aircraft of which each subject was aware and the number that were actually present can be made, as can the destinations of current aircraft, number of aircraft about to enter the sector, and

status of aircraft next to landing. Additionally, errors, omissions, and TLX ratings (composite) can be compared by subject and condition.

In the verbal de-briefing, two subjects reported that the automated assistant made them less comfortable and confident and more pressured, while one reported the opposite. These answers, however, seem to be directly related to the extent to which each subject trusted the automation. When asked if they felt the automated assistant had helped or hindered their performance, the subject who claimed it helped him relied almost entirely on the automated assistant, the subject who claimed it hindered him frequently strayed from the recommendations, and the subject who said it neither helped nor hindered him later said that he used it as a self-check.

Unfortunately, due to the nature of the simulation, there are limitations that may contribute to subject's lack of trust in the automated assistant. The script that feeds commands to the automated assistant receives no genuine feedback and is not dynamic, and it cannot respond in any way to changes or deviations from the pre-planned flight paths. In other words, once subjects begin to second-guess the automation, they cannot surrender that control until they have cleared the individual aircraft from their sector. Also, if the subject makes an error or fails to issue a command, the automated assistant is unforgiving and cannot incorporate those mistakes back into the flight plan, thus causing the subject to lose confidence in the system. This ability to allow for controllers' errors is vital to the success of any automation, and has been incorporated into currently proposed automated systems for Air Traffic Control (Erzberger, 1992).

Despite these limitations, the techniques discussed above should prove to be an adequate means of investigating the situation awareness of air traffic controllers in the presence of automation. A future study that would utilize these measurement techniques to test situation awareness in different levels of automation would ameliorate or knowledge of human awareness in the presence of automation.

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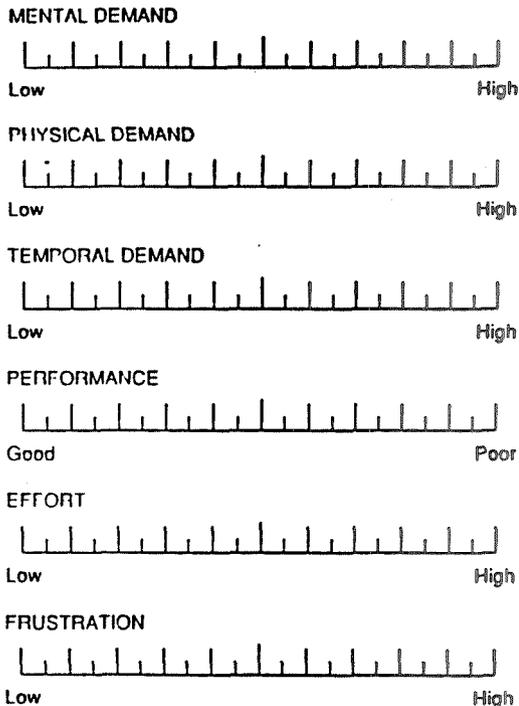
Appendix B

Subject ID: _____ Study ID: _____

Rating Scale Definitions

Title	Descriptions
MENTAL DEMAND	How much mental and perceptual activity was required (e.g., thinking, deciding, calculating, remembering, looking, searching, etc.)? Was the task easy or demanding, simple or complex, exacting or forgiving?
PHYSICAL DEMAND	How much physical activity was required (e.g., pushing, pulling, turning, controlling, activating, etc.)? Was the task easy or demanding, slow or brisk, slack or strenuous, restful or laborious?
TEMPORAL DEMAND	How much time pressure did you feel due to the rate or pace at which the tasks or task elements occurred? Was the pace slow and leisurely or rapid and frantic?
PERFORMANCE	How successful do you think you were in accomplishing the goals of the task set by the experimenter (or yourself)? How satisfied were you with your performance in accomplishing these goals?
EFFORT	How hard did you have to work (mentally and physically) to accomplish your level of performance?
FRUSTRATION LEVEL	How insecure, discouraged, irritated, stressed and annoyed versus secure, gratified, content, relaxed and complacent did you feel during the task?

Place a mark at the desired point on each scale:



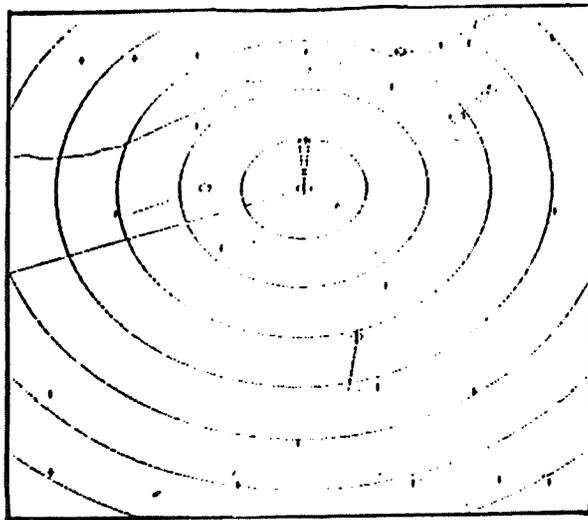
			A/c on screen	A/c reported	Non-landing a/c	Non-landing a/c reported	Pending a/c	Pending a/c reported	Next-to-land a/c correct (y/n)	Missed approaches	Handoff errors	TLX
Subject 1	Manual	Freeze 1	5	5	2	2	0	n/a	no	2	0	22
		Freeze 2	2	2	0	0	0	1	yes			4
	Automated	Freeze 1	6	5	2	2	0	2	yes	1	0	26
		Freeze 2	2	2	0	0	0	0	yes			5
Subject 2	Manual	Freeze 1	5	5	2	2	2	2	yes	0	0	59
		Freeze 2	5	7	2	2	4	2	yes			72
	Automated	Freeze 1	6	5	1	1	3	7	no	1	1	84
		Freeze 2	9	7	2	1	2	2	no			87
Subject 3	Manual	Freeze 1	9	9	4	0	2	8	yes	0	1	28
		Freeze 2	10	10	4	2	4	10	yes			24
	Automated	Freeze 1	5	4	1	1	3	4	no	3	2	9
		Freeze 2	7	7	2	2	2	7	yes			17

Appendix A

Subject number _____ L of A _____

Freeze Technique Questionnaire

1. Please indicate the general positions of all aircraft you are currently handling on the image of your sector below. Use an arrow pointed in the direction your aircraft is traveling to represent each airplane and its heading.



2. In the diagram above, place a box around any aircraft that you are currently handling which are *not* landing.
3. How many aircraft are currently shown under the heading of 'Pending' on your paper strips?
4. What are the altitude and speed of the aircraft that is closest to landing?
5. What are the point of origin and destination of the aircraft with which you most recently established radar contact?

Appendix C

Subject Data and Performance

Subject ID _____
 Level of Automation in second simulation: suggest / concur / veto

Timing:
 Tr1 _____ start _____ end XTr1 _____ start _____ end DC1 _____ start _____ end
 Tr2 _____ start _____ end XTr2 _____ start _____ end DC2 _____ start _____ end

Data
 Number of unsuccessful handoffs in NON-automated mode: _____

Number of missed approaches in NON-automated mode: _____

Number of unsuccessful handoffs in automated mode: _____

Number of missed approaches in automated mode: _____

Deviations from Automation: _____

Questions prior to Verbal Debriefing
 Were you more comfortable with or without automated assistance?
 Did having automated assistance make you more or less confident?
 Did having the automated assistance make you feel more or less pressured?
 Do you think having automated assistance helped or hindered your performance, or neither?

Observations: _____

LaRC Patent Process
and
Patent Counsel Team Article

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Technology Applications Group
Technology Transfer Team

Abstract

The rules concerning patenting at NASA-LaRC have changed with the new emphasis on technology transfer. Many researchers here at the Center do not know how to go about patenting their inventions, and in addition to this, they do not realize the rewards and benefits that are associated with patenting their technology. The Patent Counsel Team in the Technology Applications Group is open to all employees who wish to use their services. My project involved writing a series of articles for the *Researcher News* to inform those with potentially patentable inventions about the process.

Project Summary

The article for the *Researcher News* was divided into two separate sections to be printed in consecutive issues of the paper. The first dealt with the actual patent process -- from the innovator's first disclosure to the rewards that can be gained once the invention is patented. The second article focused on the members of the Patent Counsel Team and their duties.

The initial article involved an extensive amount of research into patenting inventions. Using the NASA publication *Invention Disclosure Information for NASA Inventors* and data obtained from the Patent Counsel Office, a simplified interpretation was written.

The patent process is a rather tedious one and requires much effort, and the task of sorting through the information belongs to the members of the Patent Counsel Team (PCT). Before the PCT can submit an application to the Patent and Trademark Office (PTO) in Crystal City, Virginia, the researcher or researchers responsible for the invention must disclose their invention to the PCT. This disclosure includes the name(s) of the inventor(s); how, when and where the invention came to be; and a description of the technology. The PCT reviews the data in the disclosure and determines the patentability of the invention. If the invention appears to be patentable and has sufficient commercial potential, a detailed application for a patent grant will be submitted to the PTO.

The results of obtaining a patent can be lucrative, and many researchers do not realize the rewards that can come with patenting an invention. The technology can be licensed to private companies for their exclusive use, netting the inventor and NASA royalties; awards are given to innovators by NASA Headquarters; and the peer recognition received is very gratifying.

The first *Researcher* article also compared the volume of disclosures, applications, and grants issued between the different NASA centers. LaRC led all centers in each category. This information was used to motivate and encourage more researchers to take the chance of getting their technology patented.

The second article centered on the actual members of the PCT. Found in building 1229, the PCT is a small but integral part of the Technology Applications Group. Composed of six members, including three attorneys, the PCT performs duties ranging from preparing applications, amendments and other documentation to recommending actions concerning patent infringements.

George Helfrich serves as LaRC's Chief Patent Counsel and leads the PCT. He oversees all chemical technology applications. Kimberly Chasteen, also an attorney,

focuses on aeronautical technologies. Robin Edwards, the third attorney in the PCT, concentrates on the mechanical applications. Elaine McMahon serves as legal information specialist and is the primary point of contact for matters such as invention disclosures, licenses, and legal research. Theresa Walker, a legal technician, administers quasi-legal functions of the PCT and acts as a specialist in the handling of formal matters between LaRC and the U.S. Patent and Trademark Office.

Without the constituents of the PCT to litigate the details of patent applications, many commercial companies would find themselves without new technologies to move them into the future. The researchers that develop these technologies could not possibly divide their time and attentions between legal matters and the development of exciting new information. As part of the second *Researcher* article, the data from the sources mentioned above was summarized. Using this summary, a concise translation of the patent process was written not only for the inventors at LaRC, but for all employees.

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FINANCE

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ABSTRACT

The objective of my summer internship at NASA Langley Research Center was to learn and understand some of the budgeting practices and principles used by the Programs and Resources Division. As a third year finance student many of the skills I have acquired this summer through the LARSS program will not only benefit me in my college career but also in the business world. As an intern in PRD I was involved in a detailed training program, the Program Operating Plan 95-2, and general day to day work. Each exercise included an overview of various basic skills needed so that I could thoroughly understand the financial operations of a government agency.

During the ten weeks that I interned in the Programs and Resources Division (PRD), the Program Operating Plan 95-2 (POP 95-2) needed to be completed. A POP occurs twice a year and is necessary for the financial support of program offices. My major project was to help in preparing a unique database essential to the completion of the POP. In order to do this I had to participate in a series of events as part of training. In addition to my project, I worked with other PRD employees, helping with day to day work.

The training program organized by PRD contained several parts. One part consisted of a video tape by Mr. Joseph R. Struhar, Chief Financial Officer, explaining the fundamental terms and principles of the budgeting process. Everything I needed to know to perform my project was covered in this tape. Another part of the training program were several small one-on-one information sessions with other employees of my division. These were useful in understanding what occurs at a more specific level. The Space Resources Branch head, Buena E. Crawford, also explained to me the structure of the Langley Research Center (LaRC) and NASA as a whole. This was very important in the budgeting process because PRD frequently interacts directly with Headquarters as well as with all groups and divisions at LaRC. I also attended the comptroller monthly status review and other meetings dealing with the budget at LaRC. This was to further increase my knowledge of the finance process at Langley. In addition I attended a Microsoft Word class.

My main project this summer was to help in a significant way with the POP 95-2 budget call. This year NASA utilized a different method for completing the POP. Program office budgets for LaRC were sent by the Institutional Program Office (IPO) under the Office of Aeronautics (Code R). It was PRD's responsibility to distribute the guideline information to all center managers. I helped develop the database which distributed program guidelines to all non-aeronautics program offices. The database was created at the 9-digit RTR level and included input cells for dollars and workforce, both civil servant and support service contractors. The Space and Atmosphere Science Program Group (SASPG) provided the dollar and workforce amounts which they believed would be appropriate for them. We then entered it into the database. The main purpose of the database was to analyze the centers NOA (Net Obligating Authority) and to prepare trace documents and Program Financial Plans (PFP's). These in turn are submitted back to Headquarters where the final funding decision is made for the years 1996-2000.

In addition to my project, I helped the division with day to day work requirements. This included creating spreadsheets, flowcharts, and other miscellaneous documents needed for use in PRD or to be provided to the division's customers.

In order to successfully complete my project I used a Macintosh IIfx computer equipped with the following software: Microsoft Word version 5.1a, Microsoft PowerPoint version 3.0b, and Microsoft Excel version 5.0. I also used a hand calculator.

ACTIVE FLOW CONTROL

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Instrumentation Automation
and
Experimental Technique

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Student

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Mentor

Rich W. Wlezien

ABSTRACT

In investigating the potential of a new actuator for use in an active flow control system, several objectives had to be accomplished, the largest of which was the experimental setup. The work was conducted at the NASA Langley 20x28 Shear Flow Control Tunnel. The actuator named "Thunder", is a high deflection piezo device recently developed at Langley Research Center. This research involved setting up the instrumentation, the lighting, the smoke, and the recording devices. The instrumentation was automated by means of a Power Macintosh running LabVIEW, a graphical instrumentation package developed by National Instruments. Routines were written to allow the tunnel conditions to be determined at a given instant at the push of a button. This included determination of tunnel pressures, speed, density, temperature, and viscosity.

Other aspects of the experimental equipment included the set up of a CCD video camera with a video frame grabber, monitor, and VCR to capture the motion. A strobe light was used to highlight the smoke that was used to visualize the flow. Additional effort was put into creating a scale drawing of another tunnel on site and a limited literature search in the area of active flow control.

Introduction / Background Information

The motivation for investigating active flow control is based on the notion that overall performance of an aircraft can be dramatically improved with active systems as opposed to the traditional passive aerodynamic schemes. In pursuing active flow control, it is apparent that the system can be broken down into three subsystems. These are the sensors, the control scheme, and the control mechanism. The dramatic increase in computational and material technologies over the past years has begun to make the realistic implementation of each of these possible. Computer technology is currently capable of completing the necessary nonlinear computations for the control scheme, and MEMS technology is promising to deliver cheap and reliable sensors that could be embedded within a composite material. This experiment investigates the use of a high deflection piezo actuator, developed at NASA Langley Research Center, as a means of controlling a turbulent flow. The actuator is controlled by means of a voltage which makes the system relatively light and easy to implement. The experiment was performed in the NASA 20x28 Shear Flow Control Tunnel.

In setting up the experiment, LabVIEW virtual instruments (VIs) were developed to automate many common wind tunnel data acquisition procedures. Effort was made to produce a modular system that is easily portable to tunnels with similar configurations. This is desirable in order to reduce the setup time and effort that will be necessary for future research. VIs were required to monitor tunnel flow conditions including speed, atmospheric and dynamic pressure, temperature, viscosity, density, as well as the relative humidity in the room to be used in future humidity based corrections. An additional set of VIs was developed to produce waveform functions at various phase angles, frequencies, peak-peak amplitudes, and DC offsets on two independent channels that could be phased together if desired. Attention was paid to usability in all cases to further increase its usefulness in other lab settings. The experimental setup also made use of a smoke generator, a strobe light, and a means of recording the motion by means of a VCR and a video frame grabber.

This setup was performed both for the experiment that it facilitated, as well as for the experience of conducting a wind tunnel experiment from start to finish. Additional experience was gained by producing a scale drawing of the NASA 2x3 Boundary Layer Channel Flow Tunnel. This was necessary for the design of planned tunnel modifications.

Summary of Research Project

The research was initiated by a short study of the LabVIEW graphical programming language and the GPIB bus. This was conducted by means of the National Instruments tutorial and other pieces of documentation that were included with the package. Based on this, and by using many of the device drivers as supplied by National Instruments as examples, the necessary virtual instruments (VIs) were written.

The first VIs were written to control the HP 3245A Data Acquisition / Control Unit, and its accessories, through the GPIB bus. The accessories included HP 44705 multiplexors and a HP 44701 integrating voltmeter. These were used in conjunction with Barocel differential pressure transducers, and a pitot tube, to determine the dynamic pressure and the difference between the static and atmospheric pressures. This required becoming familiar with the HP BASIC programming language and many of the machine independent commands for each device. Due to the unsteady nature of the airflow, the measurements are averaged over a specified time in intervals of 1/60 seconds by means of the integrating feature of the voltmeter. The 1/60 interval eliminates the interference of the

electrical line noise and produces a more accurate measurement. The VI also took advantage of machine generated interrupts in order to signal the host computer when the operation was completed. This allows the user to average the pressure over long periods of time while not demanding the computer to repeatedly check for the answer.

Other readings were taken by a high precision pressure transducer to record atmospheric pressure and return the result to the computer via the GPIB bus. The initial stages of a TCP/IP client-server system was also developed so that atmospheric pressure reading could be taken from a remote site if the transducer was not locally available. This works by the client addressing the server computer, where the atmospheric pressure transducer would be present, with a request. The server computer would then prompt the device for a reading and pass the result back to the client computer. This would be effective since atmospheric pressure tends to vary only slightly from room to room on a given day. The high cost of the devices makes the small error associated with such a system acceptable due to the large cost savings associated with purchasing only one device for multiple laboratories.

A similar VI was then written to determine the temperature based upon an RTD positioned in the flow and a 4 wire resistance reading. The 4 wire method is used to eliminate any resistance due to the electric leads, which reduces the uncertainty of the measurement. The 4 wire method works by taking the resistance across two of the wires as in a standard resistance measure. The other two leads are then used to measure the voltage drop which eliminates the internal resistance of the wires. Lastly, a General Eastern relative humidity sensor was used to determine the percent relative humidity and was read by the computer based upon an output voltage. Since several of the parameters can vary based upon humidity, and due to the relatively high humidity associated with the south-eastern Virginia climate, this could prove to be a valuable correction when high orders of accuracy are needed. Based upon the measured parameters, the remaining ones including density, speed, and viscosity were then determined. Speed was based upon the definition of the dynamic pressure along with the density that was determined based upon the ideal gas law. Viscosity was based on an empirical correlation based upon temperature.

The next phase of the research then consisted of writing a user friendly LabVIEW interface and set of VIs for the HP 3245A universal source. The resulting VI makes use of most of the capabilities of the device. This includes producing both standard and arbitrary waveforms for two independent channels. The standard waveforms include sine waves, square waves, and ramp waves. For additional flexibility, the frequencies, phase angle, DC offset, and peak - peak voltages or currents can be determined. The user has the option to synchronize the phasing of the two channels, so that they can be used together. All these features are available at the push of a button or the turn of a dial. If an arbitrary waveform is desired, the user may either manually input the required 2,049 points, or may input the numbers from a text file generated in a spreadsheet such as Excel. A separate VI was also written to modify the phase of a given channel in real time. This allows the user to vary the relation of two phase synchronized channels during the course of an experiment, without interruption.

In setting up the experiment the above mentioned VIs and equipment were used. The first set of VIs were used to monitor the conditions of the flow, and the universal source VIs were used to control and synchronize the strobe light and the actuator. The strobe light was a General Radio 1540 Strobolume, which was desired for this experiment because of its intensity. The strobe was controlled by means of a TTL wave produced by the universal source which was inputted into an optically isolated triggering device built for this application. The triggering device would then trigger the external trigger connection on the strobe light within 3 microseconds. The strobe light was used to light up the smoke so

that it would be visible to the camera. The strobe light was positioned directly above the model and the light passed through a narrow Plexiglas window directly above the model. This allowed the smoke to be effectively lit while maintaining contrast between the smoke and the black background that was painted to the left of the model. A CCD camera was positioned on a tripod to the right of the model so that it watched the model in profile with the black background immediately behind the model.

The model was mounted on a Bakelite plate that was manufactured to fit in the middle of a flat plate that is the third of three interconnected aluminum flat plates that run the length of the 15 foot 4 inch test section. Trips were applied at the leading edge of the first plate and on all sides of the tunnel just after the contraction. The first plate has a rounded leading edge and a flap is located at the trailing edge of the third plate. The flap was adjusted until the flow remained attached on the upper surface. Since the plates were mounted towards the bottom of the test section, the tunnel floor caused blockage effects which tended to move the stagnation point below the leading edge. By raising the trailing edge flap, the stagnation point was moved back to the leading edge, thereby preventing separation. This was tested by applying oil to the plate and observing it's motion while the tunnel was running with various flap settings.

In between the first and second plates, a small gap was made through which the smoke was introduced. The slot was about 2 inches wide and located at the center of the gap between the plates. The edges were all filled and the remaining portions of the gap were covered with duct tape. The slot was fitted by means of an adapter to a one inch plastic tube that passed through a hole in the bottom of the tunnel and into a wooden plenum that was produced to cool the smoke. The smoke was generated by means of a F-100 Performance Smoke Generator. The water and glycerin based smoke is hot as it leaves the device. It was feared that this would cause a buoyancy effect when the smoke entered the flow. It was assumed that the hot air would remain at the top of the plenum and would fall as it cooled. Thus the smoke was pumped into the plenum by the smoke generator and was pulled up from the bottom of the plenum by the plastic tube due to the low pressure produced by the air moving over the slot in the tunnel.

The actuator was powered by means of an external amplifier that was in turn connected to the universal source. It was run with a sine wave that was synchronized with the strobe. The camera was connected to a monitor, a VCR, and a Computer Eyes/RT video frame grabber that could digitize a frame or make a Quicktime movie of any observed phenomena.

The air would become tripped just after the leading edge of the first plate and form a turbulent boundary layer. Then flow would then proceed down the plate where the smoke was injected and was carried along with the flow. It is assumed that the smoke particles were light enough to accurately follow the flow. The smoke would then proceed downstream and cover the actuator where the actuators motion should produce some sort of disturbance. This disturbance should be followed by the smoke which will be lit up by the strobe and in turn captured on the VCR while being viewed in the monitor. The purpose of the experiment was to observe what sort of effects the actuator will have on the flow.

Results / Conclusion

The results of the experiment were as yet undetermined when my term was ended. The setup seems to work as described in a useful and predictable manner. The most useful result to date was the experience gained in working with a developing technology, and in the fine points of conducting a wind tunnel investigation. Specific experience was gained

in setting up the instrumentation. This included use of the GPIB / IEEE 488.2 bus, and learning both HP BASIC and the LabVIEW graphical programming language. All of these are general enough to be useful in future experiments. Additionally, the experience of working with a tunnel technician, and by getting hands on experience in working with much of the equipment, I feel better equipped to conduct in future wind tunnel I might encounter in the future.

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Dynamic Acoustic Detection of Boundary Layer Transition

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Abstract

The 1995 LARSS Research for J.r Grohs is a wind tunnel investigation into the acoustic nature of boundary layer transition using miniature microphones. This research is the groundwork for entry into the National Transonic Facility (NTF) at the NASA -- Langley Research Center (LaRC). Due to the extreme environmental conditions of NTF testing, low temperatures and high pressures, traditional boundary layer detection methods are not available. The emphasis of this project and further studies is acoustical sampling of a typical boundary layer and environmental durability of the miniature microphones.

The research was conducted with the 14 by 22 Foot Subsonic Tunnel, concurrent with another wind tunnel test. Using the resources of LaRC, a full inquiry into the feasibility of using Knowles Electronics Inc. EM-3086 microphones to detect the surface boundary layer, under differing conditions, was completed. This report shall discuss the difficulties encountered, product performance and observations, and future research adaptability of this method.

Introduction

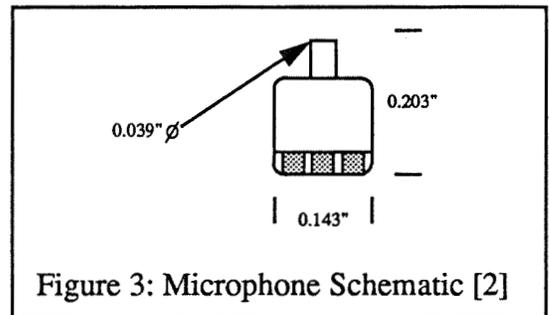
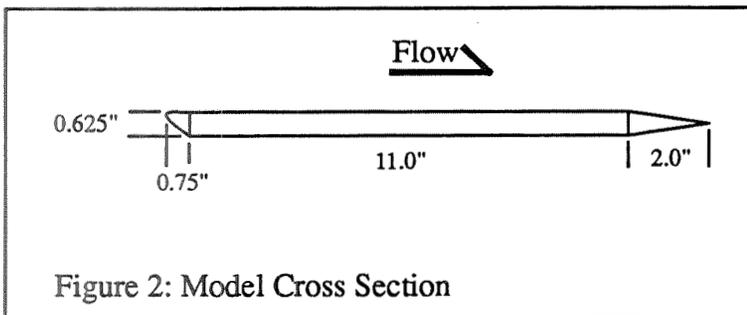
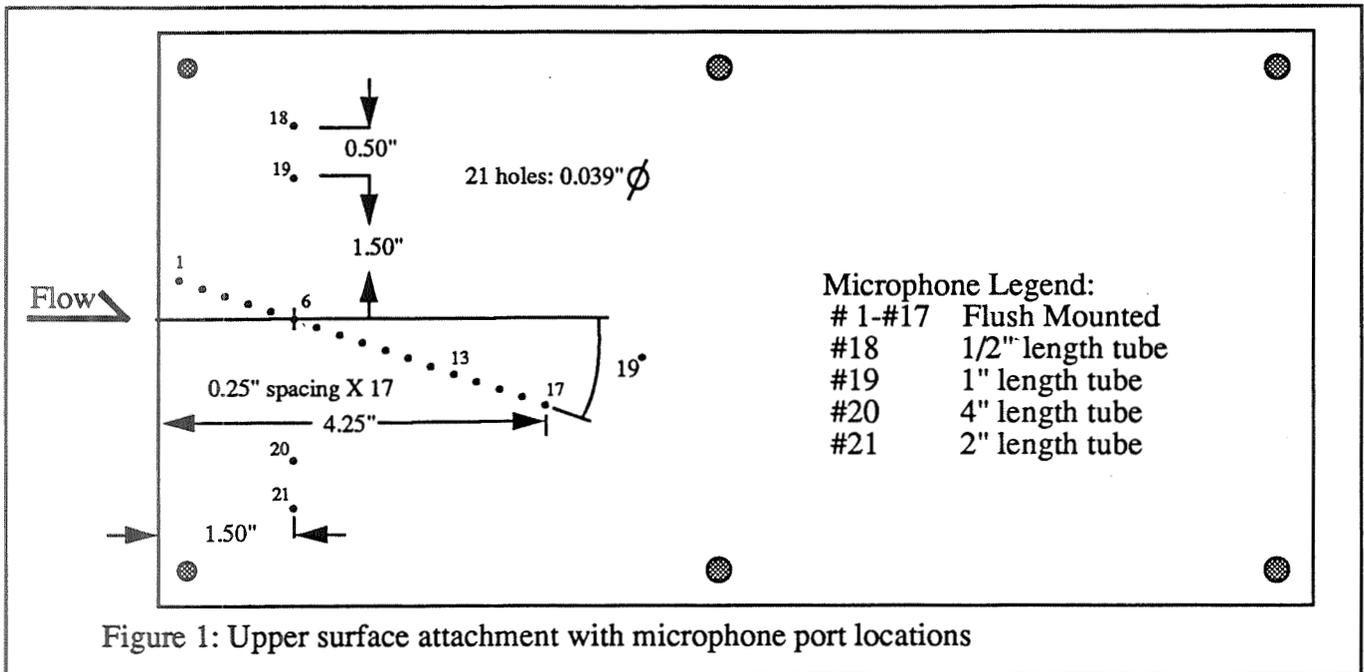
Within traditional wind tunnel testing conditions, detection and study of the surface boundary layer can be found in variety forms. Resources such as hot film, pressure transducers, and pressure sensitive paint are a few such methods. However, within the adverse operating conditions at the National Transonic Facility (NTF) at NASA -- Langley Research Center (LaRC), such techniques are impossible to use. Therefore, the investigation of acoustical measurements of a boundary layer with miniature microphones was initiated. While acoustic testing of aerodynamic properties has been conducted previously, it has not emphasized on undisturbed measurements along the surface of an airfoil.

The groundwork for this study was research into the resources available to collect such measurements and information on the topic. Using the previous investigation of Agarwal and Simpson [1] as background information, an initial plan to place miniature microphones within the surface of an airfoil was started. Through the acquisition and comparison of dynamic acoustic data, the feasibility of measuring an active boundary layer could be studied.

Approach

Provided with the Knowles Electronics, Inc. EM-3086 microphones, the author designed and had fabricated an aluminum plate to incorporate a set of the microphones into the upper surface of a preexisting idealized flat plate model. Through a direct connection in the interior of the airfoil, data from the microphone was extracted and analyzed through a portable HP Dynamic Signal Analyzer and oscilloscope. The entire setup was then entered and floor mounted into the 14 by 22 Foot Subsonic Wind Tunnel to the rear of an High Speed Civil Transport (HSCT) Test. Data was accumulated at a dynamic pressure of 85 psf.

The setup of the microphones was such that differing conditions of a boundary layer could be determined simultaneously along the entire plate. Figure 1 shows the orientation of the setup on the upper surface, Figure 2 provides a model cross section and Figure 3 includes a microphone schematic. Note the offset of the streamwise row of microphones, used to remove any effect of a



previous microphone port's wake from disturbing downstream microphones. Due to equipment restraints, many factors limited the availability of every data possibility, but the designs for this project included many ideas for future research opportunities. For example, the four spanwise microphones were included to eventually investigate signal attenuation of the boundary layer signal, given different metal tube lengths connecting the port with the microphone. The priority of the current research was to establish a baseline system and to begin taking data on the feasibility of measuring the acoustic signals of the boundary layer of the plate.

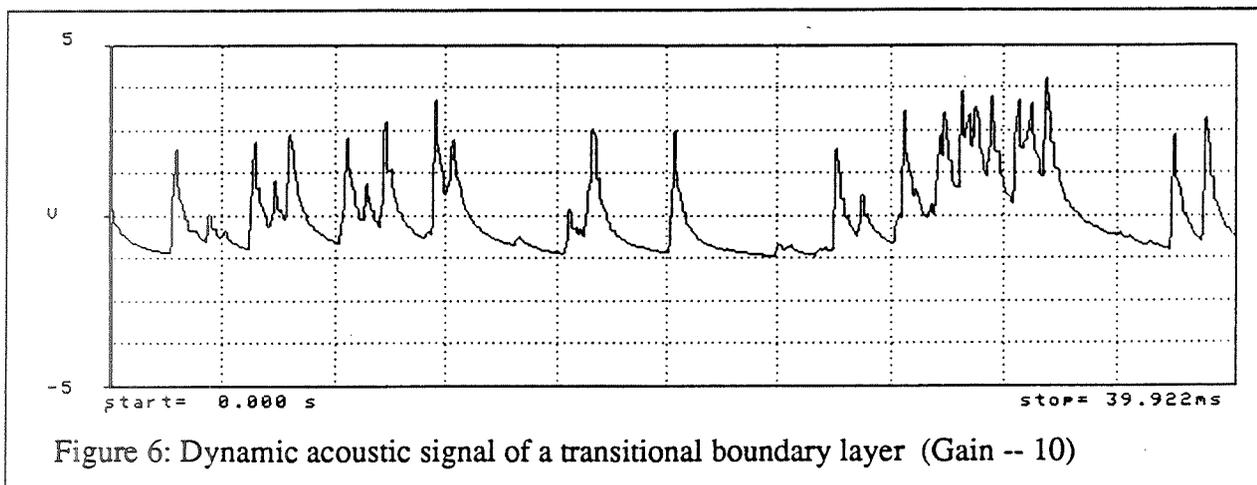
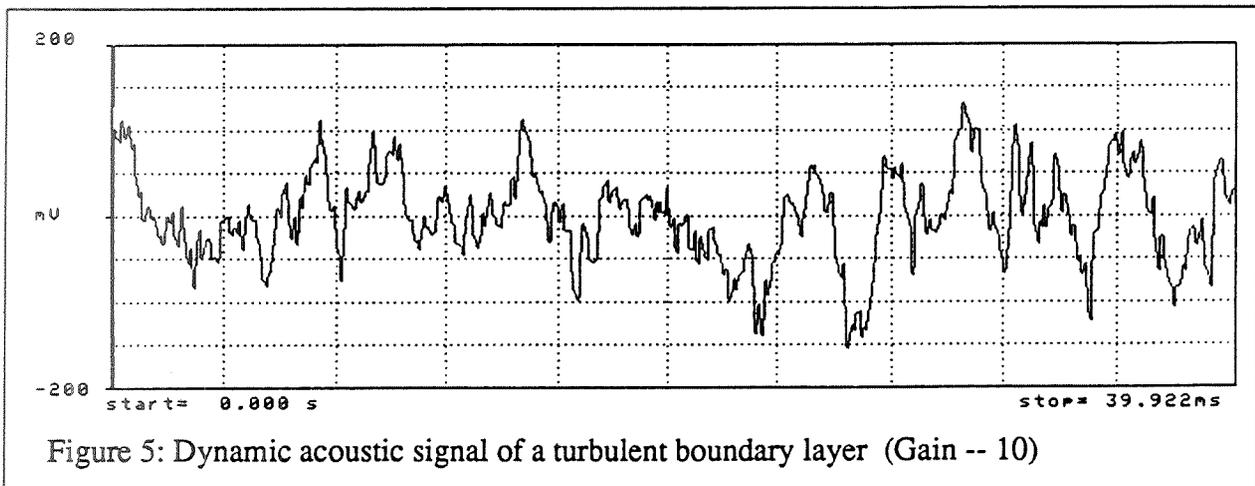
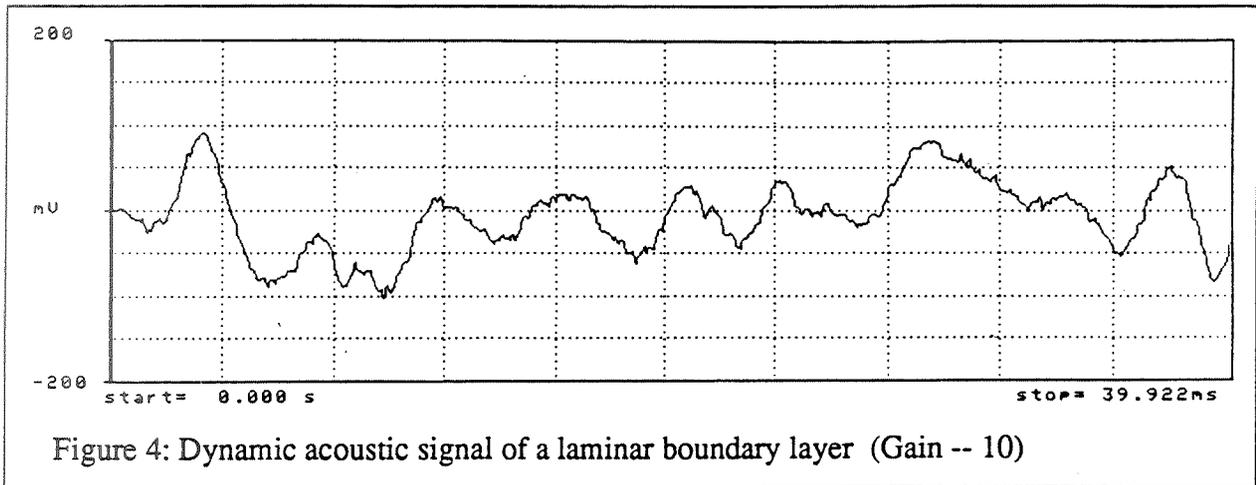
The majority of the research time was consumed in the actual buildup process of these microphones, leaving very little time to pull real-time data. Initial concerns of this technique included wake effects from the HSCT model disrupting the flow over the microphones, the microphone ports themselves tripping the flow into transition, the actual detection of the boundary layer over

the background noise, and the ability to differentiate between transition, laminar flow, and turbulent flow. Through preliminary real-time signal analysis, it was determined that the boundary was detectable and different types of flows could be observed, given certain conditions. Thus, to address as many of these problems as possible, a schedule of runs was established to test each plausible condition. Through the use of grit, to trigger transition in the flow, cover tape, to remove the effects of the microphone ports on the flow, and timing, to prevent the HSCT model's wake from disturbing the flow, the signals of different boundary layer regions could be determined. As a side investigation, a speaker was also installed to determine the audio difference in such conditions.

Results and Conclusions

Through the run schedule, it was determined that the microphones can distinguish between boundary layer types only after removing any adverse flow effects. The microphone ports were found to be disturbing the flow just by being exposed, causing some concerns. Note that pressure ports, frequently used in wind tunnel testing to determine the pressures along an airfoil, are approximately the same size as the microphone ports, and thus can be influencing the airflow directly over the ports. While a small disturbance would not alter a non-dynamic measurement such as a pressure, it does introduce an error in any such calculation, thus addressing the issue of pressure port accuracy. For the affected dynamic acoustic signals, measures must be taken to remove this effect.

Through the use of cover tape, beginning from the leading edge and sealing the microphone ports to provide a smooth surface, it was found that dynamic acoustical data of the boundary layer was still obtainable. Although dampened, the difference in a laminar boundary layer and turbulent boundary layer, can be distinguished. Figure 4 demonstrates laminar flow while Figure 5 samples turbulent flow. These graphs were obtained using the same microphone, once with forced transition, and once without. Transitional dynamic signals were also recorded as an entirely different pattern of vertical spikes as shown in Figure 6. Note that this data was obtained under another configuration without cover tape, thus the difference in output voltages. Therefore, through the implementation of cover tape, the research to determine the feasibility of detecting the boundary



layer was a success.

Many possibilities of this project are still to be researched, prior to actual testing within the confines of the NTF. Aspects such as physical durability to both pressure and temperature, and tube length attenuation are to be investigated in the near future. Some groundwork has been conducted, and the burden of research development has been removed in the original setup of this experiment. Through further study, similar dynamic acoustic data could be used to determine the precise flow over an airfoil surface in facilities that lacked the ability previously.

Acknowledgments

The author would like to thank the following people for their efforts in making this project come about: Guy T. Kemmerly, who served as mentor; Ronnie Callis, who aided in construction; Tom Jones, who provided the electrical support; Naval Agarwal, who advised the research; Bryan Campbell and the July HSCT Test staff, who allowed my research during their testing period; and the entire Subsonic Aerodynamics Branch, who supported my attendance in the LARSS Program.

References

- [1] Agarwal, N.K., and Simpson, R.L., "A New Technique for Obtaining the Turbulent Pressure Spectrum From the Surface Pressure Spectrum." *Journal of Sound and Vibration*, 135, 346-350 (1989)
- [2] Knowles Electronics, Incorporated, EM-3068 Microphone Schematic

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FIGURES OF MERIT FOR AERONAUTICS PROGRAMS

and

ADDITION TO NASA LARC FIRE STATION

Belinda M. Harper
LARSS student

Walter S. Green
mentor

Office of the Director

Office of Safety, Environment, and Mission Assurance

Office of Mission Assurance
and
Office of Safety and Facilities Assurance

ABSTRACT

This report accounts details of two research projects for the Langley Aerospace Research Summer Scholars (LARSS) program. The first project, with the Office of Mission Assurance, involved subjectively predicting the probable success of two aeronautics programs by means of a tool called a Figure of Merit. The figure of merit bases program success on the quality and reliability of the following factors: parts, complexity of research, quality programs, hazards elimination, and single point failures elimination. The second project, for the Office of Safety and Facilities Assurance, required planning, layouts, and source seeking for an addition to the fire house. Forecasted changes in facility layout necessitate this addition which will serve as housing for the fire fighters.

INTRODUCTION

Langley Aerospace Research Summer Scholars (LARSS) program time was spent in the Office of Safety, Environment, and Mission Assurance (OSEMA). Program managers involved in aeronautics research, space payloads, or facilities planning at any NASA center may contact OSEMA. Once called upon, the office will not partake in any direct research or engineering. Rather, OSEMA assumes the role of a disinterested third party which objectively reviews the quality of the engineering, the parts, and the program itself. Once involved with a program, OSEMA has the power to prevent that program from taking place if it proves potentially dangerous to personnel or equipment. OSEMA believes their services add value to NASA programs by assuring the quality and reliability of the systems and structures involved.

Personal involvement with OSEMA was in the areas of both aeronautics and facilities safety, reliability, and quality assurance. The first half of the program was spent in the Office of Mission Assurance, a subset of OSEMA responsible for the review of aeronautics programs and space payloads. There, the assignment was to survey two of the aeronautics programs OSEMA was asked to oversee in order that a figure of merit be determined. The figure of merit is a subjective method of determining the probable success of a program on the basis of the following five factors: parts, complexity of research, quality programs, hazards elimination, and single point failures elimination. A single point failure is the failure of any one item that will result in the complete destruction of property and/or death. The aforementioned categories are assigned weights, and are then subjectively rated on a scale of 0-4 on the basis of a review of the quality and reliability programs in place. The products of the weights and ratings for each category are then summed. The total score will be between zero and four and is evaluated much like a GPA, with a zero being a likelihood of failure, and four being the likelihood of complete success. It should be mentioned that the figure of merit model inherently assumes that the more complicated a project is, the less likely it is to succeed. Figure 1 shows a schematic of the figure of merit categories, weights, and ratings.

The second half of the summer was spent in the Office of Safety and Facilities Assurance, another sub-area of OSEMA. The project in the facilities area was to research and provide layouts for a prefabricated addition to the fire station. This addition will serve as housing for the fire fighters and will become necessary when the NASA Langley emergency operations center (EOC) comes on-line, for the EOC will be located in the area which currently shelters the fire fighters. This project required research of potential vendors, study of existing NASA facilities and utilities, interface with vendors and NASA personnel, cost estimating, and cost engineering.

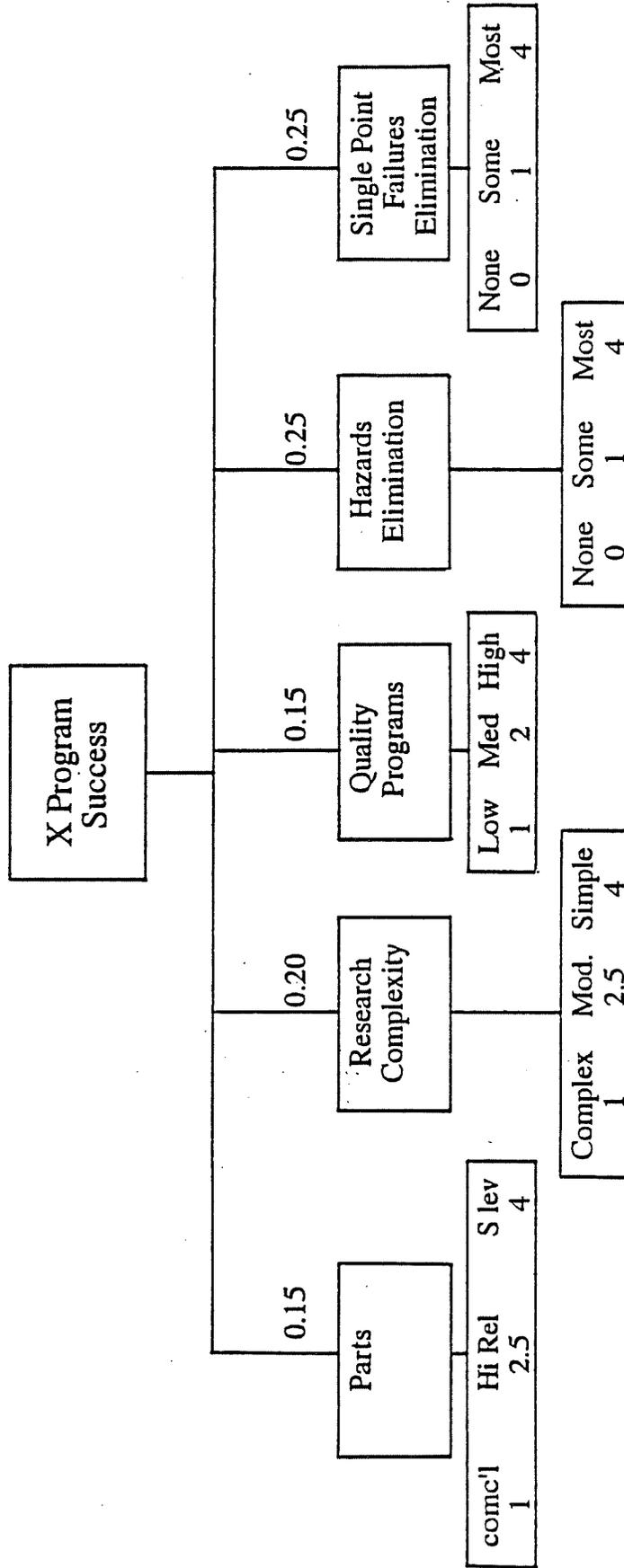
AERONAUTICS PROGRAMS

F-16XL LAMINAR FLOW CONTROL:

This experiment, which involves one of two proposed lift control devices for the high speed civil transport, aims to maintain laminar flow over a longer extent of the wing chord than is currently possible. Since friction between the wing and boundary layer air is responsible for the onset of turbulent flow conditions, this project proposes to extend laminar flow by using suction to pull the boundary layer air into the wing.

The apparatus for this experiment includes the F-16XL (ship no.2) which is located at NASA Dryden Flight Research Center in California, a wing glove, and a suction control system. The design, engineering, and assembly of the wing glove and the suction system was subcontracted by Rockwell International to Boeing Commercial Airplane Group and McDonnell Douglas Corporation (MDA), respectively. Rockwell International was involved as the prime integrating contractor and served as a liaison between NASA and the contractor team. As such, Rockwell was

Figure of Merit



comc'l - commercial
 Hi Rel - high reliability
 S lev - space grade

Figure 1

responsible for coordinating interface meetings and providing the performance, schedule, and cost status.

In the most brief and general terms, the glove is a 0.5 inch deep sandwich panel. The outer skins consist of two titanium sheets. The outer skin is perforated with laser drilled holes, the inner sheet is unperforated. A series of aluminum "I" stiffeners run parallel to the leading edge of the true wing and are bonded to the two sheets. These stiffeners provide the core of the panel sandwich. The wing glove attaches to the existing wing by means of a series of inverted channel members which run perpendicular to the leading edge. These ribs break up the suction panel into acceptable planform dimensions and provide a means of attaching the glove to the true wing.

The suction system, which is located between the glove and the true wing, consists of a series of valves and sensors, ducts and couplings, plenum, and an onboard suction system controller which provides automatic management of all flow control valves. The suction system pulls the boundary layer air through the perforations in the glove, ducts it to the suction manifold, and discharges it overboard.

OSEMA'S ROLE:

As mentioned previously, Boeing was responsible for the wing glove. They provided a satisfactory product and delivered it on schedule. MDA, however, requested exemptions and extensions and provided no interim design or engineering information. These circumstances prompted the program manager to call in OSEMA to provide test requirements for the delivered product which would insure hardware function within the limits of the schedule.

MDA delivered the control box on schedule -- overweight and oversize. Additionally, since MDA subcontracted the design and assembly of the box to a model shop with no previous experience in the aerospace industry, OSEMA supposes that the box was not engineered to withstand the dynamic environment of an aircraft. However, this issue cannot be investigated because MDA claims they have no drawings for the box. Further, the box smoked during testing, and the cause of the smoke has not been investigated.

Finally, the presence of the glove on only one wing results in an asymmetric arrangement. The contractors claim this design will not cause adverse handling effects or compromise flight safety at test speeds or in the Mach-altitude corridor which gives access to the test region. This observation is true, but fails to address issues of controllability at landing approach speeds where the rudder loses authority to compensate for the modified planform.

All the above mentioned safety issues must be resolved before OSEMA will allow the experiment to fly.

OV-10 WAKE TURBULENCE:

This program aims to study the dangerous and potentially deadly wakes of aircraft and the atmospheric conditions that surround these occurrences. NASA believes that air traffic may be managed more efficiently once these events are better understood.

The test aircraft is an OV-10 Bronco outfitted with equipment to measure and record the atmospheric conditions surrounding wake vortex events.

OSEMA'S ROLE:

While the scientists and experimenters on this program already had safety programs in place, OSEMA was called in to review their processes. This review included an assessment of the integrity of aircraft modifications, an investigation into the possibility that test equipment located on the wing could induce destructive vibrations, and a critique of their hazards analysis.

GENERAL:

OSEMA's role in any aerospace program is to be present at Airworthiness Safety Review Boards (ASRB's). ASRB's represent a formal occasion to bring up and resolve any outstanding safety issues. If any board member believes that such issues remain, there is a possibility that the experiment will not fly.

FIGURE OF MERIT RESULTS

The Figure of Merit results for the F-16XL Laminar Flow Control program and the OV-10 Wake Turbulence program follow.

Figure of Merit for F-16XL Supersonic Laminar Flow Control Experiment

PARTS:

Parts for the project will be purchased "off the shelf" as well as specially made. Therefore, parts merit a weight near two.

RESEARCH COMPLEXITY:

The project is quite complex in that several contractors must interface ideas as well as equipment. Additionally, this project will require the inception of several original designs as well as the fabrication of those designs. Once the design and construction is complete, a means to collect and analyze test data becomes necessary which further requires the availability of ground and flight support teams. These observations correspond to a weight near 1.

QUALITY PROGRAMS:

The establishing of quality control measures is the responsibility of the individual contractors and subcontractors. Per the memoranda on file and on the basis of past conversations, it is apparent that Boeing's quality control actions were satisfactory, while McDonnell Douglas had no quality control programs whatsoever. When the two come together, quality approaches a medium value of 2.

HAZARDS ELIMINATION:

Neither contractor specifically calls out a hazards elimination program, or a hazards identification program, for that matter. The quality assurance measures that Boeing had in place could infer a reduction in the potential for hazards, but the fact that no specific review programs are mentioned suggests that no such program exists. As for McDonnell Douglas, their lack of quality programs guarantees the lack of a hazards identification or elimination program. These observations warrant a rating of 0.

SINGLE POINT FAILURES ELIMINATION:

No single point failure identification or elimination program is mentioned, and no measures have been taken by either contractor to enact such a program. This state conforms to a rating of 0.

FIGURE OF MERIT:

Parts:	2(0.15)
Research Complexity:	1(0.20)
Quality Programs:	2(0.15)
Hazards Elimination:	0(0.25)
Single Point Failures Elim.:	<u>0(0.25)</u>
	0.8

Shortly after the completion of this review, the contractor team submitted a preliminary hazard analysis. The team's examination identified potential hazards, their severity, causes, and effects. Control measures are also included in each scenario. The presence of this review brings the hazards elimination rating up to a 4.

A single point failures program is still not specifically mentioned. Some critical hazards which could cause loss of life and/or aircraft are included in the hazards analysis. However, the team's historical lack of quality programs leads to a reluctance to give the single point failures elimination program a rating higher than 1. The above factors lead to a revised figure of merit of 2.05.

Figure of Merit for OV-10 Wake Turbulence Program

PARTS:

This experiment utilizes commercial parts, modified commercial parts, and specially fabricated parts. Commercially available equipment constitutes the majority of the parts requirement with some items necessitating minor modifications. In general, these changes proceeded without event. Likewise, the design and fabrication of specialized parts required limited effort. While most parts were commercially available, part modification added slight complication to the project, and design and fabrication of original ideas further added to the project's complexity. Therefore, the sum of all these factors constitutes a rating of two. This airplane is maintained to FAA standards with TSO'd parts.

COMPLEXITY OF RESEARCH:

The project seeks to address unanswered questions, but utilizes conventional means to achieve that end. The measurement tools, recording instruments, and means of analysis are standard and, with few exceptions, commercially available. Arrangement of these instruments, however, was quite a bit more complicated, requiring rather extensive overhaul and modification of the test aircraft. These alterations occurred according to plan and within the limits of the schedule. Additional difficulty could have arisen with respect to the interface of facilities and research partners. However, most exchanges transpired without incident or delay. While the logistics of this experiment are not simple in nature, the personnel involved made it appear commonplace. Therefore, the complexity of research merits a moderate weight of 2.5.

QUALITY PROGRAMS:

The engineers and designers instilled quality into each step of their programs. The engineers addressed matters of structural integrity and design limitations by testing questionable items. Further, weekly meetings kept all involved parties "up to speed" and addressed various areas of concern. In addition, aviation safety review boards (ASRB's) were scheduled and briefed, and all review board recommendations were carried out. Moreover, QA inspected all modifications to insure safety and integrity. These items demonstrate the presence of an admirable quality program warranting a high rating of four.

HAZARDS ELIMINATION:

Hazard analyses were conducted and documented. The hazard reports identify causes and effects as well as any other relevant information, including an assessment of the probability of occurrence. Further, the reports cite means of control or corrective actions. The analyses are thorough, follow standard NASA guidelines, and serve to eliminate most of the hazards or potential for hazards, entitling the program to a rating of four.

SINGLE POINT FAILURES ELIMINATION:

While a single point failures elimination program is not specifically called out, the hazards analysis covered areas that are considered single point failures. The examination consists of causes and effects, additional pertinent information as well as an evaluation of the probability of occurrence.

The analysis also identifies failure controls or corrective actions allowing the program a rating of four.

FIGURE OF MERIT:

Parts:	2(0.15)
Research Complexity:	2.5(0.20)
Quality Programs:	4(0.15)
Hazards Elimination:	4(0.25)
Single Point Failures Elim.:	<u>4(0.25)</u>
	3.4

FACILITIES PROJECT

NASA Langley Research Center is currently involved with the development of an emergency operations center. This facility will be located in the area of the fire station which currently houses the fire fighters on duty. Therefore, it will be necessary to provide alternate shelter for the fire fighters when the EOC comes on-line. Due to budget constraints and restrictions on new construction the housing facility must be a prefabricated Butler-type building.

The first step in the project was to establish a minimum and maximum arrangement, and estimate the square footage requirements. The minimum layout would include a bunkroom capable of housing approximately ten men and two women and full bath facilities. Ideally, the structure would include full bath facilities, kitchen facilities, a men's bunkroom, a women's bunkroom, a day room, a one man office which would also include room for a bunk, and an equipment room (for washer/dryer storage). Approximate square footage ranged from a minimum of about 2000 sq.ft. to an upper end near 3000 sq.ft. Any designs would include hook-ups for plumbing and electricity.

Next, it was necessary to find vendors that could provide such a service. This task involved contacting those people on-center who have had recent dealings with the erection of a prefabricated building. It was assumed that they would be able to provide names and numbers of vendors and, ideally, be able to provide vendor literature and brochures.

The most important and most challenging task involved placement of the facility. Any arrangement must provide direct access to the bay. This constraint, coupled with funding limitations, severely confined site development. The original idea was to erect the building on the "1247" side of the fire house, or the grassy area between the fire house and East Reid Street. However, upon investigation, it was discovered that many underground utilities converge in this area. These utilities included several electrical conduits, a 36" storm sewer with various connectors, two separate sets of telephone lines, and a buried headwall. An alternative was to place the building on the "1232" side over the existing parking area. This arrangement, however, would necessitate relocating the emergency generator and the condensing unit in addition to removing the asphalt parking surface. Moreover, providing direct access to the bay would necessitate cutting a hallway through the existing living space. All of these factors proved cost prohibitive. The last choice would be to go up -- add a modular second story. This option brings up the question of whether or not the foundation and the structural supports could accommodate the additional load.

Resolving all the aforementioned issues required extensive consultation with personnel in the Facilities and Systems Engineering Division and the construction services section of the Operations Support Division. Those consulted advised that building over the electrical lines is allowable, as long as the manhole is left accessible. As for the storm drain, it is possible to build over it, but it is not good engineering practice. If the pipe were to rupture, the resulting washout could collapse the building. Moving the drainage pipe was an alternative, but that option would prove superfluous and costly. With respect to going up, the present structure had not been engineered to accommodate a second floor. The resolution was to go with a long narrow structure, approximately 25 ft. by 70 ft. that would probably only provide the minimum accommodations of a bunkroom and a bathroom.

Once these issues were resolved, and while waiting to receive vendor information, time was spent sketching various arrangements. The 1800 or 1900 sq. ft. allowed inclusion of all but one of the desired elements. Depending on the configuration, either the dayroom, kitchen, or chief's office was sacrificed. Several contacts with building suppliers and erection firms were also made in order to determine a rough cost estimate. However, at this time, no pricing information has been delivered.

omit

Royalty Sharing For Private Employees Under the Stevenson-Wydler Act

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The College of William and Mary

Kimberly A. Chasteen, Mentor
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28 July 1995

Abstract

This study addresses an issue arising from the transfer of federal research technology to commercial use. The National Aeronautics and Space Administration (NASA) transfers much of this technology by the means of patent licenses. These licenses can be valuable to businesses and therefore have the potential to generate considerable income. In the Stevenson-Wydler Act, the U.S. Congress directed federal agencies to return a minimum percentage of this income to inventors. In this act, Congress hoped to encourage invention disclosure, strengthen cooperation between public and private researchers, aid small businesses and to foster technology transfer.

However, the wording in parts of the Act is not clear. When NASA established its royalty policy, it asked the U.S. General Accounting Office (GAO) for guidance as to the congressional intent. The GAO responded that Congress intended to reward government employees and a small set of private inventors who assigned their rights in an invention directly to the government. This narrow application of the Act did not reward inventors who worked for private entities, such as universities, because their assignment was through their employer and hence, indirect. In perhaps the most extreme of cases, one co-inventor could receive large payments of royalties while the other might receive nothing.

This study examines the reasoning of the GAO and current NASA policy. In addition, this study recommends a policy alternative that might aid in achieving the goals of the Stevenson-Wydler Act. The organization of this document is a merger of a technical report and a legal memorandum.

Memorandum

Question Presented/Introduction

Is an inventor entitled to royalties from licensing income when that inventor is an employee of a non-government organization and the inventor assigned his rights in the invention to his employer, which subsequently assigned its rights to NASA for technology commercialization?

Facts/Background

In April 1993, the National Aeronautics and Space Administration (NASA) requested guidance from the U.S. General Accounting Office (GAO) concerning the distribution of patent licensing royalties under the Stevenson-Wydler Act.¹ The GAO determined that (1) the plain language of the statute, particularly 15 U.S.C. § 3710c, does not allow royalty sharing when the government gains title to an invention by assignment from one other than the inventor, (2) private employers are best suited to reward their employees, and (3) legislative history does not support royalty sharing with private employees.² In short, the GAO argued that the Stevenson-Wydler Act contemplated royalty sharing only for those individual inventors who assign their rights directly to the government. Such an inventor would be a sort of “free-agent” researcher, who dealt individually with the government. In the case of researchers employed by others, the government deals with the employer during the assignment of title, thus the inventor-employee is not a party to the transaction. If the employer and the government desire to include private employee inventors in royalty sharing, then they would have to agree separately on the terms. The means for such an agreement could be a condition to the employer’s assignment of title to the government or as a limitation to the underlying research contract.

Accordingly, NASA policy does not provide for comparable distribution of royalties to federal and private inventors.³ The implications are most visible in the inventions produced by collaborative work; for in that case, NASA policy can operate in conjunction with the federal laws that govern the ownership of inventions to produce a stark inequity in license royalties among co-inventors. In collaborative efforts, non-government researchers work alongside government researchers. If the researchers cooperatively invent, then each co-inventor possesses an undivided partial interest in the invention. Government employees routinely assign their interest in inventions to the government pursuant to 37 C.F.R. § 501. Similarly, non-government employees usually assign their interest to the employer as a condition of employment.

Thus, the parties holding interest in the invention are the government and the employer. The allocation of ownership between these parties is governed by The Space

¹ Technology Innovation (Stevenson-Wydler) Act, 15 U.S.C. § 3701 (Supp. IV 1986)(as amended by the National Institute of Standards and Technology Authorization Act for Fiscal Year 1989, Pub. L. 100-519, Section 303(a), 102 Stat. 2589, 2597 (1988)).

² U.S. General Accounting Office, Gen. Couns. Mem. B-235063 (April 3, 1991)(*hereinafter* Mem.).

³ NASA Management Instruction (NMI) 3450.8 (Effective Date Dec. 1, 1992).

Act.⁴ In general, the government has a right to the title of any invention produced during the performance a NASA contract. However, if the contractor is a small entity (i.e. small business, non-profit or university), then the contractor may elect to take title to the invention.⁵ If not, then title falls to the government. If the contractor is a large entity, then in order to gain title the contractor must request NASA to waive its rights to the invention.⁶ Additionally, if the government desires to commercialize the technology by exclusive license, then it must receive clear assignment of rights in the invention from all the inventors.⁷

For example, if a small business decided that it was unable to prosecute a patent for a collaborative invention, it could assign its interest in the invention to the federal government. In turn, the government could offer an exclusive license to a commercializing entity. The Stevenson-Wydler Act,⁸ implemented by NASA Management Instruction (NMI) 3450.8, would govern the distribution of the licensing royalties. The standard Stevenson-Wydler Act distribution of royalties in section 7 of that instruction applies only to government "employee-inventors." This section gives royalties to NASA employees when the invention was produced by NASA alone, when NASA retains an undivided interest in a joint invention, or NASA receives the full title of a joint invention. Because section 7 gives royalties to government employees only, the non-NASA co-inventor is left with section 8 for reward. Section 8 permits the government, through the Inventions and Contributions Board, to make "awards to the inventors." These awards are merely a discretionary alternative to using licensing income for "promoting the transfer of NASA technology." It is likely that such an award could match neither the dollar amount of royalty payments nor the duration of a long, license royalty scheme. Experience has shown that awards to non-NASA co-inventors under section 8 are infrequent and fall short of the royalty scheme of section 7.

In some cases, this has prompted non-NASA employees to encourage their employers to take title of the invention without an accurate assessment of their ability to commercialize. If the employer is a small business, such as an end-user of the technology, it might be unable to develop or market the technology, stifling the purpose of the collaborative effort. If a private employer is in fact capable of developing and marketing the technology, then the harm to technology transfer would be less direct. The non-NASA employee would be rewarded under the small business's royalty plan. The NASA employee would receive no reward under NMI 3450.8 section 7, which is limited to "Whenever NASA licenses..." Under a different regulation discussed below, the government may be able to recoup some royalty income for the government co-inventor; however, this guarantee is not applied uniformly and is not available to private co-inventors.

Each outcome is unsatisfactory for some of the co-inventors. The non-NASA co-inventor faces the dim prospect of discretionary awards under section 8 in lieu of a credible royalty sharing scheme. The NASA co-inventor faces the prospect of a research partner who may claim the sole reward for the joint work. In cases where multiple government employees work with a single private employee, the deprivation can be severe. This arrangement is squelching the enthusiasm of inventors in joint projects and thwarting the intent of the Stevenson-Wydler Act.

Approach

⁴ Section 305(a), 42 U.S.C. § 2457(a) (1988); *see also* FAR clause 52.227-11, and NFS clause 18-52.227-70.

⁵ FAR clause 52.227-11.

⁶ NFS clause 18-52.227-70.

⁷ *Cf.* 37 C.F.R. § 404.7(a)(1)(ii)(C) (1993).

⁸ 15 U.S.C. § 3710c.

The approach of this study included problem definition, research of governing documents and a brief comparison of different agencies. Problem definition included discussing with Technology Transfer Team personnel some of the challenges and benefits arising from the current royalty distribution policy. The goal of the research step was to collect the applicable legal references and to reconstruct the development of current NASA policy. Additionally, the references would show if there were otherwise acceptable, alternative policies. Guidance on this issue included NASA management instructions, statutes, regulations, congressional committee hearings testimony and reports. The comparison of different programs included telephone conversations with technology transfer personnel from different agencies. This step was informal and aided the identification of pertinent references. The agencies included were the National Institute for Science and Technology, Department of Energy, Department of the Navy and the National Institute of Health.

Results

There is little direct guidance on the issue of distributing patent licensing royalties. It is clear that the example described above defeats the intent of the Stevenson-Wydler Act: "Cooperation among academia, Federal laboratories, labor, and industry, in such forms as technology transfer, personnel exchange, joint research projects, and others, should be renewed, expanded, and strengthened."⁹ Indeed, in a different context, the GAO has reported that "royalty sharing would be a more effective incentive if fewer inventors were disappointed in the rewards they receive."¹⁰ Due in part to the paucity of authoritative guidance, NASA policy depends heavily on the GAO's interpretation of the Stevenson-Wydler Act.

In general, the history of this Act shows a trend of expanding scope in order to aid the commercialization of government technology. Prior to 1988, the distribution of royalties among public and private co-inventors was not an issue because the inventor was required to be an employee of the agency at the time of invention.¹¹ However, in that year Congress amended the Stevenson-Wydler Act to provide that:

The head of the agency or his designee shall pay at least 15 percent of the royalties or other income the agency receives on account of any invention to the inventor (or co-inventors) if the inventor (or each such co-inventor) has assigned his or her rights in the invention to the United States.¹²

This tone echoes the congressional intent for the Stevenson-Wydler Act throughout the 1980's, which was to "improve the transfer of commercially useful technologies from Federal laboratories and into the private sector."¹³

The GAO examined 15 U.S.C. § 3710c and decided that if an inventor individually owns the rights to an invention and directly assigns those rights to the government, then that inventor falls clearly within the scope of the Stevenson-Wydler Act and is thereby entitled to 15 percent of "the royalties or other income the agency receives."¹⁴ Curiously, this "free agent" inventor is not included in the royalty scheme of NMI 3450.8 section 7. This section rewards only government employees. Presumably, the Inventions and

⁹ 15 U.S.C. § 3710(3); *see also* 15 U.S.C. § 3710c.

¹⁰ U.S. GEN. ACCT. OFF., TECHNOLOGY TRANSFER: IMPROVING INCENTIVES FOR TECHNOLOGY TRANSFER AT FEDERAL LABORATORIES 3 (Oct. 26, 1993)(GAO/T-RCED-94-42).

¹¹ *See* Mem., p.2.

¹² 15 U.S.C. § 3710c(a).

¹³ S. Rep. No. 283, 99th Cong. , 2d Sess. 1 (1986).

¹⁴ *See* Mem., p.5.

Contributions Board is responsible for ensuring that such an inventor is rewarded under NMI 3450.8 section 8 in a manner compliant with 15 U.S.C. § 3710c. At any rate, “free agent” inventors independently working for NASA are rare.

In a case where the government gains rights to an invention by assignment from a non-government employer, royalty allocation to the employee “is not as clear.”¹⁵ The GAO argued that (1) the plain language of the statute¹⁶ does not allow royalty sharing when the government gains title to an invention by assignment from one other than the inventor, (2) private employers are best suited to reward their employees, and (3) legislative history does not support royalty sharing with private employees. Therefore, such inventors do not fall within the scope of the Stevenson-Wydler Act. Accordingly, the only provision to reward private inventors when the government receives right to an invention by assignment by the employer is through NMI 3450.8 section 8 (as discussed above) or by separate instrument, such as a contract or condition of assignment.¹⁷ There are aspects of the GAO analysis which, because of their implications for technology transfer, demand close examination.

Plain Language

The plain language of 15 U.S.C. § 3710c does allow an interpretation that gives royalties to inventors when the government received the rights from one other than the inventor. For ease of reference, such an interpretation might be considered “broad” when contrasted to the “narrow” GAO interpretation that the assignment must be made directly by the inventor. The phrase particularly at issue is “if the inventor...has assigned his or her rights in the invention to the United States.”¹⁸ Two facts color this dispute: most private inventors are employees of private entities (i.e., “free agent” inventors are rare) and most employers require as a condition of employment that employees assign their rights in inventions to the employer.

On one hand, a broad view would be consistent with the stated intent of Congress in the Stevenson-Wydler Act:

The Nation should give fuller recognition to individuals and companies which have made outstanding contributions to the promotion of technology or technological manpower for the improvement of the economic, environmental, or social well-being of the United States.¹⁹

In this clause Congress loosely identified the set of individuals meriting recognition. Congruously, in 1988 Congress expanded the royalty scheme from those inventors employed by the agency at the time of invention to any inventor who assigned his or her rights to the government.²⁰ It follows that if Congress wanted to limit this expansion to “free agent” inventors, it would do so clearly. But Congress did not limit 15 U.S.C. § 3710c. Indeed, elsewhere in the Act, Congress shows the ability to clearly differentiate between public and private personnel. For example, at one point Congress qualifies an inventor as a “Government employee,”²¹ even in the section at hand, the word “employee” is used to limit one set of inventors to public personnel.²² If Congress intended to manifest its intent narrowly, it could have more clearly excluded the private employees by simple

¹⁵ Mem., p.5.

¹⁶ 15 U.S.C. § 3710c.

¹⁷ Mem., p.6.

¹⁸ 15 U.S.C. § 3710c.

¹⁹ 15 U.S.C. § 3701(11).

²⁰ Pub. L. 100-519, § 303(a)(1) (1988).

²¹ *Id.* § 3710d.

²² 15 U.S.C. § 3710c(3).

word choice. Congress did not do this; the plain language signifies merely a concern that if the government gains a valuable invention, then an inventor should be rewarded.

On the other hand, a narrow reading of this phrase assumes the restriction of an implied, reflexive pronoun; such a phrase would read: "if the inventor [himself or herself] has assigned his or her rights to the United States." If this were the case, then Congress would have intended to exclude private employees through the odd mechanism of their employment contracts. In other words, to satisfy this narrow reading, an inventor seeking royalty income would have to convince the employer to write an exception in the employment contract that allowed the inventor to keep the rights to an invention as long as those rights were to be assigned to the government pursuant to a contract. Such a narrow reading treats the private employee inconsistently. For the purposes of the contract between the government and the private employer (contractor), the government treats the employee as an element the contractor; this enables the government to bargain for the total product of the contractor employees' work under the contract. Yet for the purposes of invention ownership, the government treats the employee as an independent inventor who has fairly exchanged his rights to one in privity with the government. In short, a narrow reading requires unwieldy legislative construction, creates inconsistencies within the Act and treats private employees inconsistently.

Private Employers Are Best Suited To Reward Their Employees

The second prong of the GAO's argument was that Congress intended to exclude private employees. The GAO grounded this intent by arguing that private employees did not need an incentive to disclose nor a reward for contribution: "the government cannot promote or reward inventors as easily as can private industry... The desired incentive [for disclosure of inventions]...presumably is effected through the employment agreement."²³ The fact that the employee has assigned the rights in the invention to the employer removes the employee from any relationship with the government. Indeed, giving royalties to a private employee would restore the employee's rights to an invention when the employee had assigned those rights away. Furthermore, the employer did not merit incentive or reward when the employer was not the inventor. Thus, the GAO viewed the employee much like a subcontractor who has already been paid by the contractor for his product. If the government were to pay the subcontractor again, then the subcontractor would be double rewarded. Similarly, the contractor required no special incentive or reward for the work of the subcontractor.

This position is flawed on several grounds. First, the strength of this argument necessarily depends on the merit of the plain language argument. Recall that the GAO considered "free agent" inventors to be clearly within the scope of the Act. At the same time, the GAO would hold that private employees, the bulk of such inventors, are excluded by virtue of the indirect implication of customary employment contracts. No explanation is given for why such a strong limitation of the stated policy would be presented indirectly. In fact, this distinction is not supported elsewhere in the Act. If Congress found this issue to be a compelling problem, there would be more evidence. Yet the only manifestation of this forceful policy argument is the GAO construction of the unclear language of 15 U.S.C. § 3710c.

Second, the concern that private employees would be doubly rewarded is not accurate. The GAO argues that private employers are better able than the government to compensate employees for giving their rights of invention to the employer. If the government were to give royalties to the private employees, then the inventor would be doubly compensated. Thus, the GAO describes royalty sharing with private employees as a restoration of the inventor's rights in an invention. In comparing public and private inventors, this is a curious approach. The regulations which address government

²³ Mem., p.5 (emphasis in the original).

ownership of the inventions of public employees are quite similar to the invention ownership clauses customary in employment contracts.²⁴ Both employees are paid under their respective employment agreements for performance of their assigned duties. For the private employee, these duties are pursuant to the government contract. The merit of this agreement is not at issue. However, the income from license is external to this bargain; licensing royalties derive from the commercial value of the invention and not the completion of the duties of an underlying contract. If the government keeps all the income from licensing, then the private inventor cannot be rewarded from the commercialization of the invention. In that case, the flow of royalty income never reaches the private parties. Any reward an employer might give one of its inventors must come from the employer's general income and not from the licensing royalties. In other words, the market value of the license plays no role in the reward to the employee. The employer and the employee never see the income arising from the commercial value of the invention. Thus, a reward to a private inventor would be a loss to the employer; accordingly, only those inventions that produce an incidental benefit to the employer would merit a reward. This reward is far different from sharing the licensing royalties from commercialization. To argue that the incentive for the disclosure of inventions is effected through the employment agreement assumes a flow of income that simply does not exist.

Moreover, this approach ignores the practical implications of the roles of the parties. The employer that rewards its employees generously from its income will likely be less competitive than an identical employer that offers little or no reward. Depending on how much of the employer's income is derived from government work, the effect may be to depress the reward programs of the private employers. Such a result is clearly contrary to the objectives of reporting inventions and contributing to their commercialization. Thus, when the government undertakes to commercialize the inventions of private employees, the private employers are poorly suited to reward the inventors.

Legislative History Does Not Support Royalty Sharing With Private Employees

The third prong of the GAO's argument is that the history of the legislative process shows that Congress did not intend to restore the private employee's rights in an invention. The GAO posited that "There is no support in the legislative history to suggest that Congress intended that result."²⁵ Indeed, the GAO argued that Congress expressly did not intend to set a precedent for royalty sharing for private employees. However, this assertion is misplaced. The legislative history on point is scarce and seems to accept a broad application of the Stevenson-Wydler Act.

First, the legislative history does show that Congress intended not to interfere in private employment contracts. The express refusal to set a precedent in this area did not refer to the government provision of royalties to private employees. On April 21, 1986, in reference to an earlier, government-only royalty sharing provision,²⁶ Sen. Danforth of the Committee on Commerce, Science, and Transportation noted:

Some representatives of businesses that employ scientists fear that establishing royalty sharing for Federal employees will set a precedent for legislation mandating royalty sharing for private inventors. The Committee believes that the government is different from private industry in that it cannot promote or reward inventors as easily, and that more inventions will be reported and developed if Federal employees have a guaranteed share in

²⁴ 37 C.F.R. § 501 (1995).

²⁵ Mem., p.5.

²⁶ That is, pre-Pub. L. No. 100-519.

potential royalties. The Committee does not intend for this provision affecting Government employees to set a precedent for private employees.²⁷

Thus, the concern of business was that if Congress discovered royalty sharing for federal employees to be beneficial, then Congress would force private employers to establish their own royalty sharing schemes as an element of general labor reform. The context of the above statement shows that it is irrelevant to the issue at hand.

Second, the little legislative history that is available seems to indicate congressional acceptance of broad scheme of royalty sharing. It is common for summaries of the act to identify the set of inventors as including both government employees and other inventors. Indeed, the GAO memorandum refers to a letter from National Institutes of Health complaining of pre-royalty sharing inequity:

Guest researchers, volunteers, or GOCO employee scientists may be inventors jointly with Federal scientists. Presently the Federal employee would be eligible for royalties from the joint invention, but the other inventor would not. This creates an inequitable situation which cripples morale and the efficiency of the laboratory.²⁸

It is apparent that the testimony included the private employees of the contractor as a *sui generis* party. Similarly, the Stevenson-Wydler Act has been hailed as requiring "Federal Agencies to pay Government employees and inventors at least fifteen percent of any royalties or other income received for an invention...".²⁹ If the subject party of inventors were as limited as the GAO argues, such unqualified language is not merely careless but misleading. Instead, it is much more consistent with the Act that the word inventor does include private employees.

A Separate Instrument

The GAO argued that because private employee reward is not provided by the Stevenson-Wydler Act, it is available only by the terms of the employer's assignment to the government, the terms of the contract, or by the terms of a cooperative research agreement.³⁰ This position depends on a number of assumptions. First, the GAO assumes that the private employee is able to leverage the employer into conditioning its relationship with the government in order to recoup licensing income. Second, the GAO assumes that the government would allow conditioning of government contracts and invention right assignment. Third, the GAO assumes that the commercial environment would permit the employer to undertake such a move and remain competitive. Finally, underlying these assumptions is the position that if the Stevenson-Wydler Act does not provide for royalty sharing with private employees, then the burden lies on the private party to change the terms of its relationship with the government. This begs the related questions of whether the public might best be served by rewarding private contributions to technology development and whether the government might be able to employ these mechanisms for such a reward.

Perhaps the most debilitating of these assumptions, if faulty, is that the government would allow such a change to the conditions of its relationship with contractors. For example, consider the obstacles to conditioning a government contract to require royalty sharing with private employees. First, any modification of the provisions in government

²⁷ S. Rep. No. 283, 99th Cong., 2d Sess. 18 (1986).

²⁸ H.R. 476, 100th Cong., 2nd Sess., 796 (1988).

²⁹ H.R. 256, 100th Cong., 1st Sess., 3 (1987)(emphasis supplied).

³⁰ Mem., p.6.

contracts must be authorized by the Federal Acquisition Regulations (FAR).³¹ It is doubtful whether the FAR envisions such an arrangement; indeed, such a cost does not satisfy the definitions of either patent or royalty costs allowed in the FAR.³² Such a nonstandard cost to the government would have to be found "allowable."³³ As such, the contracting officer must show that the private employee royalties were "chargeable to one or more cost objectives on the basis of the relative benefits received..."³⁴ Unless the commercialization of technology was one of the contract objectives, this would fail. Furthermore, such a condition implies a negotiated contract which would not terminate until the royalty agreement terminated. Disbursements under the contract could continue for the life of the patent. Thus, it is unlikely that the government would allow a private employer to condition a contract to include a royalty sharing scheme.

Consider also the obstacles to conditioning the assignment of rights in the invention. To start, such a condition would likely be an impermissible limitation of the government's property rights under The Space Act.³⁵ Currently regulations allow only the government to condition its assignment of a government employees rights in an invention to a contractor.³⁶ The law does not envision such flexibility for the contractor.³⁷ Because any modification to the terms of the government-contractor relationship must be authorized by the regulations, and this modification is not, then the provision of royalties to private employees as a condition of assignment would not be authorized.³⁸ Thus, it appears that a contractor would find it difficult, if not impossible, to change the conditions of its relationship with government.

A Brief Comparison

Other agencies interpret the Stevenson-Wydler Act to allow for royalty sharing with private employees. As noted above, the comparison included The National Institute for Science and Technology, the Department of Energy, the Department of the Navy and the National Institute of Health. The contacts at the National Institute for Science and Technology and the Department of Energy claimed that their relationships with private entities were so different as to provide a poor basis for comparison.³⁹ The Department of the Navy implements the Stevenson-Wydler Act broadly, allowing private employees to share in licensing royalties.⁴⁰ In fact, naval personnel who reviewed the subject GAO memorandum disagreed with the conclusions as producing "anomalous results" and defeating the plain intent of the statute.⁴¹ Personnel from the National Institute of Health concurred, suspecting that a narrow interpretation could be disruptive to collaborative efforts.⁴²

³¹ NFSD 18-52.104, *see* FAR 52.101(a).

³² FAR §§ 31.205-30, 31.205-37, respectively.

³³ FAR 31.201-2.

³⁴ FAR 31.201-4.

³⁵ § 305(a), 42 USC § 2457 (1988)

³⁶ 37 C.F.R. § 401.10 (1993).

³⁷ 37 C.F.R. § 401; *see* NFS 18-52.227-70 and FAR 52-227.11 as modified by NFS 18-52.227-11.

³⁸ 37 CFR 401.1.

³⁹ Telephone Interview with Terry Lynch, Technology Transfer, U.S. Nat'l Inst Sci. and Tech. (Jul. 1995); Telephone Interview with Irving Barrek, Patent Counsel, U.S. Dep't. of Energy, Oak Ridge Nat'l Lab. (Jul 1995).

⁴⁰ SECNAVINST 5870.2D (May, 16, 1989).

⁴¹ Letter from William C. Garvet, Deputy Counsel, Office of the Chief of Naval Research to Harry Lupuloff, Office of the General Counsel, NASA (Apr. 13, 1990)(Refer to 5870, Ser OOCIP/484 13 Apr 90).

⁴² Telephone Interview with Steve Ferguson, Technology Transfer, U.S. Nat'l Inst. of Health (Jul. 1995).

Conclusion/Recommendation

The Stevenson-Wydler Act allows for the sharing of licensing royalty income with private employees. Although there is little direct guidance on the issue of distributing patent licensing royalties, it is clear that the present policy counters the stated intent of Stevenson-Wydler Act. Accordingly, a recommendation that fosters cooperation with private inventors while advancing technology transfer will find its source in the equitable treatment of inventors.

One such plan might be a "mirror image" policy in which the reward to the co-inventor of the organization that relinquishes title would mirror that of the receiving organization. Under this proposal, the organization taking complete title would reward all inventors consistently under its own plan, regardless of employment status. Thus, if a non-profit organization did not elect to take title to a joint invention, then NASA would divide the licensing royalties into shares similar to the plan described in NMI 3450.8 section 7, counting the private employee as one of the co-inventors. If the non-profit organization elected to take title and NASA assigned its interest to the organization, then as a condition of NASA's assignment of its interest in the invention, the non-profit organization would reward the NASA co-inventors under its own royalty share plan. The "mirror image" policy would not apply to cases in which the parties retained undivided interests in the invention. Because the NMI 3450.8 envisions essentially a complete distribution of royalties to the inventors, there should be no increase in government expense over the current plan; the royalty income is simply split into another equal share.



United States
General Accounting Office
Washington, D.C. 20548

Office of the General Counsel

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April 3, 1991

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U.S. PATENT SECTION

Harry Lupuloff, Esq.
Director of Patent Licensing
National Aeronautics and Space
Administration

Dear Mr. Lupuloff:

This concerns the National Aeronautics and Space Administration's request for our guidance in the distribution of income from patent licensing royalties.

In accordance with your telephone conversation of April 2, 1991, with Jerold Cohen of our staff, we have closed our file on the matter.

Sincerely yours,

Robert H. Hunter
Associate General Counsel

Mr. Edward Frankle
General Counsel
National Aeronautics and
Space Administration
Washington, D.C. 20546

Dear Mr. Frankle:

This responds to the National Aeronautics and Space Administration's (NASA) request for our guidance concerning the manner in which income from its patent licensing royalties should be distributed to NASA inventors. Specifically, NASA asks to what extent the Stevenson-Wydler Technology Innovation Act of 1980, § 14(a) (1) (A), 15 U.S.C. § 3710c(a) (1) (A) (Supp. IV 1986), as amended by the National Institute of Standards and Technology Authorization Act for Fiscal Year 1989, Pub. L. No. 100-519, § 303(a), 102 Stat. 2589, 2597(1988), entitles inventors other than those who are current or former federal employees, or their employers, to receive a share of NASA's royalty income. Because Congress made section 303 of Pub. L. No. 100-519, enacted October 24, 1988, retroactive to October 20, 1986, NASA also asks whether the distributions of royalty income it made after the effective date but before the enactment date, must be recalculated to provide for distributions to any non-government inventors.

In our view, royalty payments under Pub. L. No. 100-519 may be made only to non-federal employee inventors who directly assign their ownership rights to the United States. We also conclude that section 303's distribution provision applies to royalties received by the government on or after October 24, 1988, the date of enactment, from inventions assigned to the government on or after October 20, 1986.

Background

Prior to enactment of Pub. L. No. 100-519, the Stevenson-Wydler Technology Innovation Act of 1980, as amended by the Federal Technology Transfer Act of 1986, § 7, 15 U.S.C. § 3710c(a)(1)(A), authorized a federal agency to share royalties only with an inventor who was an employee of the agency at the time of the invention. Pub. L. No. 100-519 modified that authority, "... so that it would apply to any inventor who has assigned his or her rights in the invention to the United States." S. Rep. No. 466, 100th Cong., 2d Sess. 15 (1988). The law thus now provides:

"The head of the agency or his designee shall pay at least 15 percent of the royalties or other income the agency receives on account of any invention to the inventor (or co-inventors) if the inventor (or each such co-inventor) has assigned his or her rights in the invention to the United States."

NASA reports that several of the inventions for which NASA receives royalties were made by employees of grantees or contractors who assigned their rights to NASA. According to NASA, most situations involve those where it is the

employer of the inventor (i.e., the contractor or grantee), rather than the inventor, who assigns rights to the United States. Pub. L. No. 100-519 does not state whether individual inventors whose employers have assigned rights to the United States are entitled to a share of the royalties received by the government.

Analysis--Royalty Entitlement

Executive Order No. 10096, January 23, 1950, as amended, requires the United States to acquire the entire right, title and interest to an invention made by a government employee where the government contribution to the invention is sufficient to justify a requirement for the employee to assign individual ownership rights. After the Executive Order was issued, this requirement became viewed as a disincentive for federal employees to report their inventions and to contribute to commercialization. Congress intended the royalty sharing provisions of 15 U.S.C. § 3710c(a) (1) (A) that it added through the Federal Technology Transfer Act of 1986 to provide that incentive and encouragement.^{1/}

The 1986 statute did not address royalty sharing by non-federal inventors working at federal laboratories. The laboratories undertake cooperative research with the private sector under a variety of arrangements. Under some programs, businesses, universities, professional societies, or other organizations donate the services of scientists and engineers in their

^{1/} S. Rep. No. 283, 99th Cong., 2d Sess. 12, reprinted in 1986 U.S. Code Cong. & Admin. News 3442, 3454.

employ. Patent rights for inventions that may be individually or jointly produced are governed by formal agreements. Other programs rely on less formal arrangements under which unpaid guest researchers not supervised by the government, unpaid but government-supervised special volunteers, or employees of a government-owned, contractor operated (GOCO) laboratory, participate in cooperative research projects at federal laboratories.^{2/} The legislative history of Pub. L. No. 100-519 states that among the changes made by its amendments to the Stevenson-Wydler Act, "Guest workers at federal laboratories are made eligible for the royalty sharing provisions of the Act beginning with the date of passage of the Federal Technology Transfer Act of 1986."^{3/} This addressed what was viewed as an inequitable situation in which federal employee inventors were eligible for royalties from a joint invention, but guest researchers, volunteers, or GOCO employees scientists were not. Prior to enactment of Pub. L. No. 100-519, for example, the National Institutes of Health complained that the resulting inequitable situation crippled moral[e] and the efficiency of the laboratory.^{4/}

^{2/} See 1989 National Bureau of Standards Authorization: Hearings Before the Subcomm. on Science, Research and Technology of the House Comm. on Science, Space, and Technology, 100th Cong., 2d sess. 793 at 795-96 (1988) (statement of Philip S. Chen, Jr., Ph.D., Associate Director for Intramural Affairs, NIH); Economic Development Through Technology Transfer: Hearing Before the Subcomm. on Science, Research and Technology of the House Comm. on Science Space, and Technology, 100th Cong., 2nd Sess. 96 at 97 (1988) (statement of Robert A. Kamper, Director of the Boulder Laboratories of the National Bureau of Standards, Dept. of Commerce); and S. Rep. No. 98, 100th Cong., 1st Sess. 13 (1987).

^{3/} H.R. Rep. No. 673(I), 100th Cong., 2d Sess. 24, reprinted in 1988 U.S. Code Cong. & Admin. News 3269, 3285.

^{4/} 1989 National Bureau of Standards Authorization, supra note 2.

Thus, it is clear under Pub. L. No. 100-519 that so long as the non-federal inventor individually owns rights in the invention and assigns those rights directly to the United States, royalties subsequently received by the government are available for sharing with the inventor under Pub. L. No. 100-519.

However, the situation is not as clear where the government receives rights in an invention through assignment from the employer of a non-federal inventor.

NASA advises that the government often acquires its ownership rights in inventions made by non-federal inventors by assignments from the inventor's employer. The employer presumably owns the rights pursuant to agreement with the inventor. In our view, neither the inventor nor the employer would be entitled to share in the royalties in that situation.

The reason with respect to the inventor is that by limiting the original (1986) royalty sharing provisions to federal employees, Congress expressed its belief that because the government cannot promote or reward inventors as easily as can private industry, more inventions would be reported and developed if federal employees had a guaranteed share in potential royalties. The desired incentive where a non-federal employee has assigned rights to the employer, in contrast, presumably is effected through the employment agreement. If Pub. L. No. 100-519 is constructed to permit royalty sharing with an individual inventor who has previously assigned his royalty rights in an invention to other than the United States (i.e., to the employer), the result would be to restore, perhaps unnecessarily, a portion of those rights notwithstanding that assignment. There is no support in the legislative history to suggest that Congress intended that result. In fact, the legislative history expressly states that royalty sharing for federal

employees was not intended to set a precedent for legislation mandating royalty sharing for private employees.^{5/}

Regarding the employer, Pub. L. No. 100-519 does not, in our opinion, suggest that assignment of ownership rights to the United States from the inventor's employer entitles the employer to share in royalties. As stated above, royalty sharing between federal laboratories and collaborating non-federal inventors provides incentive and encouragement similar to that originally intended for government employees, that is, to report inventions and contribute to their commercialization. Congress has not manifested any intent that royalty sharing with non-federal inventors serve any purpose other than to correct what was viewed as an inequitable situation. This was accomplished by offering the same incentives available to federal employees to inventors who might also be encouraged to report inventions and contribute to their commercialization. Because the intended incentive would not accrue to a non-government inventor who previously transferred ownership rights to his or her employer, payment of royalties to the inventor's employer under Pub. L. No. 100-519 would defeat Congress' only manifest purpose for sharing royalties.

Accordingly, Pub. L. No. 100-519 does not create an employer's right to royalties. Instead, the employer's rights are governed by the terms of the grant, the terms of the contract, or by the terms of a formal cooperative research agreement with the federal laboratory, as provided for by section 5

^{5/} S. Rep. No. 283, supra note 1, at 3455.

of the Stevenson-Wydler Act, 15 U.S.C. § 3710a.6/ Compensation and incentive to the non-federal inventor in that case would remain the responsibility of the inventor's private sector employer.

Analysis--Royalty Distributions Prior to October 24, 1988

NASA first distributed royalties to its federal employee inventors in June 1988. The following October 24, Congress amended 15 U.S.C. § 3710c(a) (1) (A) to provide for royalty payments to non-federal inventors as discussed above, and set October 20, 1986, as the effective date of the amendment. NASA questions whether its June 1988 royalty distribution must be recalculated so that royalties may also be distributed to non-government inventors, and requests guidance on the proper distribution of further royalties it has collected.

By setting October 20, 1986, as the effective date for the provisions extending royalty sharing to non-federal employee inventors, Congress clearly indicated its intent that the statute operate retroactively. However, no funds other than those from royalties received by the government were made available for payment to non-federal inventors. Disposition of those royalties had been governed by provisions of the Stevenson-Wydler Act in

^{6/} Section 3133 of the National Defense Authorization Act for Fiscal years 1990 and 1991, Pub. L. No. 101-189, provides that intellectual property rights arising out of work done under cooperative research and development agreements will be determined in accordance with the agreements and the appropriate sections of Stevenson-Wydler. "Royalties accruing from cooperative research and development agreements would be retained by the [Federal] laboratory for use in accordance with Stevenson-Wydler and the operating contract." Conference Report on H.R. 2461, Department of Defense Authorization Act, 101st Cong., 1st Sess., 135 Cong. Rec. S 15062 (November 6, 1989).

effect prior to enactment of Pub. L. No. 100-519. Further, the legislative history is silent concerning the retroactive [retrospective] provision and does not manifest any intent to recalculate and redistribute royalties already disposed of under provisions of law in effect prior to 1988.

Quantifiable rights to a share of the royalties received by the government prior to October 24, 1988, accrued to federal employee inventors under the Stevenson-Wydler Act provisions in effect prior to that date. In the case of inventions made jointly by federal and non-federal inventors, Pub. L. No. 100-519 does not provide for the reallocation of those rights. In addition, recalculation of royalties paid to the federal co-inventor, the laboratory, or transferred to the Treasury prior to October 24, 1988, would require NASA to recoup payments made in accordance with the law in effect at the time of payment, which we understand would not be practical.

In sum, we conclude that the retroactive effective date of Section 303 of Pub. L. No. 100-519 does not apply to royalties received by the government prior to October 24, 1988, irrespective of whether they have been distributed. The retroactive effect of that section's royalty sharing provisions is limited to royalties received after the date of enactment from assignments of ownership rights made on or after October 20, 1986.

Sincerely yours,

James F. Hinchman
General Counsel

DIGEST

Where the government acquires ownership rights in [a jointly developed] an invention by assignment from the inventor's employer under a research agreement, a statute providing for sharing of royalties with "any inventor who has assigned his or her rights in the invention to the United States" does not entitle any non-federal inventors to share royalties collected by the government, nor does it entitle the employer to share royalties; the inventor's entitlement is determined by contract with the employer, and the employer's entitlement is determined by agreement with the government. [the employer to share royalties; instead, the employer's entitlement is determined in accordance with the firm's agreement with the government.]

Retroactive provisions amending Stevenson-Wydler Technology Innovation Act of 1980 to extend royalty sharing to non-federal employees inventors who assign their rights in an invention to the United States apply only to royalties received by the United States after the date of the amendment's enactment from inventions assigned on or after the retroactive effective date.

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THE
PATENT PROSECUTION PROGRAM
OF
GEORGE W. HARTNELL, III

MENTOR
KIMBERLY A. CHASTEEN

NASA PATENT COUNSEL OFFICE
TECHNOLOGY APPLICATIONS GROUP

ABSTRACT: The objectives of the NASA summer legal clerk program were to introduce legal clerks to the field of patent law by requiring them to prosecute patent applications by responding to office action rejections by the Patent and Trademarks Office (PTO); to evaluate research material published by NASA personnel for patentable subject matter; and to prepare a patent application.

Introduction

The ten-week summer legal clerk program was primarily designed to provide law students with an opportunity to gain experience in patent prosecution by filing for patent applications; by responding to Patent and Trademark Office (PTO) examiner rejections by amending previously filed applications; and by reviewing publications prepared by NASA personnel for patentable subject matter.

A secondary objective of the legal clerk program was to introduce participating law students to the patenting philosophy and processing at NASA Langley Research Center (LaRC). In particular, the program stressed the importance of transferring technologies discovered at NASA LaRC through licensing of patents issued to inventors and scientist employed at LaRC by the U.S. Government. Inherent, in this process is the realization that technology transfer is most effective and of greatest service to the public when an exclusive license is awarded to private industry for commercial purposes. Of equal importance is the continuous evaluation and re-evaluation of the potential marketability, i.e. licensing, of the invention to warrant continuation of the patent application process. This introduction included a visit to NASA Headquarters in Washington, D.C. to meet other members of the Patent Council Office.

A final objective of the legal clerk program was to familiarize law students with the Patent and Trademark Office in Washington, D.C. by requiring them to perform a manual patentability search using the PTO classifications manuals and indices, to locate prior subject matter art.

Project Summary

1. LAR 14569-1. Evaluated PTO office action. Originally concluded that the invention was probably not patentable under Title 35 U.S.C. § 103 for nonobviousness, as the inventor's solution to a helicopter rotor blade noise problem was analogous to a noise reduction invention for a marine propeller. Upon further investigation and discussion with patent attorneys, concluded that the invention may be patentable over the existing art by focusing on the noise source problem, which is unique to a helicopter rotor blade and, consequently, distinguishable from the marine propeller used as art against the patent application. Hence, the marine propeller art was remote and non-analogous to the present invention as claimed and could not have been obvious to one of ordinary skill in the art.

Filed a continuation-in-part application to include additional subject matter in the specifications to and claims so as to avoid a U.S.C. § 102(b) novelty rejection.

2. LAR 15003-1. Evaluated PTO office action. Prepared draft amendment to overcome Title 35 U.S.C. §§ 102 and 103 rejections. Concluded that the prior art both did not teach and taught away from the invention as claimed.

Patent application was allowed following a telephone conversation with the PTO Examiner.

3. LAR 15003-3. Evaluated PTO office action. Prepared amendment to overcome Title 35 U.S.C. §§ 102 and 112 rejections. Concluded that the invention as claimed would be patentable over the prior art by highlighting the fact that the the prior art did not teach and taught away from the invention as claimed. The focus of the amendment was to highlight the novelty of the internal, mechanical and abrupt means of arresting a dropped-weight assembly device in such a manner as to minimize the shock on the arresting mechanism and the assembly as a whole.

4. LAR 15007-1. Performed an independent review of patent application prepared by the law firm of Staas & Halsey of Washington, DC. When satisfied with the product, coordinated activities for filing the patent application.

5. LAR 15072-1. Evaluated inventor's desire to include new subject matter on a patent application which had already been allowed and issued by the PTO. Interviewed the inventor and concluded that, because the inventor could not embody the "ultimate reed" concept which he would like to protect, a continuation-in-part application would not be appropriate.

6. LAR 15264-1. Reviewed inventor's disclosure of his invention. Interviewed the inventor to gather additional information regarding the prior art. Performed a manual patentability search at the Patent and Trademark Office in Washington, D.C. Confirmed adequacy of manual search by performing a computer-assisted search using LEXIS. Determined that the invention as claimed would be patentable over the prior art if narrowly-tailored by highlighting the novelty of a sealing bulkhead to prevent contamination of the bonding surface. Initiated patent application preparation.

7. LAR 15128-1. Performed an independent review of patent application prepared by the law firm of Staas & Halsey of Washington, DC. Coordinated with inventor who wanted to include additional subject matter in the application. Modified the patent application to include additional specification language and claims. When satisfied with the product, coordinated activities for filing the patent application.

Drawing the Reverberation Chambers Lab using AutoCad

By

Jonathan M. Harucki

Rochester Institute of Technology
Rochester, New York

Mentor: Richard Chase

Research and Technology Group
Information & Electromagnetic Technology Division
Assessment Technology Branch

1995 Langley Aerospace Research Summer Scholars Program
Langley Research Center
National Aeronautics and Space Administration

Abstract:

The Purpose of this LARSS project was to draw and modify the Reverberation Chambers Lab and other different schematics using AutoCad software.

The focus of the project was to draw and modify the schematics for the Reverberation Chambers Lab. I also drew the neural network engineering diagram to understand how it runs. The control computer system is placed inside the Reverberation Chamber, it is then subject to electromagnetic fields during testing.

Measurements were obtained to determine if the control computer system operates correctly when exposed to an adverse electromagnetic environment. Reverberation Chambers have a high Q factor and require less power to establish a specified field level than any other type of test chamber. Statistical Analysis is required to predict and understand field patterns in the Reverberation Chambers Lab.

Upon my arrival on June 5, 1995. My mentor, Richard Chase, showed me around the Reverberation Chamber Lab in Building 1220. He informed me that I will work with the AutoCAD release twelve software for the Reverberation Chamber Lab.

AutoCAD is a general purpose Computer Aided Design (CAD) program for preparing two-dimensional drawings and three-dimensional models. It provides a full range of drafting tools that let you create accurate and realistic images that meet the ANSI standard for drafting. AutoCAD also provides programming tools that let you create your own add-on applications. More than a million engineers, designers, and drafters have learned to use AutoCAD; hundreds of thousands of them have mastered the program with the help of tutorials such as Inside of AutoCAD.

Mr. Richard Chase demonstrated me the AutoCAD program on an Apple Macintosh computer. I was not familiar with the Apple Macintosh's AutoCAD program. I knew how to use the AutoCAD program on the IBM computer from previous experience in college.

There are few differences between IBM's AutoCAD program and Apple Macintosh's AutoCAD program. I reviewed some of the Apple Macintosh AutoCAD's manual and tutorial books. It was simple for me to review because their commands are

basically the same. I experimented with AutoCAD program in the Apple Macintosh computer and reviewed various commands such as mirror, array, circle and zoom.

I started drawing the chambers for the Reverberation Chamber lab. When I finished and showed the drawing to my mentor. My mentor gave me some feedback on drawing the chambers so I modified them. When the drawing and modification was done, I plotted it. I gave it to my mentor and an electrical technician. They checked the chamber drawing to see if they were correct. Sometime, they offered tips to add or erase lines.

I drew the NASA symbol on the AutoCAD, plotted it on five feet paper to be put on the wall for display in the Reverberation Chamber Lab. I drew many different schematics for the Reverberation Chamber Lab. I also drew Neural Network diagrams for my mentor and other engineers to lay it out for their project.

During my ten weeks of work I drew and modified the chambers and other things for the Reverberation Chambers Lab and Neural Network project. Most of the time, I worked with AutoCAD program to develop my skills better. AutoCAD program is excellent because it is so accurate and fast. It saves a lot of our time to use the AutoCAD instead of drawing on paper using the drafting pencils and triangles. It was a great experience for me to use the AutoCAD program.

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NASA Langley Exchange Investment Portfolio
Marcus A. Hathaway
James Ogiba, Chief
Office of the Comptroller/Financial Management Division
August 8, 1995

Abstract

During the past ten weeks I have been assigned to work in the Financial Management Division. While working as a Langley Aerospace Research Summer Scholar I have been assigned to research a study of investments for the NASA Langley Exchange. In researching the different types of investments I am responsible with proposing a strategic investment plan that will be used to improve the NASA Langley Exchange.

Introduction

During the past ten weeks I have been fortunate to participate as a student intern of the Langley Aerospace Research Summer Scholars (LARRS) Program. The LARRS program has enhanced my awareness in aerospace research and the overall objectives of the National Aeronautics and Space Administration (NASA). The National Aeronautics and Space Administration is a agency within the Federal Government that expands the frontiers of air and space for the benefit of all. In addition to my increase awareness of the NASA vision I have also been able to expand my knowledge in the area of financial management. This summer I assisted the Financial Management Division extensively in researching and proposing a corporate bond investment portfolio of 200k for the NASA Exchange. In addition to the corporate bond investment portfolio I also researched and analyzed data on the matching principle with regards to the value of cost in the service industry.

Summary

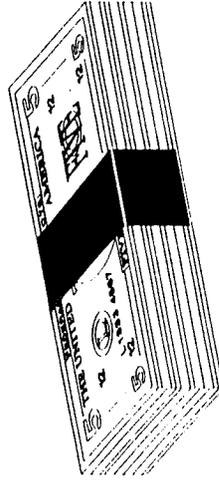
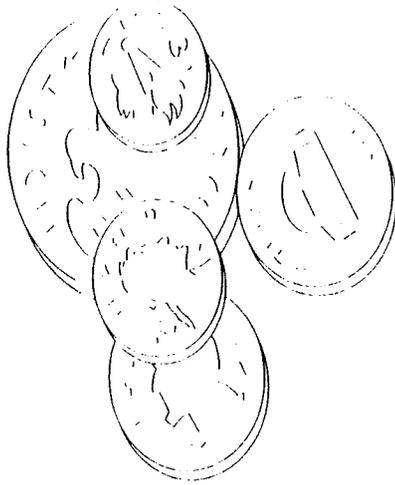
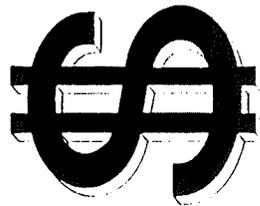
Initially in preparing an investment plan for the NASA Exchange a research team was coordinated to research various investment portfolios and investment firms. The NASA Exchange Investment Group consisted of Susie Henriksen, NASA Exchange Treasurer., Lisa Ryan, Business Manager of the NASA Exchange., and myself. Prior to visiting the various investment firms an objective and mission was established to identify the needs of the NASA Exchange. The objective was to position the NASA Exchange to fully maximize its investment securities and the mission was to offer a strategic investment plan which can be used to improve the NASA Langley Exchange. Presently, the NASA Exchange has approximately 217,370.00 in its investment portfolio. Government Bonds attribute to 130,000 of the investment portfolio while Certificates of Deposits attribute 65,000. The investment firms competing for the NASA Exchange Investment Portfolio were Equitable Financial Services, Haas Management Investment Group, Legg Mason, and Wheat First Butcher Singer. While visiting the various investment firms our objective was to invest 20% (43,000) of the current investment portfolio in AAA rated non-call Corporate Bonds. In visiting the various investment firms each firm was evaluated on the following categories:

Professionalism	Depth of Investment Firm
Investment Philosophy	Complexity
Shareholder Services	Proximity
Capital Investments	Size of firm
Experience	Background of Investment Firm
Cost/Fees	Background of Investor

In addition to evaluating the investment firms on the preceding categories the I conducted my own research on the different types of bonds that could be used to benefit the NASA Exchange. A vast majority of the relevant information was obtained from the Langley Air Force Base Library, Financial Investment textbooks, the Internet, and various publications on investing.

After reviewing the services that each investment firm could provide the NASA Exchange, I proposed that the NASA Exchange Council invest up to 20% of their current investment portfolio in AAA rated non-call Corporate Bonds with Wheat First Butcher Singer. The reason I primarily chose Wheat First Butcher Singer over the competing firms was the fact that I felt comfortable with Wheat First Butcher Singer's response toward meeting the objectives of the NASA Exchange. From our initial meeting with William Saunders of Wheat First Butcher Singer I was impressed with his investment philosophy. Mr. Saunders always stressed the importance of honesty and customer service. In my proposal I identified "What is a Corporate Bond?" along with the pros and cons of corporate bonds. I also identified the different rating categories and "Who issues Corporate Bonds?" At the conclusion of my presentation I listed traditionally recommended companies for investments in corporate bonds by Wheat First Butcher Singer. After the presentation members of the NASA Exchange Council were impressed with the proposal and eager to invest a percentage of securities with Wheat First Butcher Singer.

NASA Langley Exchange Investment Portfolio



Presentation By
Marcus Hathaway

NASA Exchange Investment Group

Marcus Hathaway, Langley Aerospace Research Summer Scholar

Susie Henriksen, NASA Exchange Treasurer

Lisa Ryan, Business Manager of the NASA Exchange

NASA Langley Exchange



Objective: Position the NASA Exchange to fully maximize its investment securities

Mission: Offer a strategic investment plan which can be used to improve the NASA Langley Exchange

Current NASA Exchange Investments

	Portfolio	Portfolio(%)
Wheat First		
Cash & Money Mkt	21,639.04	9.9
Bonds	<u>195,730.96</u>	<u>90.1</u>
Total Est. Portfolio	217,370.00	100.0

* As of August 3, 1995

NASA Exchange Investment Proposal

Objective: Invest 20% of current investment portfolio in AAA rated non-call Corporate Bonds.

What is a Corporate Bond?

A corporate bond is simply a debt contract between the corporate issuer and the investor. For the use of the investor's money, the corporation agrees to pay a stated rate of interest for a specified period of time. At the end of that period, the bond "matures" and the investor's principal is returned. The contract is recorded either on a registered certificate or through a book entry—a record entered into a computer data base.

Bonds are generally issued in \$1000 increments with interest payable semiannually at a fixed rate, sometimes called a coupon or coupon rate.

Who Issues Corporate Bonds?

There are four major types of corporate bonds, which reflect the four major types of companies that issue them. They are:

- Public Utility bonds
- Financial Institution bonds
- Transportation bonds
- Industrial bonds

✓ Advantages of Investing in Corporate Bonds

- Higher Yields
- Variety of Maturities
- Stability
- Diversification
- Liquidity
- Quality Ratings

Risks of Investing In Corporate



Bonds

- Interest Rate Changes
- Credit Risk
- Refunding Risk

Rating Categories for Investment Bonds

- Aaa/AAA
- Aa1/AA+, Aa2/AA, Aa3/AA
- A1/A+, A2/A-, A3/A-
- Baa1/BBB+, Baa2/BBB, Baa3/BBB-

* All rating categories for investment bonds are obtained from Standards & Poors and Moody's rating service.

Competitors for the NASA Langley Exchange Investment Portfolio



- Equitable Financial Services
- Haas Management Investment Group
- Legg Mason
- Wheat First Butcher Singer

Traditionally Recommended Companies

Basic Industry

International flavors & Fragrances E.I. DuPont De Nemours Inc.

Capital Goods

Duracell Rubbermaid WMX Technologies

Consumer Cyclicals

General Electric

Disney

Utilities

Central & South West

New England Electric AT & T

Central Louisiana Electric

Bell Atlantic

CitizensUtilities Co.

Bell South

Dominion Resources

MCI Comm.

Duke

Altell

Southwestern

Energy

Exxon

Mobil

Royal Dutch

Traditionally Recommended Companies

Cont'd

	<u>Consumer Staples</u>	<i>Misc:</i>
<i>Food:</i>		
Coca Cola	Heinz	Gillette
CPC International	PepsiCo	Phillip Morris
Dr. Pepper/Seven Up	Sara Lee	Procter & Gamble
General Mills	Wendy's	Tambrands
Hershey	Wrigleys	
	<u>Drugs</u>	
American Home Products	Johnson & Johnson	Warner Lambert
Bristol Meyers Squibb	Schering-Plough	Merck
	Glaxo	

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Comparisons of the Maxwell and CLL Gas/Surface Interaction Models Using DSMC

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Abstract

Two contrasting models of gas-surface interactions are studied using the Direct Simulation Monte Carlo (DSMC) method. The DSMC calculations examine differences in predictions of aerodynamic forces and heat transfer between the Maxwell and Cercignani-Lampis-Lord (CLL) models for flat plate configurations at freestream conditions corresponding to a 140 km orbit around Venus. The size of the flat plate is that of one of the solar panels on the Magellan spacecraft, and the freestream conditions are one of those experienced during aerobraking maneuvers.

Results are presented for both a single flat plate and a two-plate configuration as a function of angle of attack and gas-surface accommodation coefficients. The two plate system is not representative of the Magellan geometry, but is studied to explore possible experiments that might be used to differentiate between the two gas surface interaction models.

Nomenclature

A	area of plate
Ar	argon
C_D	drag coefficient, $\frac{2D}{\rho_\infty V_\infty^2 A}$
C_H	heat-transfer coefficient, $\frac{2q}{\rho_\infty V_\infty^3}$
C_L	lift coefficient, $\frac{2L}{\rho_\infty V_\infty^2 A}$
CLL	Cercignani-Lampis-Lord model
CO	carbon monoxide
CO_2	carbon dioxide
D	drag
E	energy per molecule
L	lift
N_2	molecular nitrogen
p	normal momentum
q	heat flux
V_∞	freestream velocity
x, y	coordinates in plane of the plate
z	coordinate normal to flat plane
α	thermal energy accommodation coefficient
ϵ	fraction of diffuse scattering in Maxwell model
ρ_∞	freestream density
σ	momentum accommodation coefficient
θ_i	angle of attack
θ_r	angle of reflection
Θ_r	mean angle of reflection in CLL model
τ	tangential momentum
Subscripts	
i	incident
n	normal
r	reflected
t	tangential
w	wall
∞	freestream

Introduction

In hypersonic flight at very high altitudes, gas-surface interactions are one of the dominant physical processes that govern aerodynamic forces and heat transfer. Our present understanding of these interactions is severely limited, especially for the highly energetic gas-surface collisions that occur during orbital or high-altitude aerobraking and entry conditions. Therefore, the prediction of aerothermodynamic performance is less accurate than desired for these conditions (Ref. 1).

The Direct Simulation Monte Carlo (DSMC) method of Bird (Ref. 2) is commonly used to simulate rarefied flow problems, and the accuracy of the method depends directly on the accuracy of the gas-surface interaction model. The most widely used model is the Maxwell model, which is based on classical thermodynamics, in which it is assumed that molecules will either reflect diffusely with complete energy accommodation, or will reflect specularly with no change in energy. An accommodation coefficient, ϵ , is defined which specifies the percentage of molecules that will be scattered diffusely, with $\epsilon = 0$ giving complete specular reflection, and $\epsilon = 1$ giving complete diffuse reflection.

While the Maxwell model is useful for describing the overall thermodynamic behavior of gas-surface interactions, it does not accurately describe the detailed molecular behavior frequently observed in fundamental gas-surface scattering experiments. For moderate to high energy scattering from engineering surfaces, the flux distribution of scattered molecules frequently has a lobular shape that is centered about an angle, Θ_r , which tends to approach the specular angle for very high energies and/or low angles of attack (Ref. 1). The Cercignani-Lampis-Lord model (CLL) (Ref. 3) is one of several models developed to handle such behavior. In the CLL model, the transformations of the normal and tangential components of velocity are assumed to be mutually independent. Analysis of the flux distribution of scattered molecules shows it to be centered around an average scattering angle, $\langle \Theta_r \rangle$, which is a function of normal and tangential accommodation coefficients, α_n and σ_t .

$$\langle \Theta_r \rangle = f(\alpha_n, \sigma_t)$$

The mean energy of the reflected molecules is also a function of the normal and tangential accommodation coefficients.

$$\langle E_r \rangle = F(\alpha_n, \sigma_t)$$

The purpose of this paper is to examine the differences in aerothermodynamic quantities (forces and heat transfer) predicted with these two gas-surface interaction models. The Maxwell and CLL models are incorporated into a DSMC code, and calculations are performed for hypersonic rarefied flow about flat plates. The conditions selected are the same as those used in a study by Rault (Ref. 4) of the Magellan spacecraft orbiting Venus. Calculations are performed for a single flat plate having dimensions the same as one of the solar panels of the Magellan spacecraft. Calculations are also performed for a two-plate configuration to explore possible experiments that might be used to differentiate between the two gas-surface interaction models.

Accommodation Coefficients and Gas-Surface Interaction Models

A variety of definitions for accommodation coefficients exists in the literature. The traditional definition of "thermal accommodation" is usually expressed as:

$$\alpha = \frac{E_i - E_r}{E_i - E_w}$$

where E_i is the incident energy per molecule, E_r is the reflected energy, and E_w is the energy per molecule corresponding to fully diffuse scattering with full accommodation to the wall temperature. This definition is frequently extended to other flux quantities to yield normal and tangential momentum accommodation, σ_n and σ_t ,

$$\sigma_n = \frac{p_i - p_r}{p_i - p_w}$$

$$\sigma_t = \frac{T_i - T_r}{T_i}$$

and a general definition of accommodation coefficient is given in Ref. 5. These various definitions have been defined partly for convenience in relating experimentally observed behavior to various empirical gas-surface models.

In the Maxwell model, the fraction of diffusely-scattered molecules, ϵ , is equivalent to the thermal accommodation coefficient defined above. Traditionally, the model is considered to have only this single adjustable parameter, and the momentum accommodation coefficients also follow once ϵ is specified, i.e. σ_n and σ_t are also determined by ϵ . However, σ_n and σ_t are sometimes viewed as being independent of the energy accommodation. In the traditional implementation of the Maxwell model in DSMC calculations, it has usually assumed that the energy and momentum accommodation are not independent, and that assumption is used in the present implementation.

The CLL model is derived assuming that there is no coupling between the normal and tangential momentum components, and treats the normal component of translational energy, α_n , and the tangential component of momentum, σ_t , as two independent, disposable parameters. However, in the implementation of the CLL model in DSMC, Bird (Ref. 2) has shown that it is equivalent to specify the normal and tangential components of translational energy since α_t can be considered equivalent to $\sigma_t(2 - \sigma_t)$. In presenting the results with the CLL model, we will use the quantities α_n and σ_t as the two disposable parameters.

In addition, the present simulations will also consider the accommodation of internal energy, α_i , the implementation of which is described below.

DSMC Method

The DSMC method is widely used for simulating rarefied flows and is described in detail in Ref. 2. The method consists of tracking the motion of representative molecules as they move in physical space while undergoing collisions with other molecules and with physical boundaries within or surrounding the computational volume. The volume is discretized into cells within which samples of density, momentum, and energy are stored for computing macroscopic properties of the flow. Surfaces within the computational volume are also discretized, and samples of momentum and energy transfer to elements of the surface are stored for computing macroscopic properties of the flow. Surfaces within the computational volume are also discretized, and samples of momentum and energy transfer to elements of the surface are stored for computing forces and heat transfer. In the present study, gas collisions are treated with the variable hard sphere (VHS) model with internal energy exchange allowed only for rotational degrees of freedom.

The DSMC computer code used in the present study is a three dimensional code described in Ref. 2 which uses uniform Cartesian cells. The code contains the Maxwell gas-surface interaction model and was modified to include the CLL model as an option. In the implementation of the Maxwell model, accommodation of internal energy is set equal to the parameter ϵ . Those molecules which scatter diffusely have their internal energies adjusted by sampling from an equilibrium distribution corresponding to the surface temperature, while molecules which scatter specularly retain their incident internal energy.

In the CLL model, accommodation of the internal energy is allowed to be independent of the translational accommodation. For all calculations presented here, however, the internal energy accommodation is kept equal to one or both of the translational accommodation coefficients, α_n or σ_t . For each molecule scattered by the surface in the CLL implementation, an energy state is sampled from an equilibrium distribution corresponding to the surface temperature, the reflected internal energy is given by:

$$E_r^i = \alpha_i E_i^i + (1 - \alpha_i) E_w^i$$

where E^i denotes the internal energy of the molecule.

Problem Conditions

The hypersonic flow over a flat plate lends itself well to experimentation because its simple geometry makes it an ideal situation in which to compare theory and experiment (Ref. 6-7). Because of earlier scientific discussions (Ref. 8) to use the Magellan spacecraft as a test for gas-surface interactions, a flat plate with the dimensions of a solar panel from the Magellan spacecraft was used for the DSMC calculations. The panel was placed in an environment consistent with Venus' atmosphere at an altitude of 140 km. Freestream conditions and panel dimensions taken from Ref. 4 are:

Density	9.5 X 10 ¹⁶ molecules/m ³
Temperature	225 K
Molar Composition	75.7% CO ₂ , 9.6% CO, 8.9% Ar, 5.8% N ₂
Free Stream Velocity	8600 m/s
Free Stream Speed Ratio (s)	28.5
Surface Temperature	300 K
Panel length in X direction	2.53 m
Panel length in Y direction	2.5 m

Results

Single Flat Plate

DSMC calculations were first performed with gas collisions disallowed and checked against free-molecule analytical predictions for both Maxwell and CLL models. Analytical solutions for the Maxwell model are taken from Ref. 2, while analytical solutions for the CLL model are taken from Ref. 5. The collisionless DSMC calculations agree with the analytical solutions within the limits of statistical error in the DSMC sample. In addition, for $\epsilon = 1$ in the Maxwell model and $\alpha_n = \sigma_n = 1$ in the CLL model, the two models produce precisely the same results.

DSMC simulations were then performed with collisions allowed. Once again, for $\epsilon = 1$ in the Maxwell model and $\alpha_n = \sigma_t = 1$ in the CLL model, the two models produce precisely the same results. Including gas-gas collisions, however, decreases both the drag and heat transfer slightly while increasing the lift significantly. The two models were then compared at an angle of attack of 45 degrees with varying accommodation coefficients (See Fig 6). For the CLL model α_n was kept equal to σ_t . The CLL and Maxwell models predict the same lift, drag and heat transfer when the accommodation coefficients are equal to zero or one. For accommodation coefficients not equal to zero or one, the CLL model produces larger lift, drag, and heat transfer than the Maxwell model. The differences are greatest for lift and drag when $\epsilon = 0.8$ and $\alpha_n = \sigma_t = 0.8$, where the CLL model gives a drag coefficient of 1.58 and a lift coefficient of 0.46 compared to values of 1.40 and 0.35 for the respective coefficients with the Maxwell model. The heat transfer coefficient, on the other hand, has its greatest difference when $\epsilon = 0.5$ and $\alpha_n = \sigma_t = 0.5$. Here, simulations with the CLL model produce a heat transfer coefficient of 0.44 compared to 0.35 predicted with the Maxwell model.

The effects of changing the tangential and normal accommodation coefficients independently in the CLL model are shown in Fig. 7. For the solid curves, the tangential accommodation coefficient is held constant (along with internal energy) at 0.5, while the normal accommodation coefficient is varied from 0.0 to 1.0. For the dashed curves, the normal accommodation coefficient is held constant (along with internal energy) at 0.5, while the tangential accommodation coefficient is varied from 0.0 to 1.0. Variations in α_n or σ_t seem to have approximately the same effect on both lift and heat transfer, i.e., as the normal and tangential coefficients vary from 0.0 to 1.0, the heat increases and the lift decreases. Varying α_n , however, has the opposite effect on drag than that caused by varying σ_t . When α_n is increased from 0.0 to 1.0 the drag coefficient decreased at approximately the same rate as the coefficient of lift. When σ_t is increased from 0.0 to 1.0, however, the drag coefficient increases at approximately the same rate as the lift coefficient decreases. Therefore, changing α_n has little effect on the lift-to-drag ratio; it remains nearly constant at a value of 0.6. Changing

σ_t , however, has a profound effect on the lift-to-drag ratio. As σ_t increases from 0.0 to 1.0, the lift-to-drag ratio decreases from 1.0 to 0.3.

The simulations were repeated with each coefficient held constant at 0.8 (along with internal energy) while the other coefficient was varied from 0.0 to 1.0. These simulations produced results similar to those simulations where the constant coefficient and internal energy were held constant to 0.5. When σ_t is held constant at 0.8, and α_n varies from 0.0 to 1.0, the lift-to-drag ratio remains constant at approximately 0.48. When σ_t is increased from 0.0 to 1.0, the lift-to-drag ratio decreases from 1.0 to .18.

One way to visualize the manner in which the two models produce these differing behaviors is to examine the density contours around the plate. When $\epsilon = 0.5$, the Maxwell model predicts that most molecules will be distributed more-or-less symmetrically along the windward side of the plate with only a slight bias in density toward the specular direction. When $\alpha_n = \sigma_t = 0.5$, however, the CLL model predicts that the distribution of molecules is strongly biased towards the specular direction. This behavior is caused by differences in the velocity distributions of the scattered molecules. With the Maxwell model, scattered molecules consist of a combination of specularly reflected molecules which have a Maxwellian velocity distribution characteristic of the surface temperature. For a "cold" plate, the same velocity magnitude as the incoming molecules and diffusely reflected molecules which have the diffusely reflected molecules remain in the vicinity of the surface longer and result in a density buildup near the plate. On the other hand, the CLL model provides a much more complex description of the velocity distribution of scattered molecules in which the overall mean velocity, temperature, and mean scattering angle are complex functions of the incoming velocity, the surface temperature, and the normal and tangential accommodation coefficients. For accommodation coefficients less than one but greater than zero, the CLL model gives a somewhat higher average velocity of scattered molecules and a more continuous distribution of molecules scattered near the specular angle. The result is that the molecules do not remain near the surface as long as with the Maxwell model, and lower densities occur near the plate. This behavior leads to speculation about possible differences one might encounter if other surfaces were present near the plate and is the motivation for the two plate calculations presented in the next section.

Two Plate System

The DSMC code was altered to incorporate a second identical flat plate. The second plate is displaced 2.5 meters in the x and z directions from the original plate, placing it 2.5 meters in front of and above the original plate. This geometry gives an angular displacement of the center of each plate that is 45 degrees from the normal to the other plate and was selected because it was believed that it might maximize the interaction between the plates. Density contours illustrate the new geometry and the differences between the Maxwell and CLL model results.

DSMC calculations were performed at a constant angle of attack of 45 degrees while the accommodation coefficients for both the Maxwell and CLL models were once again varied from 0.0 to 1.0. Lift, drag, and heat transfer coefficients for the combined two-plate system are shown in Fig. 10. The CLL and Maxwell models again give identical results when the accommodation coefficients are equal to 0.0 or 1.0, just as for a single plate. Other features of the comparison are similar to those with the single plate; the CLL model predicts higher values for lift, drag, and heat transfer when the accommodation coefficients are not equal to zero or one, and the maximum differences between the two models occur in lift and drag when the accommodation coefficients are equal to 0.8 and in the heat transfer when the accommodation coefficients are equal to 0.5.

Because the coefficients are based on the reference area for a single plate one might expect all coefficients for the two-plate system to be twice as large as for the single plate. The heat transfer coefficient is indeed approximately twice as large. The lift coefficient, however, is only slightly larger than the single plate results, while the drag coefficient is only slightly larger at $\epsilon = \alpha_n = \sigma_t = 0.0$, but increases to almost twice the single plate value at $\epsilon = \alpha_n = \sigma_t = 1.0$. This behavior is caused by the interference between the two plates caused by molecules that are reflected from the windward side

of the rear plate hitting the leeward side of the front plate. The forces caused by these secondary reflections essentially cancel out the lift of one plate. In other words, the forces in the lift direction due to these secondary reflections are negative and are only a weak function of accommodation coefficient. A similar phenomena occurs for the drag force except that the cancelling force is more strongly dependent on the accommodation coefficients. Therefore, the drag increases significantly as the accommodation coefficients are increased rather than remaining relatively constant as it does for a single plate.

In the Maxwell DSMC calculations, ϵ was held constant at 0.5, while in the CLL DSMC simulations α_n and σ_t were held constant to 0.5. The behavior of the drag coefficient is somewhat similar to that for the single plate simulations, although the rate of increase with angle of attack is lower at smaller angles. The lift coefficient, however, shows a maximum at an angle of attack of 60 degrees rather than at 45 degrees as with the single plate, and a second local maxima occurs at 30 degrees with the Maxwell model. The presence of the second plate also causes the heat transfer coefficient to reach a maximum at an angle of attack other than 90 degrees as it does with the single plate. Furthermore, the CLL model and Maxwell models give different predictions for this angle, a fact that will be discussed in more detail.

To further examine the detailed behavior of the two-plate system, surface forces and heat transfer were extracted separately for each side of the plate. These sides are numbered as follows: Side 1 is the leeward side of the front plate, Side 2 is the windward side of the front plate, Side 3 is the leeward side of the back plate, Side 4 is the windward side of the back plate. For the present DSMC simulations, there were insufficient molecules striking the leeward side of the back plate (Side 3) to gather meaningful statistics on the surface forces and heat transfer. Sides 2 and 4 dominate the contributions to the total forces and heat transfer and show essentially the same qualitative behavior as that for the complete system. Side 1 shows some interesting qualitative variations with angle of attack but no distinct differences between the Maxwell and CLL model results.

Further calculations were then performed for other values of accommodation coefficients. An examination of these results showed that Side 4 was the only side which exhibited a distinct difference in qualitative behavior between the Maxwell and CLL models. In these calculations, the Maxwell model predicts that the heat transfer is maximized at an angle of attack which is independent of the accommodation coefficient, while the CLL model predicts that the angle of attack at which the heat transfer is maximized is a strong function of the accommodation coefficients. DSMC simulations were run for several other accommodation coefficients, and the results show that the angle of attack for maximum heat transfer for Side 4 always occurs at about 83 degrees with the Maxwell model while varying from about 55 degrees for $\alpha_n = \sigma_t = 0.1$ to about 83 degrees for $\alpha_n = \sigma_t = 1.0$ with the CLL model. The behavior with the CLL model is attributed to the lobular nature of the scattered molecules which are the backscattered from Side 1 (front plate) and return to Side 4 (back plate). Since the densities are relatively low for the current simulations, gas-gas collisions are not that important. Therefore, it is likely that a free molecular analysis could be performed using the CLL model to provide a full analytical description of this behavior.

Discussion

The relative insensitivity of the aerothermodynamic coefficients to the gas-surface interaction model for a single flat plate is not too surprising. Both the Maxwell and CLL models are constructed to give the same behavior in the limits where the gas and surface are in thermal equilibrium. In fact, under more continuum-like conditions, the two models give essential identical results (Ref. 2). For the Venus aerobraking conditions used here, the flow is highly rarefied, and gas-surface interactions dominate the aerothermodynamic behavior. Although there are many quantitative differences, they are generally small (order of 10–20%), and the qualitative behavior as a function of angle of attack and overall accommodation is essentially the same for the two models. The details of the flowfield, however, are quite different for the two models. The superposition of diffusely and

specularly scattered molecules given by the Maxwell model and the more continuous molecular flux distribution with its lobular shape given by the CLL model result in a radically different density field around the plate.

The differences in flowfield structure observed for the two models were explored for a two-plate system in the hopes of finding qualitative differences in some aerothermodynamic quantity. It was hypothesized that such differences might be exploited experimentally as a means of determining which model gives a better representation of the gas-surface behavior for high-velocity aerobraking and orbital flight conditions. Intuitively it was expected that by that by placing a second plate in the near vicinity of the first, there might be some sensitivity to the lobular nature of the scattering with the CLL model. In effect, the second plate might act as a "detector" for molecules scattered from the first plate. In fact, such a sensitivity was found, although the manner in which it was manifested was somewhat unexpected. The results show a qualitative difference in the angle of attack at which the maximum heat transfer occurs with the CLL model showing it to be strongly dependent on the accommodation coefficients while the Maxwell model gives results that are independent of accommodation coefficient. The surprising feature is that the qualitative difference appears to be the result of secondary backscatter from the rear side of the front plate to the front side of the rear plate. Thus it is a second-order effect, and even though the variations in heat transfer are quite large, the actual variations in heat transfer coefficient are quite small. This makes it more difficult to determine the location of the maxima and require very precise heat-transfer measurements in order to exploit this phenomena experimentally.

The calculations presented in this report have only covered a limited number of parametric variations. Further calculations in which the normal and tangential accommodation coefficients are varied over a wide range of combinations or where the internal energy accommodation is varied independently might provide more insight into the sensitivity of the aerothermodynamic quantities to gas-surface model. Other multiplate configurations and/or other geometries might also be worth investigating in order to identify conditions where experimental measurements might be more feasible. The significant differences observed in overall flowfield behavior between the Maxwell and CLL models even for these simple cases, however, suggest that it may be important to determine which gas-surface interaction model best represents the physical behavior expected for complex aerobraking configurations.

Closing Remarks

DSMC calculations have been made to examine differences in predictions of aerodynamic forces and heat transfer between the Maxwell and Cercignani-Lampis-Lord (CLL) gas-surface interaction models for flat plate configurations at freestream conditions corresponding to a 140 km orbit around Venus. The size of the flat plate is that of one of the solar panels on the Magellan spacecraft, and the freestream conditions are one of those experienced during aerobraking.

Results were calculated for both a single flat plane and a two-plate configuration as a function of angle of attack and gas-surface accommodation coefficients. The two-plate system is not representative of the Magellan geometry, but is studied to explore possible experiments that might be used to differentiate between the two gas-surface interaction models.

Although the Maxwell model and CLL model have fundamental differences, they give similar predictions of aerothermodynamic coefficients on a single flat plate. The two models, however, differ in their predictions of the flowfield around the plate. These differences lead to predictions for the angle of attack for maximum heat transfer in a two plate configuration that are distinctly different for the two gas-surface interaction models. The angle of attack at which maximum heat transfer occurs with the CLL model is a function of accommodation coefficient, while the angle of attack for maximum heat transfer for the Maxwell model is constant. Further investigation into this behavior could provide better understanding of the accommodation coefficients of materials and gases for orbital and aerobraking conditions.

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**VARIOUS EMBODIMENTS OF THE NON-INVASIVE
ENDOSCOPIC FEEDBACK FOR LEARNING OF
VOLUNTARY CONTROL OF
PHYSIOLOGICAL FUNCTIONING**

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ABSTRACT

The research performed was a small portion of the patent to be submitted by Dr. Alan T. Pope entitled "A Method of Providing Veridical Non-Invasive Endoscopic Feedback for Learning of Voluntary Control of Physiological Functioning." The focus of this study is to incorporate the emerging technology of virtual reality with the forms of biofeedback already in existence producing a life-like, real-time model of the body's functioning without using invasive procedures, yet still producing the equivalent of a picture from an invasive endoscopic procedure in the region of interest. The portion of the project designated to me was to research and report as many possible uses for such technology as possible.

INTRODUCTION & BACKGROUND INFORMATION:

The Virtual Reality Feedback System is designed to help individuals suffering from a wide range of ailments to improve their condition with very little pharmacological intervention, if any. Biofeedback represents an alternative to Western Medicine in that it relies on the healing power of the mind and self rather than outside intervention.

One of the advantages of feedback training over its pharmacological counterpart is that the results of the biofeedback training appear to continue even once the training has stopped, whereas pharmacological treatments tend to work only as long as they are administered. The other benefit of feedback training is that it acts externally and cannot, therefore, cause adverse internal effects, such as those experienced by many people using pharmacological treatment.

As stated in the patent application, "the invention is a method of transforming and displaying physiological information obtained from skin surface sensors in such a way as to accurately represent the functioning of the underlying physiological sources in both action and appearance. The display of the physiological information is intended to be what would be seen in real-time from the vantage point of an invasive endoscope positioned near the physiological sources and capable of dynamically changing the viewing perspective. The result is an immersive (virtual reality) display environment for training of voluntary physiological function control (biofeedback training)."

The advantage of such a system cannot be determined until a prototype has been produced and subjects responses tested and analyzed; however, it is possible that by being able to both view and understand biofeedback through a glimpse into the body's actual systems, biofeedback results will be more intense and produce better results than biofeedback training as it exists at present.

SUMMARY OF STUDY OR RESEARCH PROJECT

APPROACH:

In order to tackle the large amount of information available on the subject of biofeedback and to discern which physiological functions would be appropriate for use in a virtual reality setting, the majority of my time at NASA was spent reading and researching a myriad of ailments common in our culture, especially those which had been treated successfully through non-Western modes of treatment. Once I had researched as much as my time here would permit, I began a report to Dr. Pope on which physiological functions and ailments could be aided by the use of virtual reality feedback. My final report will be turned over to Dr. Pope who will choose which portions to add to the original patent.

LaRC EQUIPMENT AND FACILITIES:

Unfortunately, due to the nature of my research, my only exposure to LaRC facilities consisted of the Technical Library, the Macintosh computer I used to type up my findings, and Netscape. The only other resource I had access to was the knowledge of the Human Engineering Methods Group with whom I worked. Their knowledge was indispensable during my research.

RESULTS / CONCLUSION:

The result of my research is that Dr. Pope will now have more examples of uses for the system described in his patent application. I'm afraid I cannot go in to detail concerning these applications since the patent has not yet been approved. After Dr. Pope finishes with any and all changes to the patent, it will be turned in to the patent office at NASA and from there will be sent to the United States Department of Commerce Patent and Trademarks Office for approval.

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Implementation of a Remote Acquisition and Storage System

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Abstract

The existing system for gathering and processing acoustical test data had several shortcomings and limitations in the areas of microphone array size, sampling rate, and background noise. A new remote acquisition and storage system (RASS) is being designed for applications not suited for the existing acquisition system. One of the first tasks in the design of the RASS was to redesign the microprocessor card of the existing system to include RS-232 serial ports to accept communications through the radio modem used in the RF link. Cost and parts availability comparisons were made between the newly designed board and commercially available models, and a commercially made model was selected. This model was tested for basic I/O operations. The prototype of the RF telemetry system was set up and tested. Plans are now being developed for integrating the RF telemetry system with the other RASS subsystems.

Introduction

The standard configuration for acoustical testing is an array of microphones that are set up to capture the acoustic signature of a test aircraft. This test requires a data acquisition system that can retrieve the data from the microphones, convert it to digital format, do any necessary processing, and store the information for post-test analysis. In the current data acquisition system, each microphone is wired directly to a remote digitizer box containing an analog to digital (A/D) converter. The converter digitizes the microphone output, improving noise immunity and data processing. A microprocessor controller card keeps track of the run numbers and time codes and generally controls the execution of the test. Each remote digitizer box is directly wired to a base station in an acoustic van that collects, processes, monitors, and stores the data.

This system has several limitations that are inherent in its structure. As noted above, each remote box is directly wired to the base station. The connecting cable transmits the collected data in real time, and also sends and receives control information from base station. It is desirable for the microphones to be at least 1000 feet away from the base stations because of noise reasons, and there are some acoustic arrays that require booster boxes every 1000 feet to retransmit the signals. Thus, for a typical test session with two base station vans each handling nine microphones at 3000 feet apiece, approximately 54,000 feet (more than 10 miles) of cable must be laid. This is assuming that the cable can be laid in a straight line. There are instances where the test terrain contains lakes or swamps that do not permit a straight-line cable from the base to the remote sites. In this case, a new, longer route for the cable must be chosen, extending the time and work required to set up the experiment. It is not enough to just lay the cable, however. Since some animals are prone to chew through exposed cables, each cable has to be suspended with special rods for protection. Thus, large arrays can require extensive setup times.

The current setup also has a couple of other limitations. For one, the finite amount of cable and time to lay it means that the ultra-sensitive microphones will pick up background noise from the vans and generators. While this noise usually can be filtered out from the significant data, there are some cases where the background noise interferes and makes data analysis very difficult.

A third limitation with the current system deals with the way the data is collected. Currently, as soon as the data is collected and digitized, it is transmitted to the vans via the cables. A computer at the base station then receives these different data streams simultaneously and must multiplex the signals to store them together on a single medium. Since the data is collected in real time, the processors back at the vans must be able to work at or above the sample rate of the data. Because of the physical limits on the speed of the storage medium, there is a ceiling on the sample rate and the number of channels that can be sampled with the current system.

To solve these problems and to provide more flexibility when testing, the acoustics team in the AOCMB began developing a system that would rely on radio communications to relay information between the base and the remote sites. It is called the remote acquisition and storage system, the RASS. This system has a similar basic structure to the current system, except there are no cables. The RASS relies on a radio link in the 403-416 MHz range to handle all of the control and diagnostic information from the main base. Because the radio modems in the RF transceivers are not very fast (9600 baud), it is not possible to transmit the data to the main base

as it is collected at a sufficient sample rate. So, each remote unit in the RASS will contain a data storage device that can hold a full test day of data. The system information handling will also be upgraded to handle not only the run numbers and time codes, but also to monitor health data of the system, like temperature and battery voltage. The microprocessor controller card will act as the interface between the microphones, the health data sensors, the data storage device, and the RF transceiver at the main base station.

These improvements provide several benefits that remove many of the limitations of the current system. The combination of the RF transceiver and the remote data storage device eliminate the need for cables, saving a great deal of time and work in setting up the system. The remote setup also eliminates any problems caused by terrain that would not be compatible for direct wiring. This freedom in system configuration combined with the five mile range for the RF transceiver gives the RASS great flexibility for acoustical testing. For example the RASS can be used in residential neighborhoods to sample the acoustic footprint left by a supersonic aircraft without having to run a large amount of cable through the neighborhood. It also makes it possible to conduct tests in places where it would be difficult to run cables, like underground tunnels. All that is required is that the antennas be placed somewhere with RF visibility. The five mile range of the RF transceivers also greatly reduce any possibility of noise interference from the vans or generators. The addition of the storage devices at the remote sites removes the need for real time transfer of the data. The large storage capacity of the devices means that researchers could run a full day of tests and then go out to the remote sites to pick up the data, which would be analyzed later. This also removes the limit on the sample rate and number of channels. Since the data can be stored on separate channels and then multiplexed into a single stream at a later time, there is no hardware speed limit to restrict the accuracy and breadth of the test.

Project Summary

The remote acquisition and storage system consists of four main parts: the analog/digital converter, the data storage device, the system information handling board, and the RF transceiver. Full implementation of the system involves designing or acquiring and testing the required components and writing code to make the parts work together. The A/D converters and the data storage systems are not too difficult to implement since the A/D converters are already in use in the current system and the data storage systems are SCSI tape drives. More work is required to have the other two components working properly. The controller cards from the system information handling have to be modified to use RS-232 serial communications so that they can communicate with the radio transceiver. Then a program has to be burned into its ROM chips that tells it how to communicate and interface between the various parts of the system that it is attached to. The RF telemetry system is the only totally new link in the RASS, so it requires a good deal of testing to check its capabilities, its reliability, and its ability to communicate with its client ports. The RF system also has to be programmed to set up the network configuration and to fill in the communications parameters like baud rate and polling rate.

My project focused on the two latter components. Specifically, my tasks for the summer were to design and test RS-232 ports for the microprocessor controller board and to set up and test a prototype RF system. To prepare myself for these tasks, I started out by training on the CHAS 68000 microcomputer and by reading some background material on RS-232 communications. The CHAS is an open-board computer that introduces the user to microprocessors, specifically the Motorola 68000 microprocessor. The computer can be hooked up to a wide range of training peripherals through its I/O lines. The user then learns how to use the computer by programming it to manipulate the inputs and outputs of the peripherals.

After training with the CHAS, I moved on to my first task for the summer, the integration of RS-232 communications into the existing board. The controller board was 3.3" x 8.3" and it contained two CY7B144 dual port RAM chips, a MC68000 microprocessor, three MC68230 PI/O chips, an EPM5128JC programmable logic device (PLD) chip, two 27256 EPROM chips, two external ports, and miscellaneous resistors, bypass capacitors, switches, and LED's. My first design for the addition of RS-232 communication required an additional three chips and two external serial ports. Two of the chips were actual RS-232 drivers that would convert TTL/CMOS signals from the chips on the board to RS-232 values for transmission. Each chip had two transmitting and two receiving channels, one for data and the other for a handshaking signal, and they could each service one serial port. The third chip was a DUART (dual universal asynchronous receiver/transmitter), which served as an interface between the RS-232 chips and the rest of the board. The main function of this chip was to convert parallel signals from the microprocessor and PI/O chips to a serial form that the RS-232 chips could use. Since the current board was already highly populated, it would be difficult to find room for three extra chips, two ports, and all of the required interconnections on the PCB. If they could not fit, we would have had to consider using a board with two levels or a multi-layer board that had the printed interconnections running through several layers in the board's thickness, which would give more space for actual chips on the board. I was able to simplify the design by replacing the two RS-232 chips with a single chip that had four receiving and transmitting channels. I then used P-CAD, a circuit drawing and modeling program, to redraw the board schematic with my suggested modifications included. My next step was to order the chips so that a prototype board

could be manufactured and tested. I discovered that many of the chips that were currently on the controller board were being phased out of production as they had been replaced by models with more integrated functions. This gave us the option of either buying the last of the parts on the market or redesigning the board. Trying to use the current design would have been difficult because of the unavailability of the chips in a temperature-resistant ceramic packaging, the long lead times to make the chips since they were rarely in stock, and the scarcity of spare parts if any of the chips were to fail once the system was up and running. Redesigning the board, while it could have saved space on the board, would have incurred serious costs and time losses for redesign of the hardware and possibly converting the software if the new processor were incompatible with the old one.

The solution to the problem came unexpectedly. We discovered a commercially available single-board computer that fit our needs. This board, Z-World's Little Giant™, had all of the features of our current board plus RS-232 ports, the ability to program it in assembly or C, an adequate operating temperature range, and an optional expansion board with 96 bits of digital I/O. Even better, buying this board was more cost-effective than modifying the existing one.

I spent almost two weeks writing simple C programs to test out the board's I/O capabilities. Unfortunately, a large portion of this time was spent trying to find errors caused by a mislabeled jumper position in the documentation. After the error was corrected, the board performed flawlessly.

My other main task for the summer was to set up and test the prototype RF telemetry system. The system that was used as a prototype was the MAVRIC 2000™ from Metric Systems Corporation. This system used a STAR-RING topology, meaning that there was a primary station in a central hub position which could send and receive data from secondary stations spread out in all directions. Each of the stations was equipped with three client serial ports which allowed peripheral devices to hook into the system. A fourth serial port, the radio port, allowed each station to hook up with a PATHFINDER 9600™ radio modem that handled the actual RF transmissions. The primary station polled each of the secondary stations at a user-specified rate to send data and check for data that needed to be received. The stations could be configured to route data between each of their client ports and any of the ports on any of the other stations. Thus, the main purpose of the MAVRIC system was to create a virtual circuit (no wires) between any two peripheral devices.

For expandability, each primary station could handle up to 100 secondary stations, depending on the desired polling rate and data packet size. If this was not enough, a network of primary stations, each controlled by a centralized hub station, could be configured to give maximum networking capability. Also, the transceivers could be set to use any of 15 different frequency channels to keep signals from getting crossed in complex networks.

The MAVRIC system was also highly interchangeable. Each MAVRIC was identical as far as hardware was concerned. The only thing that made one unit differ from the other was the user-written configuration file. This file defined the type of node (primary or secondary), the data path over the RF connection for each of the client ports, and various other parameters like poll rate and baud rate. The only other difference was that the transceiver for the primary station contained an optional power amplifier and would use an omnidirectional antenna, whereas the secondaries would use directional antennas. This allowed for flexibility when debugging because problems within the actual unit could be checked by quickly switching in a different one to see if the problem persisted.

The testing of the RF system was no small endeavor. The test setup included two MAVRIC stations with radio modems, each with a VGA monitor and a keyboard. Each station was connected with a null modem cable on its client port 1 line to an 80286 computer (another keyboard and monitor!) that was running the PATHWORKS™ test software for the MAVRIC. Also, each modem required its own 12V power supply. For the first test, another null modem cable was run between the radio ports on the two MAVRIC's, effectively taking the modems out of the loop. The test software sent a data packet to one of the stations, which then transmitted it over the hardwired radio lines to the other station, where it was routed back to the test computer. This test would have been simple enough had it not been for my inexperience coupled with some key omissions in the documentation and some alterations that had to be made to the configuration files for the test to work.

The next phase of testing was identical to the first except that the radio link between the two MAVRIC's was enabled. This time, I encountered problems with a confusing setting in the test software and with the power supplies not delivering enough current to the modems. In fact, we are still working on supplying enough current to the modem with the power amplifier. After these hurdles were cleared, the system passed with flying colors, even when test data lengths were constantly varied in content and length and the distance between the modems was increased.

Looking toward the future, there are several steps left to be taken before RASS is operational. The RF telemetry unit must be tested for speed and accuracy at distances similar to those that will be used in the tests. Also, the tests must be expanded to include more MAVRIC's with the single board computers acting as the peripheral clients. Code must be written for the Little Giant, so that it can handle the different devices that it will be controlling and monitoring. But for now, the existing parts of the RASS appear more than adequate to do their respective jobs.

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**A Comparison of Three Determinants of an Engagement
Index for use in a Simulated Flight Environment**

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Abstract

The following report details a project design that is to be completed by the end of the year. Determining how engaged a person is at a task is rather difficult. There are many different ways to assess engagement. One such method is to use psychophysical measures. The current study focuses on three determinants of an engagement index proposed by researchers at NASA-Langley (Pope, A.T., Bogart, E.H., and Bartolome, D.S., 1995). The index ($20 \text{ Beta}/(\text{Alpha}+\text{Theta})$) uses EEG power bands to determine a person's level of engagement while performs a compensatory tracking task. The tracking task switches between manual and automatic modes. Participants each experience both positive and negative feedback within each trial of the three trials. The tracking task is altered in terms of difficulty depending on the participants current engagement index. The rationale of this study is to determine the optimal level of engagement to gain peak performance. The three determinants are based on an absolute index which differs from the past research which uses a slope index.

Introduction

There has been a recent surge of interest in the area of adaptive automation. Automation is the result of advancement of technology and the need for complex systems to be operated in a more simplistic manner. The theory behind adaptive automation is that the system is flexible. The theories of adaptive automation have found their way into the field of aviation. A majority of airline accidents are the result of human error. The logical answer to the problem would be to remove the human (and the human error) from the scenario. Chambers and Nagel (1985) suggest this should increase safety and decrease the number of accidents due to human error.

While automation in the cockpit has increased the level of performance, it has also changed the role of the pilot from that of active participant to one of controlling and monitoring. The major question that needs to be addressed is the best level of automation in the system. Several approaches can be taken to determine allocation of function within an automated system. The first approach has the user in control of the decision to use automation. The second approach gives control of automation back to the system. Adaptive automation combines both of these approaches and allows the operator as well as the system to control in the level of automation (Scerbo, 1994). Although many believe that automation is the solution to human error, several authors have expressed the potential problems associated with the implementation of adaptive automated systems (Weiner, 1988; Rouse and Morris, 1985; Parasuraman, Bahri, Deaton, Morrison, and Barnes, 1990). They have foreseen problems related to alienation of aviation personnel, perceived loss of control, and erosion of skills.

One method to demonstrate the usefulness of adaptive automation is using bio-cybernetic measures to determine when changes in automation should occur (task allocation). This has been proposed by Morrison and Gluckman (1994) and researchers at NASA-Langley (Pope, Bogart, and Bartolome, 1995) are currently collecting empirical evidence to support the use of bio-cybernetic measures (EEG).

Pope et al. (1995) have formed a closed-loop, bio-cybernetic system which adjusts the mode of operation (manual/automatic) based on EEG power band ratios (Beta/(Alpha+Theta)) under different feedback contingencies. In the current system, the slope of an engagement index determines the task allocation.

The task functions in one of two modes, manual or automatic. The level of automation in the bio-cybernetic system is based on the level of the engagement index (EEG power band ratios). Under the negative feedback condition, the tracking task was switched to (or maintained in) manual mode when the engagement index was decreasing (negative slope) over a moving forty second window. This moving window is updated every epoch (2 sec). Under positive feedback, the level of automation was switched to (or maintained in) automatic mode when the index was decreasing (negative slope).

Therefore, under negative feedback, the changes in the level of automation are designed to induce a steady, stable environment (illustrated by many small oscillations). The index can neither be too high or too low without the task changing mode. In comparison, during a positive feedback condition, the level of engagement will be retained and amplified. Smith and Smith (1987) showed that positive feedback, if left uninterrupted, will lead to an environment that is unstable (illustrated by large oscillations).

A study based on the original Pope et al. (1995) findings was conducted by Prinzel, Scerbo, Freeman, & Mikulka (1995). They attempted to examine how increases in task load

affected the closed-loop system. Using the Multi-Attribute Task (MAT) Battery (Arnegard and Comstock, 1991), these researchers varied the task load by having the participants perform a number of tasks simultaneously. Prinzel et al. (1995) found that more task allocations were made in the multi-task conditions in comparison to the single task condition. These results are in parallel with the findings of Arnegard (1991). She found that performing multiple tasks did, in fact, increase task load. Prinzel et al. (1995) also found that tracking performance was increased in the negative feedback condition.

The current study will examine another determinant for task allocation. The previously mentioned studies (Prinzel et al., 1995, Prinzel et al., 1995) have all used the slope of the engagement index as the measure to determine task allocation. The limitation of this method lies in that a floor and/or ceiling effect may be encountered. This study will test three different parameters (.2, .5, and .8 standard deviation) using an absolute index. A median level of engagement will be determined from a five minute baseline of performance from the tracking task. Six levels of engagement exist and the absolute distance between each level (measured in standard deviations from the median) will be manipulated to determine the most sensitive parameters. The six levels of the tracking task differ in difficulty. The first level being the most difficult and the sixth level being the easiest (automatic mode).

The present study will gather performance, physiological, and subjective measures of workload. Based on the Prinzel et al. (1995) study, it is predicted that better performance, increased number of task allocations, and increased levels of subjective workload will be seen in the negative feedback condition.

Also based on the data from the Prinzel et al. (1995) study it is hypothesized that the parameter estimate of .5 will result in increased tracking performance, increased number of task allocations, and increased subjective workload.

Method

Participants

Participants were xx graduate and undergraduate students (both males and females) taking psychology courses at Old Dominion University. They either received \$10 for their participation or class credit.

Tasks

The Multi-Attribute Task (MAT) Battery was used for the experiment (Arnegard & Comstock, 1991). Of the five tasks in the battery, only the compensatory tracking task was utilized.

Equipment and Apparatus

Electrocortical activity was recorded with an Electro-cap sensor EEG cap. The cap consists of 22 recessed Ag/AgCl electrodes arranged according to the International 10-20 system (Jasper, 1958). All EEG signals were amplified by BioPac differential amplifiers with high and low pass settings of 1.6 Hz and 55 Hz, respectively. The analog signal was routed to an EEG interface with a LabVIEW Virtual Instrument (VI) on a Macintosh computer. The VI calculates the total EEG power in three bands: Alpha (8-13 Hz), Beta (13-22 Hz), and Theta (4-8 Hz) for each electrode site. The VI performs the engagement index calculations and commands the MAT task mode changes. A WIN 386 SX computer with a NEC MultiSync 2A color monitor was used

to run the MAT. An Analog Edge joystick was used for the compensatory tracking task with a gain setting of 60% of its maximum.

EEG Engagement Index

EEG was recorded from four sites (Cz, Pz, P3, P4) as defined by the 10-20 system. A site between Fpz and Fz was used as the ground site and a reference electrode was placed on the left mastoid.

Before beginning the task, EEG was recorded for five minutes at difficulty level 3 of the tracking task. This was done to establish a baseline (median and standard deviation). Once the trial begins, the participants EEG index is derived every two seconds (one epoch) based on a window of the last 40 seconds. Every two seconds the window is moved forward and a new absolute index is derived. An EEG index above the baseline measure indicates that a participants' arousal is above normal and an index below baseline indicates that a participants' is below normal.

Feedback Conditions

Under the negative feedback condition, if a participants' EEG index is above baseline the task difficulty is lowered. If the index is below baseline then the task difficulty is increased. This condition never allows the participant to deviate too far in either direction. This condition should induce a steady and stable state with no large oscillations being observed.

Under the positive feedback condition, if the EEG index is above baseline then the task difficulty is increased. If the EEG index is below baseline, then the task difficulty is decreased. This condition demands continuous increases in arousal for the manual mode and the automatic mode requires further decreases in arousal.

Experimental Design and Dependent Measures

A 2 task mode (automatic or manual) X 2 feedback condition (positive or negative) X 3 parameter estimate (.2, .5, or .8 SD) within subjects design was used.

The dependent measures included number of task allocation between positive and negative feedback and the EEG engagement index. To measure the performance of the tracking task, the RMSE was analyzed. A subjective workload measure was taken using the NASA-TLX (Hart & Staveland, 1988).

Procedure

The electrode cap was fitted to the participant's head and the reference electrode was attached behind the left ear. Impedance levels for all electrodes were brought below 5 kohms. The participants were then seated in front of the MAT computer and the head cap was plugged into the BioPac amplifiers. They were allowed to practice the task for 5 minutes. After the practice session, EEG was recorded for a 5 minute period to establish a baseline measure including the median and standard deviation. Half of the participants started in the negative feedback condition while the other half began in the negative feedback condition.

Each subject was exposed to 3 sixteen minute trials. Each trial consisted of 2 blocks (8 minutes in length) of alternating positive and negative feedback conditions. The order of the three trials (parameter estimates) was counterbalanced. Following each block, the participant was asked to rate subjective workload on the NASA-TLX.

Results

The data will be analyzed using several techniques. These will include multivariate analysis of variance, regression analysis, and factor analysis. The results and conclusions from this project will be discussed in an upcoming contractor's report.

Acknowledgments

I would like to thank J. Raymond Comstock (NASA) and Ed Bogart (Lockheed) for their programming expertise. I would also like to thank Debbie Bartolome (Lockheed) and Dan Burdette (Lockheed) for their time, patience, and understanding. Finally, I would like to thank my mentor, Alan Pope (NASA). I look forward to working with you during my graduate career.

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Improvement of Subsonic Basic Research Tunnel Flow Quality as Applied to Wall Mounted Testing

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Abstract

A survey to determine the characteristics of a boundary layer that forms on the wall of the Subsonic Basic Research Tunnel has been performed. Early results showed significant differences in the velocity profiles as measured spanwise across the wall. An investigation of the flow in the upstream contraction revealed the presence of a separation bubble at the beginning of the contraction which caused much of the observed unsteadiness. Vortex generators were successfully applied to the contraction inlet to alleviate the separation. A final survey of the wall boundary layer revealed variations in the displacement and momentum thicknesses to be less than $\pm 5\%$ for all but the most upper portion of the wall. The flow quality was deemed adequate to continue the planned follow-on tests to help develop the semi-span test technique.

Nomenclature

δ = boundary layer height, in.

δ^* = boundary layer displacement thickness, in.

θ = boundary layer momentum thickness, in

R_e = Reynolds' number

Q = tunnel dynamic pressure, psf

U_e = local velocity, ft/s

U_i = freestream velocity, ft/s

U_e / U_i = velocity ratio

Background

For subsonic wind tunnel testing, it is desirable to test at as high a Reynolds' number (R_e) as possible in order to make the results closely simulate that which would be obtained at full scale flight conditions. All current tunnels are limited to a maximum R_e as defined by the test conditions and tunnel size. One conceptually simple idea by which to increase the maximum achievable R_e of a facility is to wall mount half of a symmetric configuration allowing it to be made twice as large, thus doubling the test R_e . The problem with such a technique stems from the presence of the wall boundary layer which would submit the submerged portion of the model to velocity gradients not present in real world conditions. Standard practice is to use a platform (or standoff), shaped to match the fuselage at the symmetry plane, to raise the model up out of the wall boundary layer. Unfortunately, most simple standoff shapes generate an adverse pressure gradient of sufficient strength to cause the boundary layer to separate which rolls up to form a horseshoe vortex. It is hoped that certain variations in the standoff geometry might reduce the strength of the horseshoe vortex or eliminate it completely.

In order to investigate this phenomenon, a series of tests are to be performed in the Subsonic Basic Research Tunnel (SBRT) to determine the most effective methods of alleviating the horse-shoe vortex. To that end, information is needed concerning tunnel flow characteristics near the wall; specifically the characteristics of the wall boundary layer and the uniformity of that layer across the wall.

Methodology

To ascertain the relevant information about the boundary layer in SBRT, pressure rakes were used to determine the total pressure profiles in the boundary layer of one of the tunnel walls. From this data, velocity profiles were calculated and integrated to determine values of δ , δ^* and θ at each rake location. By varying the rake location vertically along the wall, spanwise changes to these parameters could be discerned. The goal was that these parameters deviate only $\pm 5\%$ across the wall surface. It was decided that profiles were to be taken every 1 in. spanwise across the wall to generate a complete picture of the variation of the boundary layer. The original placement of the rakes had one located along the centerline of the wall with another two rakes placed 8 in. above and below the center rake. Each of these were mounted 1.5 in. downstream of the beginning of the test section (station 1). This arrangement was varied until all 17 spanwise locations had been surveyed. The process was then repeated for the case where the rakes were located 27.5 in downstream from the beginning of the test section (station 2) to determine the streamwise variation of the wall boundary layer. For both longitudinal stations, repeat runs were made for each rake location and the results averaged after the data reduction.

Facility and Test Equipment

SBRT is an open circuit, atmospheric wind tunnel having a rectangular test section 22.5 in. wide, 32.25 in. high, and 73 in. in length with other pertinent dimensions as shown in Figure 1. The tunnel can be operated up to a maximum Q of 50 psf corresponding to a Re of $1.31 \times 10^6/\text{ft}$ ($U_i = 205$ ft/s). For this investigation, Q was limited to 20 psf giving a Re of $8.4 \times 10^5/\text{ft}$ ($U_i = 132$ ft/s). As can be seen from the tunnel diagram, the contraction of this facility is unusually long and gradual with an overall contraction ratio of 6. Its design represents the thinking of early tunnel designers who thought it best to do most of the contracting early followed by a long run of continually lessening curvature.

Prior to testing, some necessary maintenance was performed on the tunnel. The turbulence screens located between the inlet and the contraction entrance were cleaned in order to remove any particulates that could affect the flow. A traversing rig attached to the inlet was removed to reduce the chance of flow separation around its corners and eliminate the unsteadiness that such a separation would cause. Because the tunnel test section operates at subatmospheric pressure, the sidewall had to be stiffened to minimize aeroelastic flexure into the test section which would have caused a discontinuity in the interface between the sidewall and the contraction exit. Furthermore, the contraction exit itself was modified to eliminate any wall waviness and construction seams present.

The two side walls of the tunnel are replaceable to allow rapid changes of model and tunnel configuration. For this test, one side wall was instrumented with three total pressure rakes mounted to the wall surface. Two of the rakes have dimensions as shown in Figure 2 with the third having the same port spacing but one fewer port than the other two rakes for a total of 50 ports. Originally, the pressure instrumentation consisted of two Datametrics 0-100 torr barocells connected by a 48 port Scanivalve to the rakes (the top two ports on the lower rake were not instrumented). One barocell was connected to a pitot-static probe to determine tunnel Q while the other read the rake total pressures. Since the barocells are differential rather than absolute, each was referenced to tunnel static pressure as measured by the pitot-static probe. A Fluke Wireless Hydra Data Logger converted the voltages from the barocells into engineering units (psi) and transmitted the results to a personal computer for storage. The data was then downloaded to a workstation for processing by a FORTRAN data reduction code written by the author to calculate U_e/U_i as a function of distance from the wall. A general uncertainty analysis determined that each pressure measurement gave a calculated velocity that was accurate to within $\pm 0.2\%$ of reading using this instrumentation.

Because of the fully turbulent nature of the boundary layer in the test section, multiple readings of a rake port at a given test condition would produce differing results. Therefore a number of runs were used to determine a time averaged reading of the rake pressures. Making such measurements with the Scanivalve-barocell system proved to be extremely time consuming. Thus, an Electronically Scanned Pressure (ESP) system was set up to take data for the final boundary layer survey. The system consisted of a 780B pressure calibration unit (PCU) with a 0-6 psi digiquartz as the calibration reference, two 32 port ESP pressure transducer modules of the ± 1 psid range, and the controller/computer interface. Data from the interface was logged into a Hewlett-Packard Apollo 9000 series workstation running an ESP program sourced from the Basic Aerodynamics Research Tunnel. The general uncertainty analysis for the setup revealed a tenfold decrease in accuracy ($\pm 2\%$ of velocity reading) as compared to the barocell system but gives the ability to take many more, in this case 2000, samples per data point in seconds rather than 10 per hour. This trade-off was deemed acceptable, but accuracy could be improved with the substitution of 10 inH₂O column modules since ESP accuracy is measured as a percentage of range and the narrower range of these devices would yield greater accuracy.

Results

A baseline survey of the boundary layer was performed with the rakes located at station 1 with a rake configuration of one on the wall centerline and the other two located 8 in. above and below the centerline (designate this placement as wide-rake configuration). The velocity profiles generated are shown in Figure 3 and are the result of 10 runs averaged at each data point (as will all subsequent velocity profiles). From this graph, three general observations can be made. The first is that the profile measured is consistent with that of a turbulent boundary layer since the local velocity is about 65% of freestream very near the wall surface. Calculations comparing the results to the "Law of the Wall" for the logarithmic region of the boundary layer support this conclusion. Also, from the top and bottom rake profiles, it can be seen that δ is about 1.1 in. Most significantly, the profile from the middle rake is showing great irregularity in shape compared to the

other two rakes. A look at the results from each individual run (Figure 4) show significant amounts of scatter in the mid rake data that was not observed for the other two rakes. It was theorized that the scatter must be caused by some unsteadiness in the flow field, but the mechanism at the heart of the unsteadiness was not yet known. In an attempt to isolate the affected region, the two outer rakes were brought to within 3 in. of the centerline. Another ten run average was taken giving the profiles seen in Figure 5 which shows good agreement between the three rakes near the wall (as did the wide-rake placement), but with a characteristic 'blip' in the curve around 1 in. above the wall indicative of a low momentum region. It was deduced that the problem most affects the upper region of the boundary layer and is influencing at least a 6 in. path along the center of the sidewall.

After discussion with members of the Subsonic Aerodynamics and Flow Modeling and Control branches, it was thought that the flow problems could be due to the tunnel design. Investigation revealed the presence of a three inch straight wall section between the last turbulence screen and the start of the contraction creating a corner that could possibly cause the flow to detach from the wall and form a separation bubble in that region. Previous work has shown that vortex generators (VG's) can be effective in keeping flow attached in wind tunnel diffusers, but the application of them in a wind tunnel contraction is much less common. To test this flow control method, counterrotating vortex generators having a plow-shaped planform were applied to the straight section just upstream of the tunnel contraction along the wall of the tunnel the rakes were mounted. Two sizes were tested with the smaller having a length of 1 in. and a height of 0.5 in. and the larger being 3 in. long by 1 in. in height. These generators are commercially available and were originally intended as a drag reduction device for large commercial transport trucks. The generators were spaced such that the smaller had 2 in. between devices with the large VG's were spaced at 3.5 in. intervals.

Figure 7 shows the boundary layer velocity profiles with the small VG's applied. Significant improvement can be seen in the bottom rake profile as evidenced by the lack of the 'bump' in the profile between 0.8 in. and 1.0 in from the wall. The upper and middle rake profiles show slight changes toward a more continuous profile, but significant irregularities still exist. One other point of difference is the height of the boundary layer for the three profiles with the middle and upper being 0.2 in. and 0.5 in. thicker respectively than the lower. Given the positive, albeit small, effect of the small VG's it was thought that the larger version may be more effective in correcting the problem.

Once the large VG's were applied and data was taken, it became obvious that a solution was at hand. From Figure 7, one can see that the data points from each rake are much more coherent for a given height above the wall and that the boundary layer heights are within 0.1 in of each other. The small variations that remain between profiles were thought to be due to the small number of samples taken for each data point and not due to actual flow physics. Thus, confidence was high that the contraction problem had been solved.

One concern that arose about the application of VG's to the tunnel contraction was the effect of the added vorticity on models in the test section created by the VG. Past literature has shown that the vorticity created damps out fairly quickly and can be considered negligible at distances 100 device heights downstream or greater. Since the contraction is over 100 in. in length, it was assumed that the problem would be nonexistent. In order to verify the assumption, as well as to

try and document the existence of the separation bubble in the contraction, flow visualization tufts were placed on the contraction wall and imaged with a video camera to record their movement. With the VG's removed, the tufting was able to reveal the existence of the separation bubble as postulated. Tufts placed in the corner region exhibited a reversal in direction that can be associated with the backflow of the fluid in the corner region. Replacing the VG's eliminated the backflow condition and promoted attached flow throughout the contraction. Also evident was the rapid diminishment of the induced vorticity as one moved downstream of the generators with no visible tuft deflection due to the VG's approximately 2 ft downstream of the devices.

At this point, the full survey began using the ESP system to determine the pressure data. Because the ESP modules are sensitive to temperature variation, care was taken to keep room temperature variation during a run to within 2 degrees of room temperature at calibration. A minimum of two runs were made at each of the 17 rake locations at each longitudinal station with each run being the average of 10 data sets of 200 samples per set. Next, the data was reduced to determine the velocity profiles as well as values of δ , δ^* , and θ for each run. These values for each run were averaged to give one set of parameters at a given rake location. Figure 9 shows the result of this survey at both longitudinal stations. From the lowermost rake position until 4 in above the centerline, variations in the momentum and displacement thicknesses fall within $\pm 5\%$ of the average value of these parameters. The upper portion of the wall experienced an increase in both parameters beyond the range deemed acceptable. A possible explanation for this phenomenon is the absence of an entrance lip to the top of the tunnel inlet (due to physical limitations of the room) causing some type of unsteadiness; however, more investigation will be needed to isolate the cause. Fortunately, for the model mounting and angle of attack range planned in the facility, the variation of the boundary layer near the top of the wall will not effect the results.

Conclusions

From this investigation some conclusions may be drawn:

1. Properly sized vortex generators are effective in eliminating some separation problems caused by poor contraction designs.
2. From the standpoint of boundary layer uniformity, SBRT is adequate to test wall mounted models as long as the angle of attack range is such that the model is not placed on the upper part of the wall.

Further work could be done to optimize the spacing and size of the vortex generators to minimize the added vorticity while maintaining attached flow. Also, application of the generators could be extended to the other three sides of the tunnel possibly improving the results along the upper portion of the wall.

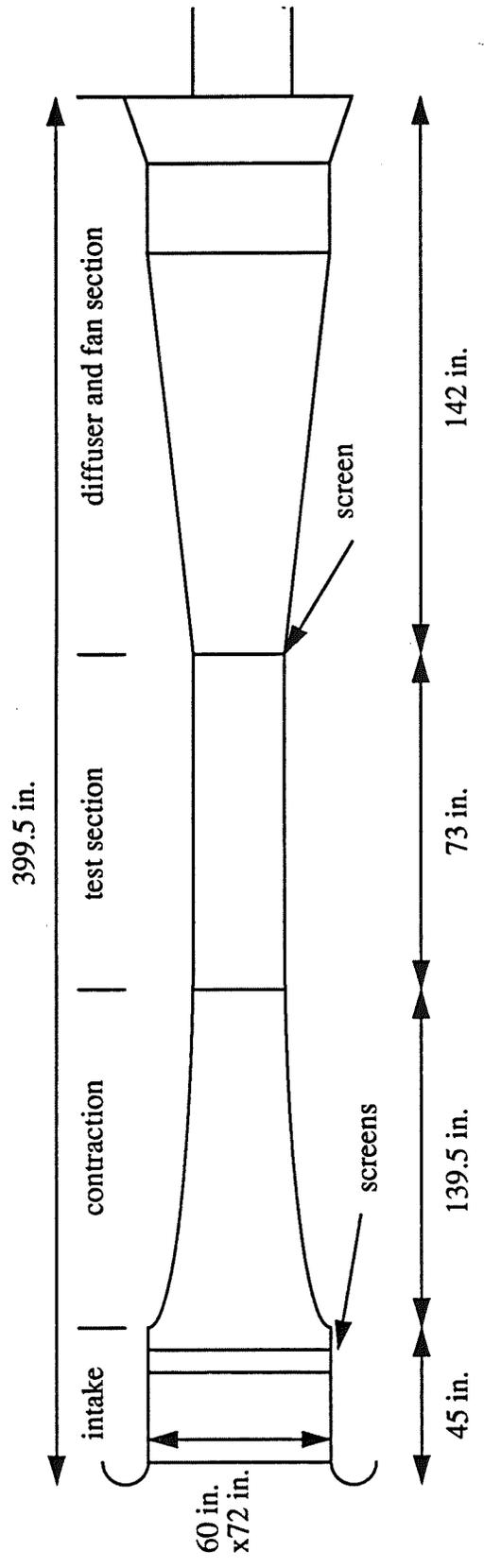


Figure 1. Plan layout of SBRT showing relevant dimensions.

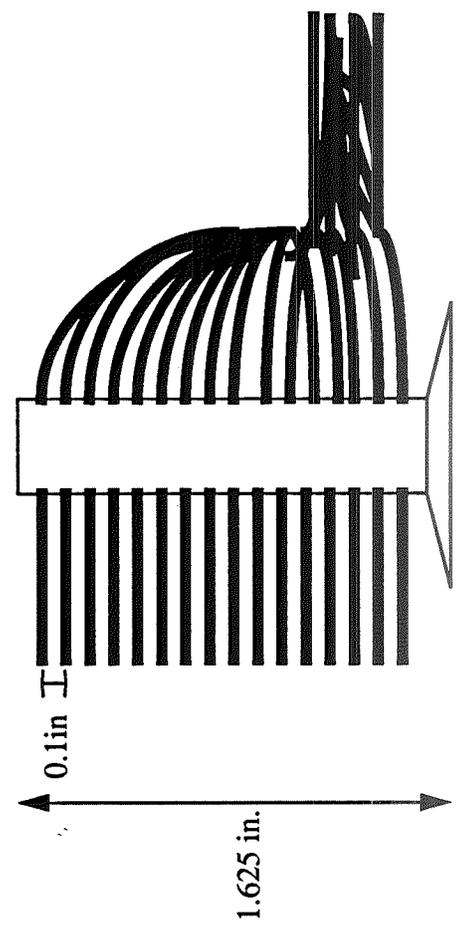


Figure 2. Boundary layer total pressure rake.

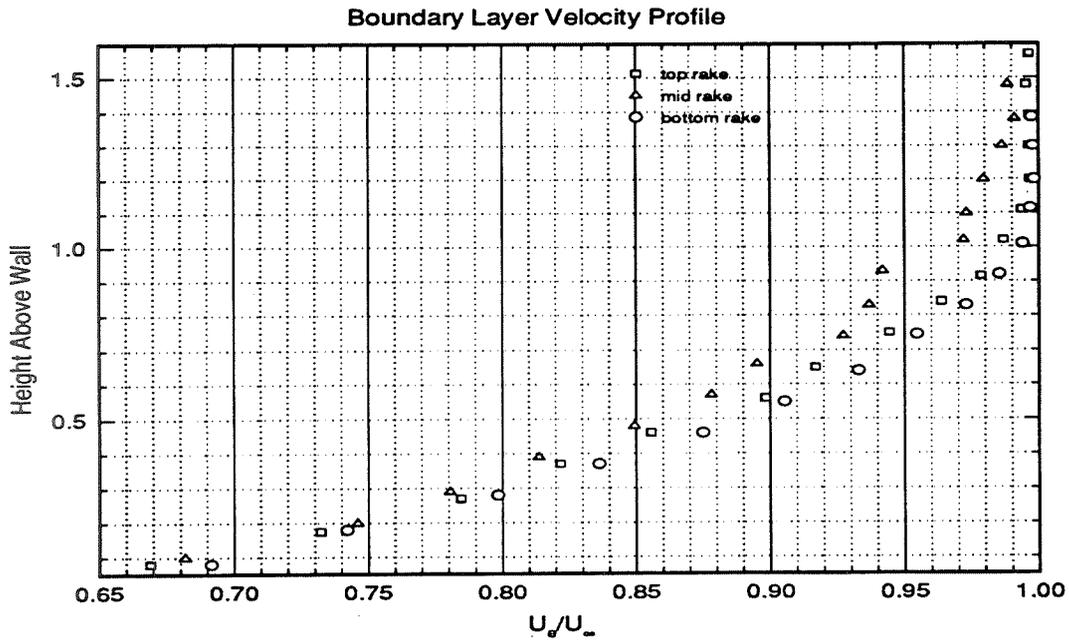


Figure 3. Baseline Boundary Layer Survey.

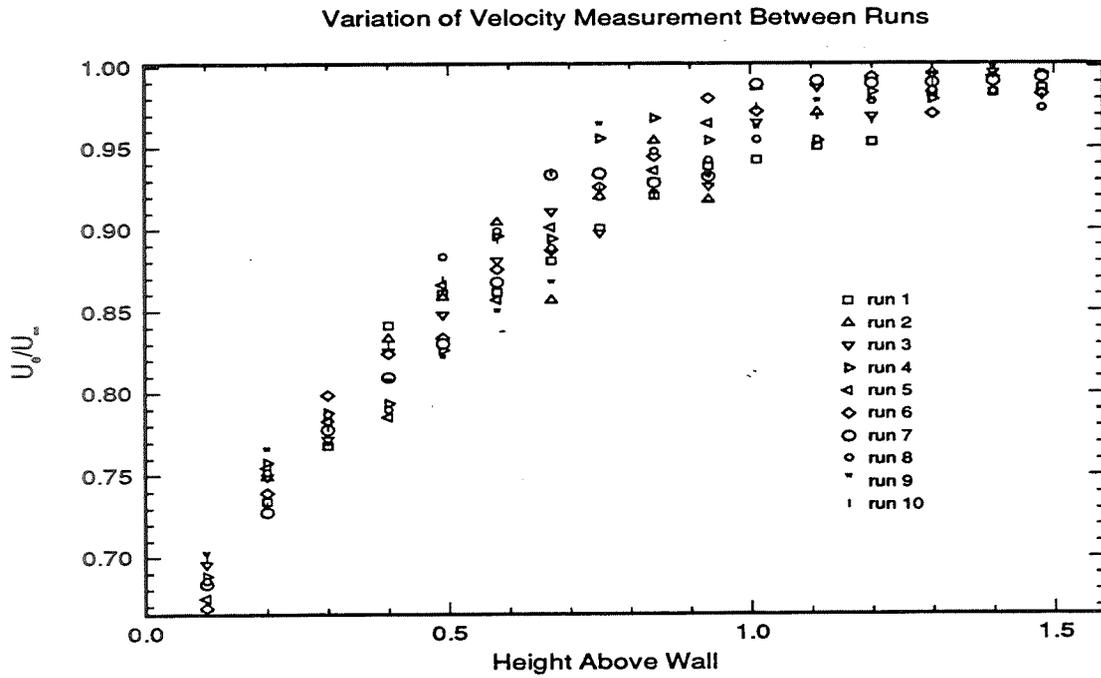


Figure 4. Scatter of Data Between Runs.

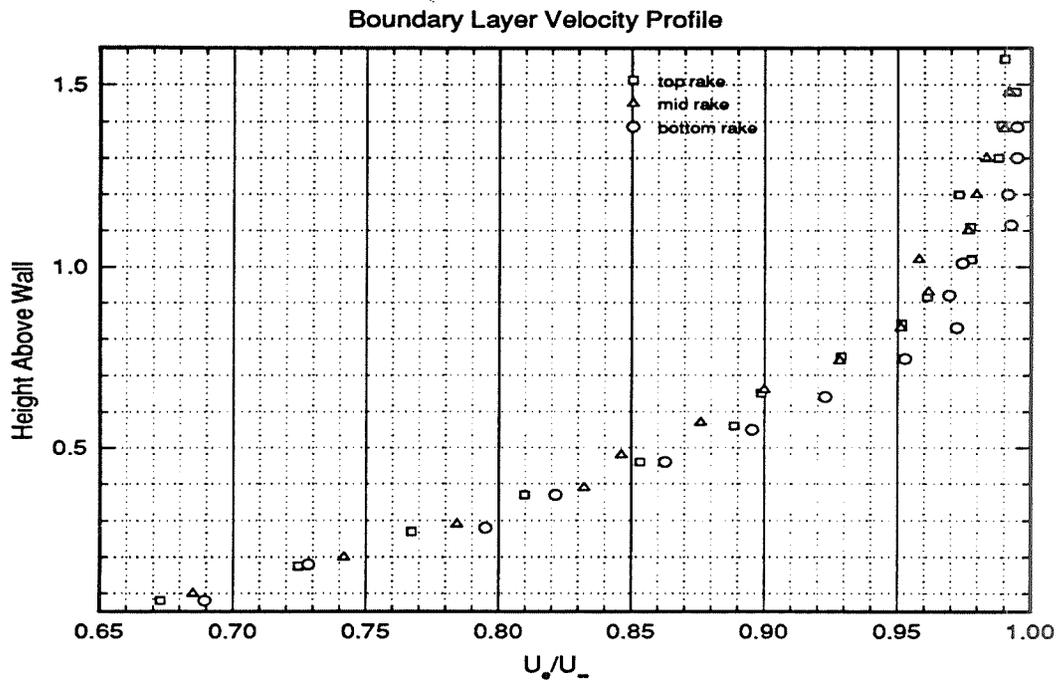


Figure 5. Narrow Rake Placement Baseline Survey.

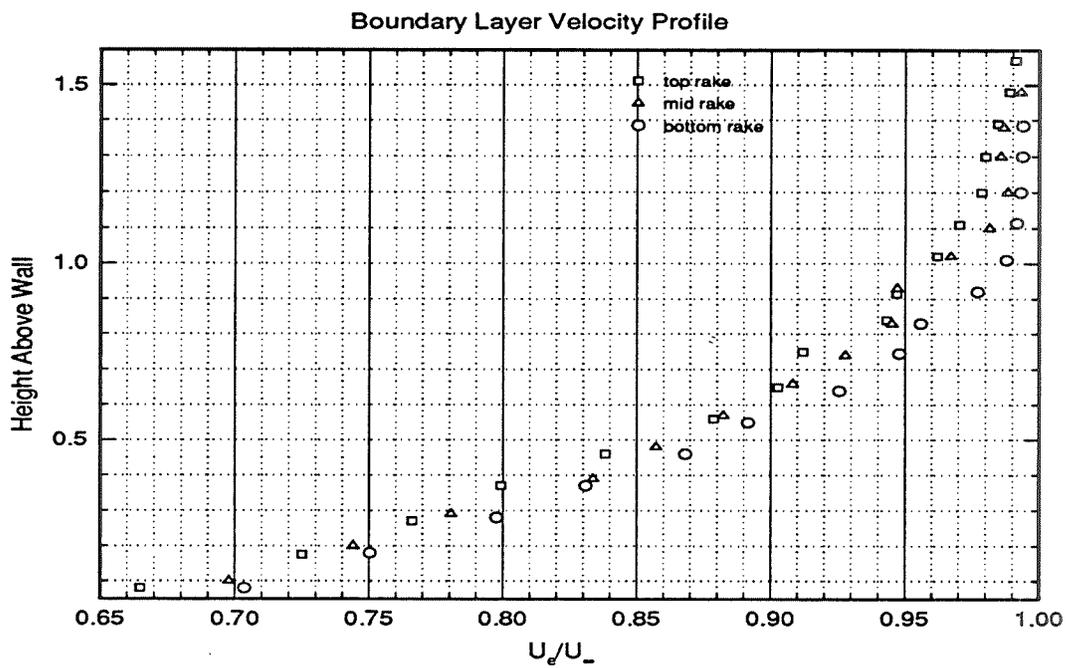


Figure 6. Narrow Rake Placement, Small VG's Applied.

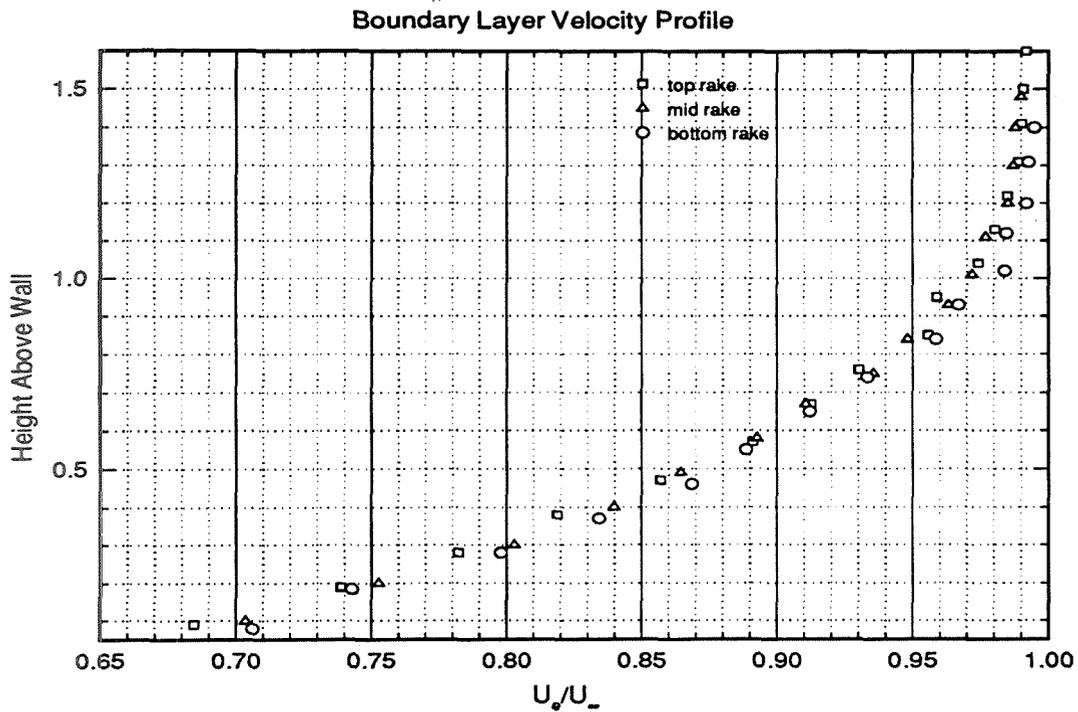


Figure 7. Narrow Rake Placement, Large VG's Applied.

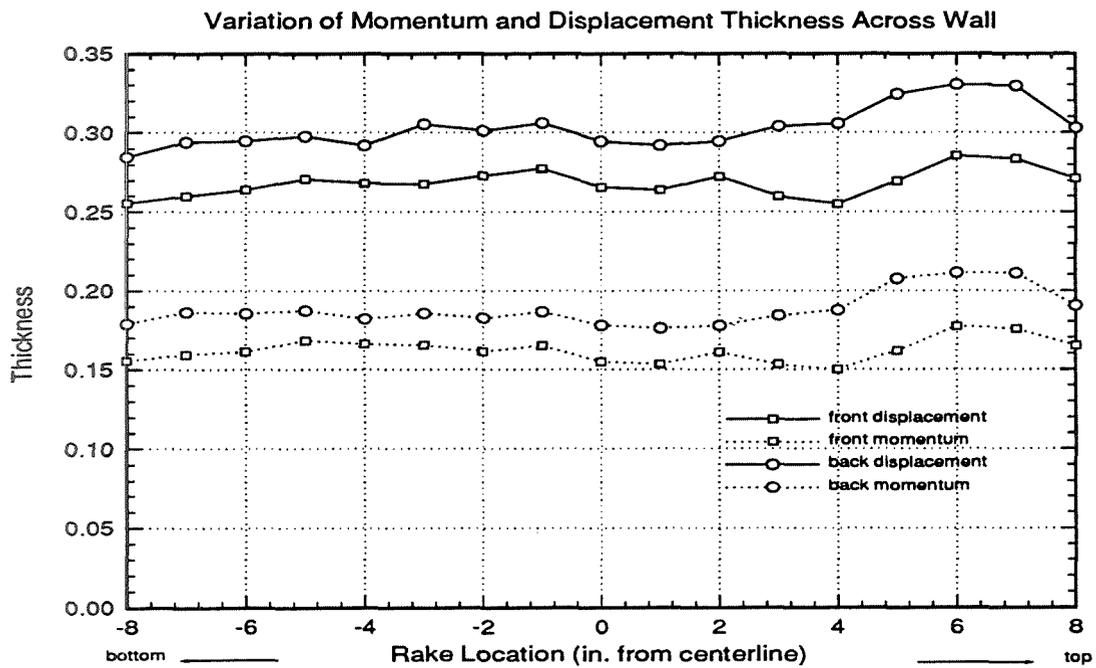


Figure 8. Variation of Boundary Layer Parameters.

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Mode I and Mode II Analysis of Graphite/Epoxy Composites Using Double Cantilever Beam and End-Notched Flexure Tests

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ABSTRACT

The critical strain energy release rates associated with debonding of the adhesive bondlines in graphite/epoxy IM6/3501-6 interlaminar fracture specimens were investigated. Two panels were manufactured for this investigation; however, panel two was layed-up incorrectly. As a result, data collected from Panel Two serves no real purpose in this investigation. Double Cantilever Beam (DCB) specimens were used to determine the opening Mode I interlaminar fracture toughness, G_{Ic} , of uni-directional fiber re-inforced composites. The five specimens tested from Panel One had an average value of $946.42 J/m^2$ for G_{Ic} with an acceptable coefficient of variation. The critical strain energy release rate, G_{IIc} , for initiation of delamination under in-plane shear loading was investigated using the End-Notched Flexure (ENF) Test. Four specimens were tested from Panel One and an average value of $584.98 J/m^2$ for G_{IIc} was calculated. Calculations from the DCB and ENF test results for Panel One represent typical values of G_{Ic} and G_{IIc} for the adhesive debonding in the material studied in this investigation.

INTRODUCTION

Laminated composite structures exhibit a number of different failure modes. These include fiber fracture, matrix failure, fiber-matrix debonding within individual layers, delamination or separation of adjacent layers, buckling, and transverse cracking through one or more layers. However, the various modes interact and can occur concurrently and also sequentially. Regions prone to interlaminar delamination include free edges, joints, cutouts, voids, inadvertently damaged areas, and defects resulting from fabrication. Because composite materials can be joined with some sort of adhesive, debonding is a potential failure mode in composite materials. Knowledge of the interlaminar fracture toughness and strain energy release rates is of critical importance in composite design.

A major weakness of laminated composite structures is the composite's susceptibility to delamination. The resistance to delamination can be characterized by the delamination fracture toughness, measured as energy dissipated per unit area of crack growth. Delamination in composites can occur due to tensile stresses (Mode I), in-plane shear stresses (Mode II) and out-of-plane tearing stresses (Mode III). In this study, Mode I and Mode II deformations were investigated and are illustrated below in Figure 1. Mode I loading deformation is the classic opening mode while Mode II is the type of deformation that involves shearing.

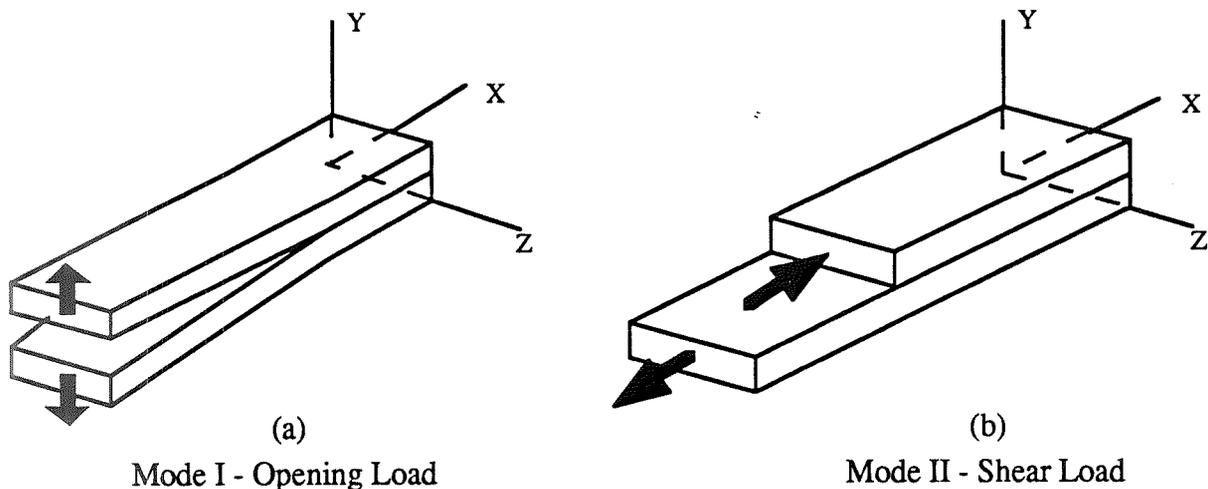


Figure 1. Two Basic Modes of Delamination

An essential part in establishing design guidelines for preventing debonding is the ability to predict the load level at which delamination occurs. In fracture mechanics, there are several criteria used to predict the onset of crack growth. These include the critical stress intensity factor, the critical crack opening displacement and the critical strain energy release rate. The stress intensity factor is a measure of the rate at which the crack tip stresses approach infinity. The crack opening displacement is a measure of the opening between the crack faces. The energy release rate is defined as the change in energy of a structure containing a crack per unit increase of crack area.

At the onset of crack growth, the fracture mechanics parameter reaches a critical value. This critical value is a material property, implying that it is independent of geometric and loading characteristics such as crack length and type of loading. The criterion for debonding examined in this study is the critical strain energy release rate. Applying energy conservation, as a crack grows, a certain amount of energy is released from the cracked specimen per unit area of the newly generated crack surface. The rate of change of this strain energy per unit area is called the energy release rate and is denoted by G . The critical value of the energy release rate at which the crack extends is denoted by G_c . Mode I energy release rate is produced by the opening mode deformation and is denoted by G_I . The Mode II component of energy release rate associated with the shearing mode deformation is denoted by G_{II} .

To determine opening Mode I interlaminar fracture toughness, G_{Ic} , the double cantilever beam specimen, using piano hinges, was utilized, as shown in Figure 2. The DCB test is used with unidirectional laminated composites that are manufactured with a thin insert at one end imbedded at the mid-plane to imitate a crack, or to serve as a delamination initiator. One end of the DCB specimen is opened by applying a force on the hinges which are bonded to the specimen while a plot of load versus displacement is recorded.

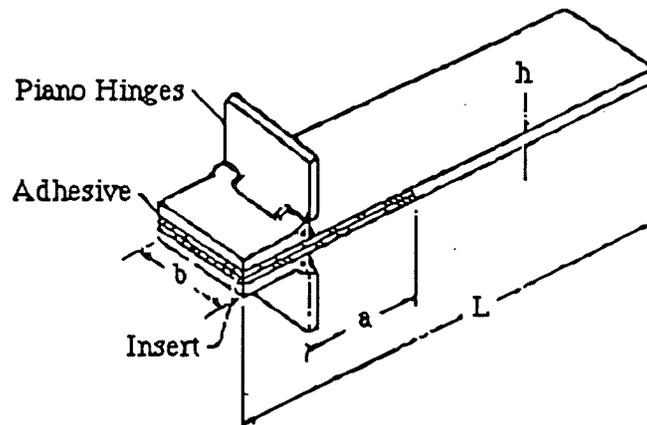


Figure 2. Double Cantilever Beam Specimen

In the calculation of G_{Ic} , linear elastic behavior is assumed because the zone of nonlinear deformation at the delamination front is small relative to the specimen thickness. In DCB testing, as the delamination grows from the insert, the calculated values of G_{Ic} first increase monotonically and then stabilize upon further growth. In this test method, a resistance curve (R-curve) depicting G_{Ic} as a function of delamination length, is generated. A sample R-curve is shown in Figure 3. This curve illustrates the initiation and propagation of a delamination in a unidirectional specimen.

Two initiation values of G_{Ic} are obtained from the load-displacement plots. These values, along with subsequent propagation values, are used to generate an R-curve. First, the onset value of G_{Ic} is calculated from the load and displacement at the point of deviation from linearity, or at the

onset of non-linearity (NL). At this point, it is assumed that delamination begins to grow from the insert in the interior of the specimen. The NL value represents a lower bound value for G_{IIc} and is used in determining failure criteria for laminated composite structures. For brittle matrices, the NL value is typically the same point at which delamination is observed to grow from the insert at the specimen edges; however, for tough matrix composites, a region of non-linearity may precede the visual delamination at the edges. Second, a visual initiation value for G_{IIc} is recorded corresponding to the first time delamination was visually observed to grow from the insert on the specimen edges.

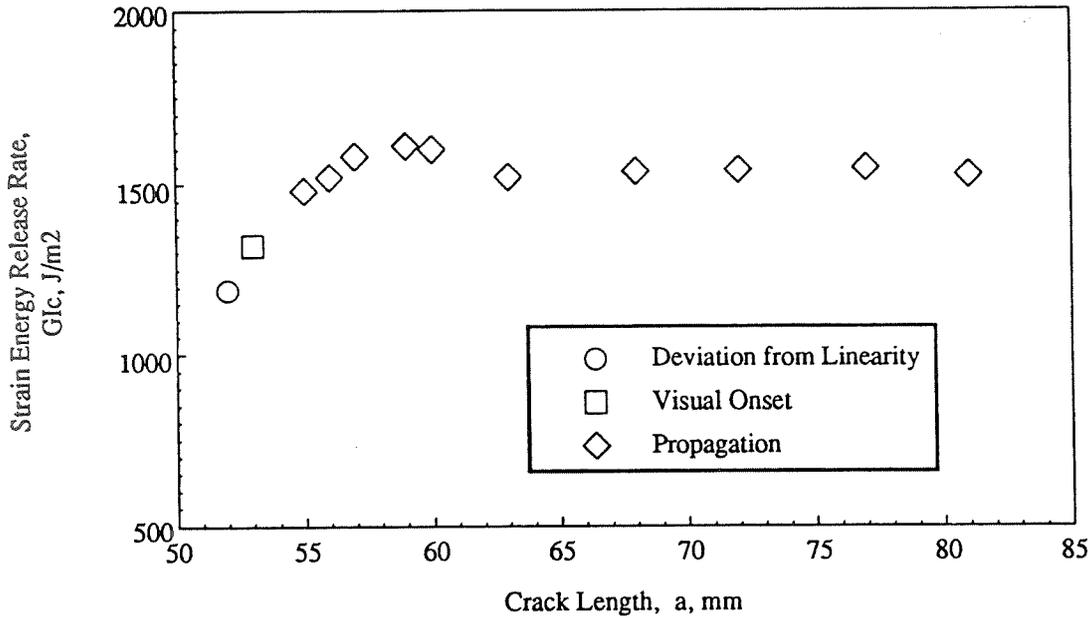


Figure 3. Sample R-Curve

To determine the critical strain energy release rate, G_{IIc} , for initiation of delamination under Mode II (in-plane shear) loading, tests were performed using the End-Notched Flexure (ENF) specimen loaded in three-point bending as shown in Figure 4. In general, the configuration, i.e. specimen thickness and distance between supports, is chosen such that large displacements would be avoided and transverse shear effects minimized.

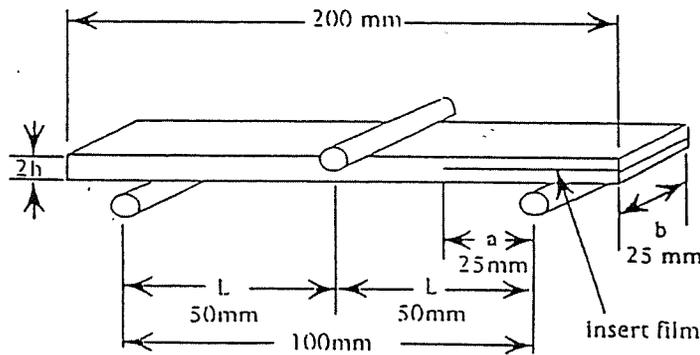


Figure 4. End-Notched Flexure Specimen

The ENF test consists of loading a split laminate beam specimen in a three-point bend fixture. Analytical methods derive a relationship between compliance and crack length using a least squares linear regression. Here, elastic material behavior was assumed.

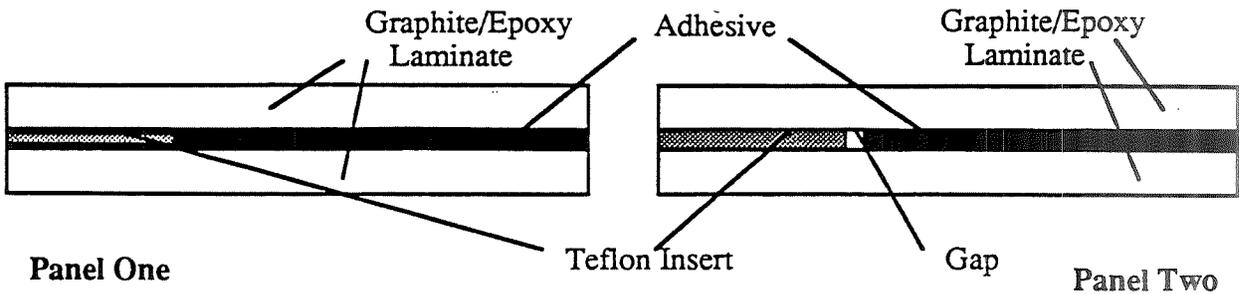


Figure 5. Panel Configurations

Two different graphite/epoxy IM6/3501-6 panels were manufactured at Boeing for this investigation as shown in Figure 5. Panel One contained a teflon insert embedded between two sheets of adhesive and the adhesive bondline thickness was nominally 5mil or 0.005". The adhesive ran the entire length of the specimen. The insert thickness was nominally 0.024mm. Panel Two also had a teflon insert with an average thickness of 0.0506mm; however, it was butted up against one layer of adhesive. Again, the adhesive bondline thickness was nominally 5mil. It should be noted that there was a gap, approximately 4mm long, between the insert and adhesive in this panel. This gap was filled by the 3501-6 resin matrix of the composite during the cure cycle. The adhesive used for both panels was a grade 8, 350°F cure film adhesive, American Cyanamid 1515. The average thickness and width measurements for Panel One specimens were 0.2805" and 1.0051", respectively, and 0.2797" and 1.0034", respectively, for Panel Two specimens.

PROCEDURE

DCB Testing

Experimental Investigation

The width and thickness measurements, for each specimen, taken at the midpoint and at 25mm from each end, were made to the nearest 0.05mm. Average values were calculated and recorded. Both edges of the specimen were coated with a thin layer of water-based typewriter correction fluid to assist in the visual detection of the onset of delamination. The first 5mm from the insert were marked in 1mm increments while the remaining 20mm were marked in 5mm increments.

Piano hinges were then attached to the specimens using Hysol 3904, a high-strength, high-temperature glue. The specimen was continuously loaded in displacement control at a rate of 0.5mm/min and a plot of load versus displacement was created by an X-Y chart recorder. A monocular with a magnification of seven was used to aid in observing delamination growth as it extended along one edge.

When delamination extended beyond the end of the insert, a hash mark was made on the load versus displacement plot and was labeled a_0 . As the delamination grew, the front continued to be observed, and, as it passed each pencil mark, a hash mark was made on the plot and labeled appropriately. For example, point a_1 represents the delamination growth 1mm ahead of the insert. After delamination exceeded 25mm, the X-Y plotter was turned off and the specimen was loaded in the machine until it broke open.

Analytical Investigation

Three data reduction methods for calculating values were followed as per ASTM Standard D5528-94a. These are: a modified beam theory (MBT), a compliance calibration method (CC), and a modified compliance calibration method (MCC).

Modified Beam Theory (MBT) Method - The beam theory expression for the strain energy release rate of an ideal double cantilever beam is:

$$G_I = \frac{3 P \delta}{2ba} \quad (1)$$

where P = load,
 δ = load-point displacement,
 b = specimen width,
 a = delamination length.

However, since the beam is not perfectly built-in, some rotation may occur at the delamination front and the value of G_I will be overestimated. In order to compensate for this, the DCB specimen is treated as if it contains a slightly longer delamination, $a + |\Delta|$, where Δ is determined experimentally by a least squares plot of the cube root of the compliance, $C^{1/3}$, as a function of delamination length, a . Compliance, C , is defined as the ratio of load-point displacement to applied load, δ/P . The Mode I interlaminar fracture toughness is then calculated as:

$$G_{mbt} = G_I = \frac{3 P \delta}{2b(a+|\Delta|)} \quad (2)$$

In addition, the modulus, E_{1f} , can be determined by

$$E_{1f} = \frac{64(a + |\Delta|)^3 P}{8bh^3} \quad (3)$$

Compliance Calibration (CC) Method - A plot of $\log(\delta_i/P_i)$ versus $\log(a_i)$ is generated using the visually observed delamination onset values and propagation values. With a calculated slope, n , the fracture toughness can be found as follows:

$$G_{cc} = G_I = \frac{n P \delta}{2ba} \quad (4)$$

Modified Compliance Calibration (MCC) Method - Using the delamination length normalized by the thickness, a/h , and the cube root of the compliance, $C^{1/3}$, a least squares plot is generated. The slope of this line is called A_1 . Here, the fracture toughness can be calculated from:

$$G_{MCC} = G_I = \frac{3P^2 C^{2/3}}{2A_1 bh} \quad (5)$$

ENF Testing

Experimental Investigation

The following method is based on *A Protocol for Interlaminar Fracture Testing* currently being used in an ASTM Round Robin Test program. In order to initiate delamination, a film was placed at the laminate mid-plane during molding, as seen in Figure 4. This film should be as thin as possible to minimize the disturbance to the composite. Furthermore, the specimen edges were coated with a thin layer of water-soluble typewriter correction fluid from the insert tip and extending toward the center of the specimen. This allowed the initiation of delamination to be seen more easily.

The specimen was loaded in a three point bending fixture. Before loading the specimen, a small load was applied to the specimen to hold it in position in the fixture, and the location of the supports were marked on the specimen. A displacement gauge, mounted upside down under the specimen, was used to measure the load-point displacement.

Dimensions and Load Rate - The width and thickness of each specimen was measured to the nearest 0.025mm at the midpoint and at 10mm from each end. Here, three thickness measurements were made: one measurement close to each edge and one at the center. Average values of width and thickness measurements were then recorded.

The specimen was loaded in displacement control at a rate of 0.5mm/min. Load vs. load-point displacement was recorded during loading using an X-Y plotter.

Compliance Calibration - For each specimen, an experimental compliance calibration is required. The specimen was initially positioned in the ENF apparatus so that the delamination length, a , equaled zero, meaning that the insert is outside the outer load point of the apparatus. A pencil mark was made on the specimen directly above the center of the outer loading pin. Next, the specimen was loaded and unloaded in the elastic range while the load-displacement behavior was recorded. This procedure was repeated with delamination lengths of $a = 15, 20, 25, 30, 35$ and 40mm .

Testing From the Insert - The specimen was positioned in the test fixture so that $a/L = 0.5$. Again, a mark was made on the specimen surface to indicate the outer load point. The specimen was then loaded at the stated load rate until delamination began and the load dropped. The specimen edge was also visually monitored for the initiation of delamination growth.

Analytical Investigation

After testing, the specimen was broken open by hand and the distance from the outer load point mark to the inside tip of the delamination starter film was measured. This initial delamination length was measured at the edges and center of the specimen and a mean value was obtained. The mean lengths from the marks made during the compliance calibration were also measured and recorded.

From the compliance calibration curves, compliance values were calculated for each corresponding delamination length. Compliance is defined as the ratio of displacement to load.

Using the values of mean crack length, a , and the corresponding values of compliance, C , a least squares linear regression of the form $C = C_0 + ma^3$ was performed and the values of C_0 and m were recorded. Therefore, the expression for G_{II} becomes:

$$G_{II} = \frac{3ma^2P^2}{2b} \quad (6)$$

where $a = 25\text{mm}$,
 $P = \text{load}$,
 $m = \text{slope of line from least squares linear regression}$,
 $b = \text{specimen width}$.

A line tangent to the initial linear portion of the loading curve was drawn; any initial deviation from linearity due to seating of the load fixture was ignored. The point at which the load displacement curve deviated from the tangent line was determined. The load and displacement corresponding to this point was used to obtain G_{IIcNL} . In addition, the maximum load and corresponding displacement was used to calculate G_{IIcMAX} .

RESULTS

DCB Testing

A summary of the DCB test results is shown in Table A. Note that the G_{mbt} value is the lowest calculated value for G as predicted by the Modified Beam Theory. Upon examining the data collected from Panel One, a large coefficient of variation (CV) is found because the data gathered from Specimen 1-1 is significantly higher than the other four specimens from the same panel. If Specimen 1-1 is disregarded in statistical calculations, values of 867.25J/m^2 , 49.64 and 5.72% are then found for the mean, standard deviation, and CV, respectively. The notably high values for Specimen 1-1 are due to a relatively high load (approximately 60lbs.) and large displacement corresponding to a_{NL} . However, since no physical defects were observed before or after the test, it has not been determined why Specimen 1-1 had such a high non-linear load.

Table A. Graphite/Epoxy G_{Ic} Data Summary
Panel One
Panel Two

Specimen	G_{mbt}^*	G_{cc}^*	G_{mcc}^*
1-1	1263.1	1316.8	1370.5
1-3	831.8	866.8	893.5
1-5	903.9	929.1	922.7
1-7	915.6	941.1	948.0
1-9	817.7	843.5	927.2
Average:	946.42	979.46	1012.38
Std. Dev.:	182.17	192.99	201.14
CV (%):	19.25%	19.70%	19.87%

Specimen	G_{mbt}^*	G_{cc}^*	G_{mcc}^*
2-1	133.5	136.6	145.0
2-3	167.5	169.7	173.6
2-5	150.2	155.4	175.2
2-7	112.8	116.5	121.5
2-9	147.0	148.3	152.0
Average:	142.20	145.30	153.46
Std. Dev.:	20.42	20.07	22.21
CV (%):	14.36%	13.81%	14.47%

**All G values are in J/m^2*

The results obtained from Panel Two largely differ from those gathered from Panel One because of the different panel configurations. Because of the epoxy filled gap between the insert and adhesive, a load drop was observed for all five specimens at around 25lbs. Therefore, 25lbs. was used as the point of non-linearity as compared to about 54lbs. for specimens 1-3, 1-5, 1-7, and 1-9. This discrepancy caused the calculated toughness values for Panel Two to be about 6.5 times smaller than the values for Panel One. The values of G_c found for Panel Two are representative of values for a graphite composite, while Panel One is indicative of the stronger adhesive.

ENF Testing

Table B compares the ENF test results for Panels One and Two. Panel One exhibited appropriate behavior during testing. The non-linear points were easily determined. Specimens 1-2, 1-6, and 1-8 had non-linear loads at approximately 2020N (450lbs.) while 1-4 had a higher non-linear load of 2257N , or 507lbs. This high non-linear load, in addition to scatter in the calculated values of m (slope from linear regression), led to a high coefficient of variation of 21.06% . However, if Specimen 1-4 is excluded from statistical calculations a very respectable CV of 6.93% is found. It was not determined why specimen 1-4 had such a high non-linear load. However, its failure load was consistent with the other three specimens as shown in Table B. Calculated values of $G_c(\text{MAX})$ only differed by 11.57% since all the maximum loads were in the range of 4600lbs.

In examining the results calculated for Panel Two, the discrepancy in values as compared to Panel One is due to the 4mm epoxy filled gap. Upon examining the results from Panel Two, one will notice a significant discrepancy in the values of $G_c(\text{NL})$. The $G_c(\text{MAX})$ could not be calculated for this panel because of the gap between the insert and adhesive.

Table B. Graphite/Epoxy G_{IIc} Data Summary

Panel One

Specimen	P(NL)*	P(MAX)*	Gc(NL)*	Gc(MAX)*
1-2	2012.8	4581.67	487.1	2523.9
1-4	2257.5	4659.51	769.2	3276.9
1-6	2035.1	4637.27	523.9	2720.4
1-8	2012.8	4692.87	559.7	3042.4
Average:			584.98	2890.90
Std. Dev.:			126.34	334.52
CV (%):			21.60%	11.57%

Panel Two

Specimen	P(NL)*	Gc(NL)*
2-2	3436.25	1395.9
2-4	3458.49	1394.9
2-6	3325.04	1271.6
2-8	3080.39	1237.4
Average:		1324.95
Std. Dev.:		82.54
CV (%):		6.23%

*P values are in N, G values are in J/m^2

CONCLUSIONS

The DCB and ENF data collected from Panel One is consistent with similar adhesives. Even though a high CV was calculated for Panel One specimens, one must realize that a small number of specimens were tested. If a larger pool of specimens were tested, more reliable and more accurate results could be found. Due to a gap between the insert and adhesive, results from Panel Two serve no real purpose in this investigation. In regards to Panel One, the average value for G_{Ic} is $946.42 J/m^2$ while the average G_{IIc} value is $584.98 J/m^2$. These results illustrate that a crack in the adhesive requires more energy to grow in the opening mode than the shearing mode. This is just the opposite of what is typically observed for delamination within the composite.

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**AN EXAMINATION OF NASA LaRC
TRAVEL REIMBURSEMENT PROCEDURES**

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ABSTRACT

My goal while working in the Travel Section is to become as proficient as possible in the procedures for processing travel vouchers. There are many different definitions of NASA travel by its employees, and each type is governed by a different set of regulations. The process of learning these regulations is complicated by several elements: first, the basic procedures for working with the computer equipment and program is not clearly stated, and second, the definitions of each aspect of the computer program are learned only by vocal instructions from co-workers, each of whom may have conflicting ideas of how to operate inside the program. My objective in this project report is to clarify some of the more basic elements of travel voucher examination. This is not a reiteration of the regulations by any means, but merely a statement of what every voucher examiner needs to know in order to properly utilize the voucher examination program.

● BACKGROUND INFORMATION

I arrived at Langley Research Center (LaRC), Financial Management building, after my orientation into the Langley Aerospace Research Summer Scholars (LARSS) program Monday morning, June 5, 1995. After some consideration my Mentor, James Ogiba, placed me into the Travel Section as opposed to Cost Accounting because as an English and Anthropology major I am more experienced in organizational and qualitative data than in finances and quantitative data. Since I have served as the business manager for two student-run organizations at the University of Virginia (a literary magazine and a women's chorus) I possess the basic accounting skills necessary to handle the reimbursement and voucher-completion procedure.

Upon my arrival in the Travel division I was placed in my own cubicle with a computer, a printer, a telephone, an adding machine, and a typewriter. On the first day my co-worker Tracy showed me around the office and introduced me to all the other employees. I was shown where all my supplies were stored and allowed to arrange my cubicle as I pleased. My first assignment was to complete forms granting American Express cards (which are necessary for the reimbursement of government travel) to NASA employees, following a sample form. During the course of the summer I was also trained to schedule vouchers and travel advances for payment. By the last few weeks in the office I was trained to do the exact same work that the rest of the full-time voucher examiners were doing.

The travel section apparently was undergoing a period of great change and stress at the time of my arrival. They had lost a significant number of their personnel during the buy-out and were renovating many of the procedures to increase efficiency and reduce the time elapsed until the travelers got their reimbursements. The procedures were changed or amended daily and everyone, travelers and travel clerks, was confused. I believe that I had a slight advantage in learning everything as a new experience instead of having conflicting orders in my head.

1. Objective

Eventually the main focus of my work revealed itself to be the completion and printing of travel vouchers for LaRC employees' reimbursements, which proved to be the most complicated and involved part of my job. The process can be extremely frustrating because of the constantly variable rules governing allotments. The major problem I encountered in completing these vouchers was that there was no standard procedure for determining the definition for each fiscal category, beyond word-of-mouth from my fellow employees. Often the information I received from different co-workers was either conflicting or directly contradictory. At this point I experienced some concern that work in this office may not qualify as actual research as stipulated by the LARSS program requirements. True, I was very quickly learning a great deal about LaRC's financial involvement and relationship with its employees, but the learning process did not necessarily constitute experimentation (although learning to deal with the printer perhaps qualified). I soon realized that a viable occupation with which to absorb myself during the summer weeks that I spent in the Travel department would be to write a manual describing the exact procedure for completing travel

vouchers. If the procedure remained consistent for any period of time (which threatens to be impossible), then the manual could be useful for future employees who sought to learn the procedure. What follows is a summary of the directions for examining and completing a travel voucher according to the directions I was given during the summer of 1995.

● **MANUAL FOR COMPLETION OF TRAVEL VOUCHERS**

2. Materials

At present the materials that are needed for completion of the vouchers are as follows: a computer installed with the LaRCtrip program (run from either IBM or Macintosh computers), a printer, a staple remover, a stapler and staples, paper-clips, a manilla envelope marked specifically for the Travel department, one red pen, one blue pen, and three copies of the NASA N-482 form (two white and one yellow). Some of these descriptions and numbers are variable; for instance, it doesn't really matter what color pen you write in on the documents (the distinction is useful for organization and clear comprehension), and formerly some of my co-workers had used two yellow forms and one white instead of the other way around. Apparently the yellow forms have a tendency to stick in the computer and cause it to jam frequently, to which I can personally attest. During my second week it was determined that everyone should use two white sheets (one for an original copy of the voucher and one for the traveler's personal copy) and one yellow, for the office's records.

3. Procedures

A. Load the Printer

First, place the paper into the printer tray. Instruction for placement is based on the configuration of the Hewlett Packard Laser Jet 4L, which is the standard printer supplied to the Travel office. Place the paper face-down with the top of the sheets facing you into the tray, making sure all corners are secure. For my printer, when the yellow sheet is on top with the two white sheets underneath, the jamming is minimized. Push the tray into the body of the printer. The red paper light may remain on until you complete the vouchers and tell the computer to print them.

B. Prepare the Voucher

Next, pick up the travel voucher. There should be at least three sheets: two pages of the actual voucher, and one order form. There may be several receipts stapled to the back of the order form. Use the staple remover to take out the one staple connecting all these forms. During the course of completing the voucher you will be searching for information among these forms and later re-stapling additional sheets among them.

C. Follow the Computer Program

Opening the Program and Personal Information. Enter the LaRCtrip program

through the "Accessories" window in Word Perfect for Windows, and select the option for "Voucher Preparation." Once inside LaRCtrip it is no longer possible to use the mouse to select an option, so use the arrow keys. A screen will come up where the first instruction asks for the travel authority number (T-number) of the traveler. The T-number can be found, typewritten, in the upper right-hand corner of the order form. After typing this into the computer the cursor will automatically move to the next line where you enter the name of the traveler, last name first. The computer puts the letters in all capitals without instruction, which is the proper format. Skip the next item, which asks if you want to make any comments. The next item requests the social security number of the traveler, then his or her phone extension and mail stop (M/S). A different procedure is followed here if the traveler has Invitational status. Type the character "I" instead of a mail stop, and when the screen comes up type in the traveler's temporary home address (if that is where he or she wishes the check to be sent).

Times of Travel. The program will then ask for the times of travel, starting at the date and time when the traveler left his or her residence (or LaRC, depending on time elapsed at each point) and ending when the traveler returned to his or her residence. In order for the expenses to be reimbursable, the period of travel must exceed ten hours and the final time entered must be two hours or more after the end of the work period. All of these times are written on the first page of the voucher forms that the traveler has completed.

Travel Advance. After recording these times, the program requests the amount of the travel advance allocated to the traveler. If a travel advance was given, it will be marked on the first page of the order form, and a card will be stapled to the back with the amount of the advance and the advance number (AD number) written on it. If no advance was given, hit return four times until the cursor moves to the next segment of the program. However, a special procedure must be followed if the traveler was given an American Express Cash Advance (or ATM Advance) and took money out of it. All of the rules and regulations for this procedure are delineated in *the NASA ATM Cash Advance Policies, Procedures, and Enrollment Guide*. The basic instruction is that if cash was taken out of the account, then the traveler will be granted 2.75% of the withdrawal (the standard fee for cash withdrawals) under "miscellaneous expenses." A receipt of this transaction must be attached to the order form in order for the expense to be reimbursed. No advance will be entered into the computer at that point, where normally there would be an AD number along with the amount.

Duty Station and Meals. The next item that appears on the screen requests the number of travel stations, which is written in two places: the traveler's orders, which come to the voucher examiners attached to his voucher, and item 25 of the voucher itself. It will then ask if any meals were provided in the course of the travel. Whatever program the traveler attends may include certain meals as a part of the overall cost. If the traveler is attending a seminar, the information sheet should say whether meals (perhaps a banquet, or continental breakfast) are included. If the traveler is attending a training course at Hagerstown, MD, or Wallops Island, VA, and is on a \$2/day per diem, then all of his or her meals at the duty station are provided.

Transportation. The section that comes up next verifies the traveler's mode of transportation. The first question asks if the traveler used a private vehicle (POV) in lieu of

government transportation or commercial air. This means that the traveler drove his or her own car to the duty station instead of taking a NASA car or bus or getting a plane. If this was the case, it will ask for the mileage of the trip, which is given on the voucher under the odometer readings, recorded by the traveler. Mileage is taken from the average of the two differences between the departure and arrival readings (the computer will automatically double this number). One possible complication at this point is whether the traveler was authorized to use a government vehicle but chose not to in favor of his or her own vehicle. In this case (it will be mentioned on the orders) the POV mileage must be changed to \$0.235/mile instead of \$0.3. This can be done under "Maintenance" on the main menu of LaRCtrip.

The transportation section will continue, if the answer to the above question was "no," with a question as to whether commercial air was used. If the answer is "yes," the program will ask whether POV was used for transportation to and from the terminal. On the voucher the traveler should have indicated the mileage for this transportation. If the car was left at the terminal, indicate on the program that the transportation was round-trip and type the mileage (the computer will again automatically double it unless you designate it as one-way). However, if the car was not left at the terminal, double the one-way mileage and record it as round-trip, indicating that the car was driven to and from the terminal twice. This procedure of recording mileage to and from the terminal is used even if the traveler did not use commercial air, but used a NASA vehicle and picked it up at LaRC or some other point. LaRC is then considered to be the terminal and the same principles apply. The final question for the transportation section asks if a rental car was used in the course of travel. Even if a rental car was paid for, the only times "yes" is marked for the answer here is if the orders were approved before May 1, 1995, or if the traveler accumulated personal miles on this rental. If not, then the cost of the rental car is included in the miscellaneous expenses (shown later in the program).

Actual Subsistence. In certain circumstances the per diem is not adequate to cover the lodging or meals and incidental expenses due to a change of plans or special lodging requirements, so a request for actual subsistence reimbursement is submitted by the traveler. The actuals letter must be signed by an authorizing official and approved by the head of Financial Management before the actuals can be processed. If such a letter is included with the receipts and orders, answer Y when the program asks to process actual expenses. Later in the program it will ask for the specifics of the lodging.

Parking Fee. Entering the parking fee can be a very straightforward procedure. The parking at the airport terminal (if applicable) will be written on the original form under item 30. Any parking fees that were acquired at the duty station should be included here as well (they would be written under miscellaneous expenses, item 35). However, if the parking fee is inordinately high, it may be necessary to adjust it. If reimbursement for mileage and parking are too expensive, the travelers are encouraged to take a taxi to and from the airport. To determine this, calculate the total cost of the mileage (number of miles multiplied by \$0.30) added to the parking fees. If this exceeds the cost of a taxi to and from the airport, then the cost of the taxi is used for the voucher and the difference is taken off of the parking fee, which is then entered into the computer.

Telephone Calls. The program next requests a total cost for telephone costs that were made during the travel duty. This is broken down into two categories: personal and official. Official phone calls are to be fully reimbursed with no stipulations, including calls to the LaRC office, phone mail, and to the duty station. Personal calls are restricted by several regulations. The traveler is allowed to make personal calls with each call not exceeding \$4.00, and the total for a seven-day period not exceeding \$12.00. One further stipulation is that the average number of calls cannot be more than the number of days that the traveler was in travel status, starting when he or she left LaRC and ending when he or she returned.

Registration Fee. A registration fee is frequently requested when a traveler attends a seminar or conference, which is paid to the organization. Usually the registration fee is paid by NASA in advance, which would be indicated on the travel orders by saying that it was paid either "Government P/R" or by Government Visa. At times, however, the traveler pays the fee upon arrival, and for this to be reimbursed, proof of payment in the form of a receipt with the method of payment recorded must be included. This must also be authorized on the travel orders, whether or not it was prepaid. In this case the amount of the fee will be entered at the computer's prompting.

Miscellaneous Expenses. The category of miscellaneous expenses has become more complicated since most expenses began to be covered by American Express. This includes airplane tickets and cash advances, which are the two items that cause the most confusion. If airplane tickets have been paid by American Express, the last total on the last page of the airline itinerary will be zero, and the credit card line will begin with "AX." Another item in miscellaneous expenses is the American Express Cash Advance Service Charge, which is explained under the section for travel advances in this report. Another item included here is the total cost of the rental car (if applicable). The rental car must be authorized on the orders and the specifications must match those authorized by Omega World Travel or by the travel orders. Other expenses shown in this category are gas for the rental car, parking fees at the duty station, and tips for handling of government equipment. Other smaller expenses are not listed here for the sake of brevity. All of these expenses are added together. (This method is currently being renovated so the break-down will be clearer, but this is the current procedure.)

Duty Station. The program next requests the state in which the travel duty took place. Once this is entered, a screen comes up with a listing of cities and counties from that state. One of these should be chosen, and "F9" hit to close the screen. The city or county name should be taken from the orders instead of the traveler's voucher, because of the difference in per diem rates between duty stations and the actual location of the hotels.

Lodging. The next section of the program requests a lodging rate, which should be taken from a hotel receipt included with the travel orders. This rate is a nightly rate (plus tax if applicable) for government employees, which usually involves a discount. Make sure to check here that the number of nights spent at the hotel matches that stated on the travel itinerary and clarify any discrepancies. For instance, a traveler may have returned home at some hour shortly after midnight, and the program would include lodging for that night unless otherwise instructed. One way to do so

is to answer "no" when the program asks if lodging costs remained the same during travel. If an actuals letter was included with the voucher and the answer to the request to include actual expenses was "yes," then at this point the computer will ask if lodging only should be changed, which is usually the case on domestic travel. The next screen will show the per diem and M&IE rates, and ask if you want to record actual lodging. The last screen in this section is a list of the dates of travel followed by spaces to enter the amounts of nightly lodging costs. (This same screen comes up if nightly rates do not stay the same during travel duty.)

Breakdown of Meals. If meals were included in the overall cost of the program being attended (for example, if the registration fee included certain or all meals) the computer will ask if all meals were provided. The only case where that answer is "yes" is if the duty station was Wallops Island, VA, and the per diem is \$2.00/day. If the per diem is \$2.00 anywhere else, meals should be included beginning when the traveler arrived at the station and ending when the traveler left. In any other case the meals that were provided must be shown on background information for the conference or seminar.

Rental Car. The last possible specification that the computer program might request involves rental cars. If the traveler had personal miles on the rental car, then the program will ask how many cars were rented, and then the total cost. Since the total cost must be included under miscellaneous expenses, the total cost remains \$0.00 at this point. The next screen that comes up asks for further descriptions, including the total mileage, which will be shown on the rental car receipt, the personal mileage, which will be included on the voucher, and the gas costs, including both what is on the rental car receipt and what is written on the voucher (any separate purchases for the rental car). The gas costs must be included under both miscellaneous expenses and this description of the rental car in order to determine the personal cost of the rental car. The gas will not be credited twice although it is written twice. All other parts of this section remain zero, such as mileage rate.

D. Preparation for Printing

After finishing all the instructions that the computer gives you, if you are satisfied that all the information is correct, begin the process for printing. The computer will ask if the answers you gave are correct; press *Y* for yes. It will ask if you want to write a memo. There are several instances where you would wish to enter a note of explanation to the traveler or the accountants; if so, press *Y* to write a memo and when the small screen appears, type your message. Press *F9* to go back to the main screen. Next, press *Y* that the voucher is completed and *Y* again that you want to print a copy, and press any key to continue. Since you can't specify the number of copies that you want to print, it will ask again if you want to print a copy of the voucher, and press any key to continue again. You must do this a total of three times, so that there will be three copies of the voucher with the worksheet printed on the back. The reason for printing this many copies is as follows: there must be one copy of the voucher for the accounting, one copy for the traveler's records, and one copy for the travel division's records. After the the computer asks if a voucher should be printed for the third time, press *N*, and the computer will next ask if you want to print a worksheet. Press *Y* and go through the command two more times. The final prompt that comes onto

the screen says to press *X* if you want to get out of LaRCtrip or *return* to move to another voucher form. The worksheet will be printed upside down on the back of all three copies so that when the sheets are stapled together the worksheet can be read simply by lifting the bottom of the sheet.

E. Printing the Forms

When the copies are printing, they will come out onto the top of the printer in the same direction that they were placed in the tray: face down with the top of the sheets closest to the front. After the second sheet comes out of the printer, take the one underneath it (the first one to come out) and, holding it the same way it came out of the printer, insert it into the horizontal slot in the front of the printer. This is necessary because it bypasses the necessity of opening the printer tray, which would stop the printer from operating. If the edge of the sheet is held it securely in the slot as far as it will enter while the third sheet is beginning to print, after a moment the rollers will seize it and it will be pulled into the printer. Great care must be taken at this point that the paper being inserted is set absolutely straight, or else it will get folded up inside the printer and jam. If this happens, open the relevant part of the printer (the tray, the top or the back) and gently pull the paper out. Avoid excessive force if it gets stuck, because if it rips a letter opener must be used to scoop the pieces out. For the Hewlett Packard 4L, the paper must be guided as it enters the printer or else it will twist itself, but that may not always happen. After the printer takes the first sheet to print the worksheet, pick up the second sheet and, after the front roller stops moving and clicks, insert the sheet into the slot in the printer. Again, the rollers will seize it and pull it into the printer. Follow the same procedure with the third sheet.

F. Arranging the Forms

Once the printing is complete, remove the three printed sheets from the printer. Next to Item E on one of the white sheets, write *Your Copy To Keep* (or some equivalent expression, such as *Traveler's File Copy*) in red pen. This is to let the traveler know that this form is for his or her own personal files. The traveler should have signed item 13 on the form he or she turned in beforehand. Double-check that this line really is signed; then write *See Item 13 Attached* in blue or black pen in item 13 of one white sheet (not the copy). Next look at the type-written travel (or "T") number on the original form. The difficulty in distinguishing between the typewritten zero and the letter "o" has caused the travel department to devise a method to tell them apart. If the character is the letter in the alphabet, then a line will be added to the top of the letter, such as the Greek character "σ." Another way to help the accountants who process these forms is to maintain the uniformity of the T-numbers. Although the character "-" is not registered by the accounting system it still may be included in our system when the T-numbers are printed out on the forms under item 18. If there are any dashes, be sure to white them out before turning in the forms. One other item that may need to be erased also falls under item 18. If the first column's number is 6C and the amount under the last column is zero, white out the entire row. While checking the T-number, check also if the letters after the T5 are "X" or "Y." If they are, the traveler may be an Army employee. The NASA phone book will verify this (if the traveler's name is starred). If it is, then the traveler should have form filed under "non-NASA employees" in the file folder. If the form is there, xerox it and put the copy with the

travel voucher. If the form is not there, the traveler needs to be called and asked how he or she wants transfer to be handled. Since Army employees are not under the NASA EFT system, their money cannot be transferred electronically in the usual manner. As a temporary solution, the travel division allowed to use checks, but some other solution is currently being devised. Since the Army has its own set of regulations for completing its members' travel vouchers, generally a more experienced voucher examiner should handle these vouchers.

Once the travel voucher is complete and accurate, staple the printed white sheet (not the copy) on top of the white vouchers. Then staple the yellow form on top of the order form and receipts. Stack the vouchers on top, with the order form, receipts, and copy underneath (in that order). Paper-clip the stack of papers onto the upper left-hand corner of the manilla envelope, and write the name and mail stop of the traveler in the upper right-hand corner of the envelope. The final step is to pull the payroll information out of the computer, to which information summer students do not have access. Give the completed vouchers to another permanent employee and ask him or her to pull the information. If no payroll information is not in the computer, call the traveler and ask first for a mailing address to which the check may be sent, and second for the traveler to complete a Payroll Information sheet to be kept in the office. The payroll sheet is stapled behind the last page of the white sheets and the original voucher. The envelope with its attachments should then be delivered to the desk of the office head.

● CONCLUSIONS

Over the course of the summer, the process of examining and completing travel vouchers has become much more accessible, and some sequences have become second nature. The system and software have changed drastically in the past few months and promise to change further and in more extreme ways - for instance, a rumor is circulating that the travelers will be required to compute their own reimbursements in the next few years, which would render the system that I have described completely obsolete. Hopefully the travelers will be as amenable to the change as the voucher examiners have been required to be. The process, once approached and considered sequentially, is a useful and approachable system for both sides of the travel, traveler and accountant.

OMIT

**THE VALUE OF NASA FORM 533
AND THE RELATED ACTIVITIES
THAT AID IN OBTAINING RELIABLE
NASA CONTRACTORS**

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Abstract

I have spent ten weeks of my summer working in the Financial Management Division (FMD) of the NASA Langley Research Center (LaRC). Although the work done in this division does not directly influence the science and engineering involved in making aircraft, if it were not for the work done here, there would be no research performed at NASA. Behind every scientific invention, there are finances to be considered. Finances are sometimes overlooked and underrated, yet they are essential in any decision in which money is involved. This includes nearly everything that is done at NASA.

My time was spent in the Cost Accounting area in the Cost and Commercial Accounting Branch in the FMD. Although I did not have one specific research project, I dealt mainly with the Contractor Financial Management Reports, commonly known as NASA Form 533's (NF 533's). These are forms required by nearly all of the contractors that deal with NASA. Along with aiding in the updating of cost accrual worksheets for all straight-line contracts, I used an equation of absolute variances to analyze the accuracy of the estimates required on the NF 533's. I spent most of my time, though, analyzing the timeliness of the NF 533's.

With the time I spent working with the NF 533's, I wanted to define what a reliable contractor would be. Through my study of timeliness and accuracy, as well as my growing familiarity with contractors and their submittal of NF 533's, I hope to learn about one important aspect of the financial system at NASA.

Introduction/Background Information

During my ten weeks in the Financial Management Division at NASA, LaRC, I have spent much of my time working closely with Gail Temple, Team Coordinator in the Cost and Commercial Accounting Branch. She gave me a chance to learn a substantial amount about NASA Contractors.

LaRC uses both on-site and off-sight contractors to perform work that is unlike the NASA employees. Although the Acquisitions Division handles the actual contracting, the Financial Management Division handles the "financial" part of the deal. One of the very important aspects of the work that is done by this division is the obtaining and recording of the NASA Form 533. This form gives monthly costs as well as estimates of the contractors' work. The monthly submission of this form is required from most contractors, although there are a few exceptions.

From the monthly NF 533, one can calculate absolute variances, as well as determine the timeliness of their receipt. Throughout the summer, I worked with one of the accountants in recording the receipt of the NF 533 for contracts costed by the straight-line method. The worksheets needed to be updated using information from October of 1994 until present.

I also spent time calculating and recording variances from the NF 533's. This calculation would show if there were large discrepancies between estimated and actual monthly costs. I looked through records dating back to August of 1993 through April of 1995, in order to recover figures to make the calculations.

Along with updating the cost accrual worksheets and calculating absolute variances, I spent most of my time performing an analysis of the timeliness of the receipt of NF 533's. This analysis allowed the Financial Management Officer to identify those contractors that are timely or delinquent in the submittal of the NF 533's. I looked through records dating back to September of 1993 through April of 1995, uprooting dates. I recorded the accounting period ending and date received, and then calculated the date due for all on-sight/near-sight contractors as well as off-sight contractors. With this information, the timeliness of the NASA Contractors over the past one year and eight months was determined.

Towards the end of my ten weeks, I was delighted to find out that I would be helping to plan a workshop for NASA on-site/near-site contractors. This class involved the timeliness of the NF 533's and the problem of high variances on NF 533's. This was interesting to me because I could finally see what my work and research had to do with the Financial Management Division in correspondence with the contractors.

Procedures

Updating Worksheets Costed By The Straight-Line Method

Upon arrival in early June, I was instructed on how to fill out cost accrual worksheets using monthly NF 533's. At first certain dollar amounts were hard to detect on the forms, but after a few days it became routine. First, I assigned a worksheet for every contract, including information such as contract number, contract type, contract administrator, contractor name and contract value. After all straight-line contracts were assigned a worksheet I began pulling their folders. I concentrated on finding the NF 533's for the approximate months of October of 1994 through May of 1995. Using these forms, the obligations, monthly estimates, monthly accruals, cumulative accruals, cumulative actual costs, dates received, and variances were recorded. The dates received and the variances were used in later studies involving timelines and estimates. An example of a cost accrual worksheet is attached.

Calculating Cost Variances

A cost variance is a percent that allows you to determine how accurate an estimate of the month's cost was. In order to calculate the variance you need the current months cumulative actual cost and cumulative accrual, as well as the previous months cumulative actual cost. The cumulative accrual minus the cumulative actual cost divided by the actual incremental cost for the month equals to the percentage we consider the cost variance. (In order to get the actual incremental cost for the month you subtract the previous month's cumulative actual cost from the current month's actual cost.) This variance was not only recorded on the cost accrual worksheet but on a separate spreadsheet that I helped to create in order to compare contractors and come up with averages and adjusted averages. Since there had already been a beginning of a spreadsheet developed, I modified it to fit my purposes. A copy of the spreadsheet and the cost accrual worksheet is attached.

Determining Timeliness

In order to determine the timeliness of the submittal of the NF 533's, I first recorded all of the dates received by looking back through each contract folder. While examining the receipt dates from NF 533's dating back to September of 1993, I also recorded the accounting period ending date. This date was different for all contracts. The date due was then calculated by counting ten working days from the accounting period ending date, not including weekends or holidays. If the date received was within two extra days (given because of cutbacks in mail delivery) after the date due, the NF 533 was timely. If it was received anytime after that calculated date, plus two days, it was not timely. The results of this analysis of timeliness is recorded on spreadsheets. There is an example of one of the contracts attached.

Results/Conclusion

Updating Worksheets Costed By The Straight-Line Method

While recording the receipt of NF 533's for all contracts costed by the straight-line method, I observed that there were many missing. I made a list of those NF 533's that were missing, and requested that the Acquisitions File Room help me find as many as possible. When checking their records, I discovered that about half of those that were missing in my records were found in theirs. This was a valuable finding, but there are still many missing. It is most likely that the contractors have not submitted the forms to NASA. With the list of NF 533's that are still missing, notices are being mailed to those contractors that are lacking the forms. This is very important, because the information that is contained in these forms is essential in the financial management of NASA. It is essential that NASA and its contractors keep in contact in hope to keep the costs and finances running smoothly.

Calculating Cost Variances

After calculating all of the cost variances, I computed the average variances, and then the adjusted average variances. By studying the variances, I determined that, on the average, most contractors are not making accurate estimates. After doing an adjusted average by deducting any unusually high variances based on the history of their estimates, many of the averages fell within the acceptable range. According to NASA, LaRC metrics, a consistent variance of higher than 15 percent should be investigated. There are some contractors being investigated at this time.

Near the end of my ten weeks in the Financial Management Division, I was able to help organize a class for all NASA contractors. I was able to attend and listen as NASA employees explained the importance of keeping variances low. It was rewarding to hear that the work I had been doing was actually a study of something that is very important to the financial system at NASA. It would be interesting to be able to contact contractors directly about their variances, and do an analysis of any changes in the accuracy of their estimates.

Determining Timeliness

When determining timeliness, I discovered that the majority of NF 533's were submitted late. Although most were consistent with the amount of time they took to submit them, they were still not timely.

In the same class with the contractors, timeliness of the NF 533's was emphasized. NASA explained that the deadlines were set because we too had financial deadlines to meet. Timely reports also ensure more accurate cost in the financial

management system. Many contractors showed their discontent with a ten working day deadline, but NASA employees explained the purpose well.

One thing I realized when doing an analysis of timeliness is that when people miss their deadlines, it makes the work of everyone else more difficult. The fewer that are tardy, the smoother everyone's job flows.

I feel that in order to be considered a reliable contractor for NASA,LaRC, the contractor must do good work, as well as have good financial information. This would include being timely with the return of the NF 533's and making more realistic monthly estimates. The Financial Management Division is still working hard with contractors in order to make the financial processes more efficient.

FY 95 COST ACCRUAL WORKSHEET

CONTRACT NUMBER: _____

CONTRACT TYPE: CPFF(7)

AWARD DATE: 12-6-93

EFFORT: AR 11

COMPLETION DATE: 12-6-98

TECH MONITOR: _____

CONTRACTOR NAME: _____

CONTRACT ADMIN: _____

CONTRACT VALUE: _____

COST ESTIMATE SUPPLIED BY: _____

COST ACCRUED BY: _____

OTHER (SPECIFY): _____

10 0 0

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
Cost Variance %	6.7%	-4.0%	5.7%	-4.3%	7.3%	7.5%	2.2%	8.7%	0.3%			
Obligation	1,207,233	1,776,229	1,052,751	1,252,751	1,952,751	1,492,751	1,202,751	2,022,751	2,222,751			
Monthly Cost Est. Per 533 Report	22,667	94,510	91,264	35,325	98,447	39,506	104,669	112,376	114,306	107,933	131,576	
Monthly Accrual	30,222.41	20,180.92	95,226	80,459.78	102,309.40	21,020.84	29,210.07	102,443.06	105,177.24			
Accrual Adj.												
Cum. Accrual (Est.)	701,235.33	876,225.09	971,451.09	1,006,776.09	1,105,085.49	1,126,106.33	1,230,716.33	1,333,159.39	1,438,336.63			
Accrued By / Date	0-0-00	11-28	1-1-91	1-22-95	3-22	3-22	5-22	5-22	5-22			
Accrual Est. By	533	533	533	533	533	533	533	533	533			
533 Cum. Actual Cost	901,007.85	890,888.23	906,527.61	1,065,003.01	1,156,707.41	1,240,222.51	1,226,029.51	1,327,485.65	1,427,293.16			
Date 533 Received	11-1-94	12-2-94	1-5-95	2-3-95	3-7-95	4-3	5-2-95	6-2	7-7-95			
Tot Disb. Cum. Actual Cost												
Total Disbursed												
Line #												
CIEO												
Acc. Method Code												

NAS1

FMD-AB 1-895

NASA Langley (Rev. Sept. 1991)

COST ACCOUNTING SECTION

OCTOBER 1983 THRU APRIL 1988

ABSOLUTE % VARIANCES ON NEAR SITE/ON SITE CONTRACTORS

CONTRACT#	POP	NOV 83	DEC 83	JAN 84	FEB 84	MAR 84	APR 84	MAY 84	JUN 84	JUL 84	AUG 84	SEP 84	OCT 84	NOV 84	DEC 84	JAN 85	FEB 85	MAR 85	APR 85	AVG VAR	EXPLANATIONS
		1.29%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	30.82% OK	
		1.4%	22%	8%	22%	3%	4%	3%	2%	25%	14%	16%	44%	84%	0%	0%	3%	1%	14%	16.23% OK	
		3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	54.03% NO NOTES	
		6%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	21.35% OK	
		3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	35.83% not better (11.88)	
		29%	35%	37%	64%	20%	1%	1%	3%	5%	11%	12%	100%	2%	5%	5%	5%	5%	5%	43.13% no notes	
		11%	7%	4%	6%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	81.34% no notes	
		6%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	10.27% OK	
		18%	2%	2%	34%	18%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	30.63% combination of materials	
		17%	2%	2%	9%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	21.86% OK (9.64)	
		17%	3%	3%	104%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	28.55% NO NOTES	
		4%	5%	5%	18%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	32.84% OK less hours, leave, etc.	
		19%	34%	23%	36%	24%	7%	65%	35%	10%	8%	3%	53%	19%	19%	19%	19%	19%	27.90% OK (19)		
		103%	156%	39%	39%	57%	91%	76%	48%	46%	47%	100%	175%	27%	124%	42%	42%	42%	39.65% no notes		
		3%	3%	3%	24%	27%	13%	16%	5%	15%	18%	30%	12%	38%	162%	103%	23%	23%	33.13% school, no notes		
		3%	5%	22%	14%	23%	24%	1%	13%	7%	18%	1%	8%	79%	68%	1%	21%	122%	27.82% no notes		
		0%	6%	17%	18%	35%	24%	46%	30%	35%	39%	49%	4%	6%	1%	1%	1%	1%	1%	18.36% OK	
		40%	50%	1%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%	21.67% OK (17.33)	
		7%	9%	3%	8%	10%	12%	10%	13%	10%	13%	1%	22%	21%	23%	48%	0%	0%	7%	14.53% OK	
		35%	30%	27%	21%	6%	27%	10%	18%	15%	2%	1%	1%	1%	1%	1%	1%	1%	1%	13.08% OK	
		108%	39%	39%	71%	11%	21%	48%	20%	18%	36%	41%	3%	14%	13%	1%	10%	25%	35%	33.00% school, no notes	
		7%	3%	7%	17%	2%	18%	2%	16%	30%	3%	1%	22%	20%	48%	33%	48%	33%	20%	20.15% no notes	
		17%	3%	6%	1%	10%	1%	5%	6%	2%	4%	4%	4%	4%	11%	7%	4%	7%	7%	7.95% OK	
		179%	17%	9%	0%	50%	25%	9%	90%	69%	125%	89%	4%	29%	3%	81%	137%	65%	17%	165.33% school, \$1.24	
		610%	45%	23%	144%	19%	7%	7%	30%	3%	14%	21%	7%	95%	4%	35%	70%	20%	9%	110.50% no recent 553.8 (39.29)	
																				127.44% no notes (28.9)	
																				6.69% OK	
																				11.64% OK	
																				35.78% new, no notes	
TOT VAR		1847%	323%	584%	2745%	651%	485%	651%	716%	655%	645%	1380%	434%	881%	916%	1082%	1850%	817%	685%	1338%	
AVG		37%	24%	108%	25%	18%	18%	24%	28%	24%	26%	69%	17%	36%	33%	36%	70%	28%	28%	26%	49%

ABS. VAR.	650%	120%	54%	725%	631%	485%	651%	716%	655%	645%	1380%	434%	881%	916%	1082%	1850%	817%	685%	1338%		
ADJ. AVG.	30%	37%	24%	31%	26%	18%	28%	24%	28%	24%	26%	69%	17%	36%	33%	36%	70%	28%	28%	26%	49%
% CONTRACTS	21	25	25	24	26	27	28	26	27	28	28	28	28	27	27	28	27	27	28	28	26

ANALYSIS OF THE TIMELINESS IN THE RECEIPT OF THE
NASA FORM 633M

CONTRACT #: 931206 AWARD DATE: 931206
 CONTRACTOR: COMPLETION DATE: 981206
 SUBMITTAL TERMS: 10 OPER DYS CONTRACT ADMINISTRATOR:

Period Ending	SEP93	OCT93	NOV93	DEC93	JAN94	FEB94	MAR94	APR94	MAY94	JUN94	JUL94	AUG94	SEP94	OCT94	NOV94	DEC94	JAN95	FEB.95	MAR.95	APR.95	
Date Due	931231	940131	940228	940331	940423	940523	940623	940723	940823	940907	941007	941104	941208	941223	950123	950224	950323	950423			
Date Received																					
	TIMELY																				

(1)=TIMELY
 (2)=INCONSISTENTLY LATE
 (3)=CONSISTENTLY LATE
 M=MISSING 633M
 *THE NEXT TWO MONTHS ESTIMATES ARE COMBINED INTO ONE FIGURE

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Y.P.

17-4 PH & 15-5 PH
Student: Howard T. Johnson
Mentor: Larry Cooper
Division: Fabrication
Section: Non-Destructive Evaluation Section
Branch: Models & Materials Technology Branch

Abstract

17-4 PH and 15-5 PH are extremely useful and versatile precipitation-hardening stainless steels. Armco 17-4 PH is well suited for the magnetic particle inspection requirements of Aerospace Material Specification. Armco 15-5 PH and 17-4 PH are produced in billet, plate, bar, and wire. Also, 15-5 PH is able to meet the stringent mechanical properties required in the aerospace and nuclear industries. Both products are easy to heat treat and machine, making them very useful in many applications.

Introduction

HEAT TREATMENT

Heat treatment is procedure of heating and cooling a material without melting. It may involve temperatures above, below, and at the ambient. Typical objectives of heat treatment are hardening, strengthening, softening, and stress relief. Heat treatment will improve formability, machinability, and dimensional stability.

My mentor Larry Cooper and I discussed my research project. He wanted me to study 2 stainless steels. The two stainless steels are 17-4 PH and 15-5 PH. Larry developed some questions that he wanted me to find answers. I went to the library to collect some information about 15-5 PH and 17-4 PH, and studied the differences between them, and their condition of heat treatment.

Furnaces are used to heat treat stainless steels. Here is the list of Furnaces:

	Temperature
1. West Pit Furnace	0 - 1150 F
2. Linderg # 1	0 - 1150 F
3. Linderg # 2	0 - 1150 F
4. Linderg # 3	0 - 2300 F
5. HeviDuty Pit	0 - 2000 F
6. Harrop	0 - 2100 F

Also, there are other materials:

1. Water - 4 feet in diameter by 8 feet deep.
2. Oil - 4 feet in diameter by 8 feet deep.

Water and oil are used for cooling the material if necessary.

Conclusion

What are their conditions of heat treatment?

Heat treatment for 17-4 PH

Condition	Hardening temperature	Hardening temperature	Type of cooling	R/C hardening
H 900	900 F	1 hour	Air	C40/47
H 925	925 F	4 hours	Air	C38/45
H 1025	1025 F	4 hours	Air	C35/42
H 1075	1075 F	4 hours	Air	C32/39
H 1100	1100 F	4 hours	Air	C31/38
H 1150	1150 F	4 hours	Air	C28/37
H 1150-M	1400 F	2 hours	Air	C24/30

17-4 PH - Solution treated at 1900 F (30 minutes). Quenched in oil, causing the steels to flare up.

Heat treatment for 15-5 PH

Condition	Hardening temperature	Hardening temperature	Type of cooling	R/C hardening
H 900	900 F	1 hour	Air	C40/47
H 925	925 F	4 hours	Air	C38/45
H 1025	1025 F	4 hours	Air	C35/42
H 1075	1075 F	4 hours	Air	C32/39
H 1100	1100 F	4 hours	Air	C31/38
H 1150	1150 F	4 hours	Air	C28/37
H 1150-M	1400 F	2 hours	Air	C24/30

15-5 PH - Solution treated at 1900 F (30 minutes). Quenched in oil, causing the steels to flare up.

What is different between 17-4 PH and 15-5 PH? What is their composition?

17-4 PH and 15-5 PH are different in the percentage of Nickel, Copper, and Chromium. Here is a chart of their composition:

Composition

17-4 PH		15-5 PH	
	%		%
Carbon	0.07 max.	Carbon	0.07 max.
Manganese	1.00 max.	Manganese	1.00 max.
Phosphorus	0.04 max.	Phosphorus	0.04 max.
Sulfur	0.03 max.	Sulfur	0.03 max.
Chromium	15.00-17.50	Chromium	14.00-15.50
Nickel	3.00-5.00	Nickel	3.50-5.50
Copper	3.00-5.00	Copper	2.50-4.50
Columbium plus Tantalum	0.15-0.45	Columbium plus Tantalum	0.15-0.45

The benefit combination:

17-4 PH	15-5 PH
* High strength	* High strength
* High hardness	* High hardness
* Excellent corrosion resistance	* Excellent transverse resistance
* Easy heat treatment	* Good forgeability

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**The Effect of Different Materials on the Accuracy of the
HYDRA Optical - Fiber - Coupled Coherent Range/Pressure
Measurement System
and
The development of the Health Care Database System
at Old Dominion University**

Kimberly D. Johnson

Sixto Vazquez

**Group : Research & Technology Group
Division: Information & Electromagnetics Technology Division
Branch: Systems Integration Branch**

Abstract

The objective of the first project involving the HYDRA laser system was to determine what effects, if any, could be seen in the system's measurements when testing was done with objects composed of different materials. Ideally we would like to have seen that the range of measurements were all within the accepted 0.4 millimeter accuracy of the system. Unfortunately our results were not as we had hoped, and there did appear to be some significant difference in the measurements made on objects composed of different materials.

The second project is a continuing project at Old Dominion University. The ultimate goal is to develop a medical database that allows a doctor or hospital to keep medical records on line. The current data of the system consisted of one patient whose medical data had been hard coded to allow for a demonstration of the potentials of the system. The short term goal for this summer was to add additional patients to the system for testing, and to eliminate the hard coding of data by creating a database where data could be stored and queried to produce the results seen in the current state.

Project A

I. Introduction/Background Information

The Hydra Optical - Fiber - Coupled Coherent Range/Pressure Measurement System was developed by the Coleman Research Corporation. (Hereafter referred to as HYDRA laser system) The Hydra laser system is able to measure both range and force. We were only concerned with range measurements. According to the operations handbook, this information is derived from a "coherent laser radar (CLR) utilizing linear frequency modulation of a laser diode source." The laser is constantly emitting a beam which is reflected back from the surface of the object being measured. When the laser picks up the frequency of the signal which has bounced back, the distance can be determined.

The Hydra Laser System has three (3) local oscillators each of which is used for a different range. The system will first focus on the object that is to be measured. This initial focus is a "guess" by the system of the distance of the object. When this is done, the initial distance is used to determine which local oscillator is appropriate, and the appropriate mixing frequency of the signal. The first local oscillator is used for short range distances from 1.8 meters to 5 meters. The second local oscillator is used for medium range distances from 5 meters to 10 meters. The third local oscillator is used for long range distances from 10 meters to 15 meters. It is harder for the system to focus at shorter distances, but there is also a smaller potential area for the target to be in. Although it is easiest to focus at long range distances, there is a greater potential for error since it is harder to find the exact target.

This Laser system was originally designed to be used in the robotics program. Potentially, a system of this type could be used in a robotic arm to assist in locating a specific target for the arm. It would be ideal for the system to target objects of different materials, and still maintain accurate range measurements. This was the motivation behind this particular experiment.

II. Project Summary

A. Approach

We chose five (5) different materials to test. These were : Aluminum, Paper, Plastic, Scotch-Lite (the reflective material used for highway signs), and Shuttle Tile. Each of the materials were tested at six (6) discrete points within the range of each of the three (3) local oscillators. A range was chosen well within the boundaries of each of the three local oscillators, i.e. the system did not have to attempt to change oscillators for a measurement on the boundary such as 5 meters. For each of the five materials at each of the six measurement points a total of 30 measurements were taken, and the average of these 30 measurements was used for comparison. This allowed us to compensate for the fact that one of the measurements may be poor due to poor focusing or some other problem. The range of measurements also allowed us to compare the standard deviation for each material within each range. The large amount of data would allow us to search for some patterns across materials and across local oscillators.

B. Equipment and Facilities

The testing was done with the HYDRA Optical - Fiber - Coupled Coherent Range/Pressure Measurement System located in building 1220. This system allows the user to save the data generated by the laser onto disk. This data was then analyzed using Microsoft Excel and NCSS.

C. Results and Conclusions

The data analysis showed that there were differences in the range measurements for different materials at the same point. Although these differences were generally less than one millimeter, they were considered to be significantly different. Our preliminary conclusion is that the type of material does have some effect on the accuracy of the range measurement. At this point, my mentor left for a four week vacation, and work on the project stopped. I had reached the limit of my usefulness for this project, and the final results and conclusions will be developed by Sixto Vazquez upon his return.

Project B

I. Introduction/ Background Information

This project is an ongoing research area at Old Dominion University. The current prototype was developed by Carl Jolly as a master's project. The ultimate goal is to provide a database system with a user friendly interface that will allow physicians to maintain medical files for patients on line. There are different levels of access into the system, doctor, nurse, receptionist, and patient. Patients would be able to view their own medical records. Scheduling would be done through this system. The nurse would record initial patient information such as temperature, height, weight, etc. on line. The doctor would be able to record progress note information for each visit on line as well by pulling up the appropriate window for data entry. The system would keep track of information such as patient allergies and medications. The goal is to allow medical personal more effective and efficient access to pertinent medical information about a specific patient.

The prototype was designed to show what could be expected from a system of this type. Carl Jolly designed windows and screens for data entry and data presentation. The medical records for one patient were hard coded into the system. The current goal is to remove the need for hard links, and to design a database to hold the information for many patients.

Currently three (3) students at Old Dominion University are working on creating and implementing a database for this purpose. There was a need for more medical files. My primary purpose this summer was to transcribe six patient files obtained from Academic Physicians & Surgeons at EVMS in such a way as to facilitate the transfer of this information into the database.

II. Project Summary

A. Approach

Since the database had not yet been completely created, and implementation had not yet begun, it was not possible to directly enter the information into the database. It was necessary for me to enter the data into files that could easily be converted later with a simple C program. Some information required scanning, and these are files that can be directly used by the database at a later point.

B. Equipment and Facilities

The medical files were transcribed at Old Dominion University and scanned at NASA Langley using the Hewlett Packard scanner at the Systems Integration Branch.

C. Results/Conclusion

At this point, all of the data has been entered into files which are ready for conversion. The database development is in progress and implementation has not yet been completed. The goal is to have the database fully implemented by the end of the summer, and then to determine what changes, if any, need to be made.

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8P.

PAYLOAD PLANNING FOR THE INTERNATIONAL SPACE STATION

Tameka J. Johnson

David T. Shannon, Jr.

Space Atmospheric Sciences Program Group

Space Systems And Concepts Division

Utilization Analysis Branch

ABSTRACT

A review of the evolution of the International Space Station (ISS) was performed for the purpose of understanding the project objectives. It was requested that an analysis of the current Office of Space Access and Technology (OSAT) Partnership Utilization Plan (PUP) traffic model be completed to monitor the process through which the scientific experiments called payloads are manifested for flight to the ISS. A viewing analysis of the ISS was also proposed to identify the capability to observe the United States Laboratory (US LAB) during the assembly sequence. Observations of the Drop-Tower experiment and non-destructive testing procedures were also performed to maximize the intern's technical experience. Contributions were made to the meeting in which the 1996 OSAT or Code X PUP traffic model was generated using the software tool, Filemaker Pro. The current OSAT traffic model satisfies the requirement for manifesting and delivering the proposed payloads to station. The current viewing capability of station provides the ability to view the US LAB during station assembly sequence. The Drop Tower experiment successfully simulates the effect of microgravity and conveniently documents the results for later use. The non-destructive test proved effective in determining stress in various components tested.

1.1 INTRODUCTION

The International Space Station is proposed to be a world-class orbiting laboratory used for conducting high-value scientific research. One of the objectives of this project is to develop the ability for humans to live and work in space taking advantage of the microgravity environment. Microgravity is one-one millionth of one unit force of gravity on Earth. The Drop Tower experiment that was observed demonstrated the effects of microgravity on several forces and fluids. It is important that each scientific experiment or payload developer be aware of these effects as they plan for their payload to be integrated with Station. It is also imperative that the process for manifesting these payloads to Station be completed carefully. The traffic model has been arranged so that researchers can benefit from early access to the microgravity environment. This will enable results to be obtained from research on station before it is completely assembled. Non-destructive testing used for monitoring some structural components was observed. This analysis contributed to understanding the importance of monitoring the structure of ISS during the build-up sequence. Also during this sequence, the capability to perform viewing analysis of the US LAB was verified.

1.2. PROJECT DESCRIPTION

The first task was to explore the definition of the ISS, its components and the objectives of the project. The ISS will further develop and use leading-edge technology to reach its goal of providing a top quality laboratory for scientific research in space. Its structure and design mandate that Station be sent up in stages called assembly flights. Integrated into each assembly flight will be payloads. The ability to send the components to orbit will be furnished by a space transportation system (STS). The ISS will orbit earth's surface 190-220 nautical miles. The decay from 220 nm to 190 nm is attributed to atmospheric drag forces.

The International Space Station gets its title from the fact that international partners are involved in its development. The United States, Russia, Canada, Japan, and Europe are collaborating to complete this project.

Figure 1 illustrates the modules contributed by each country. It shows the ISS equipped with photovoltaic arrays that are used to absorb energy from the sun, thermal control radiators that radiate excess heat, a centrifuge facility, and a pre-integrated truss structure to which many of the modules are attached. The truss also houses the control moment gyros and other devices necessary for station operation. It also provides the structure to which the external payloads will be attached including cameras used for monitoring various ISS components.

The ISS's mission objectives were as follows:

- Provide a world-class orbiting laboratory for conducting high value scientific research
- Implement early, on-going access to microgravity resources
- Develop ability to live and work in space for extended periods
- Achieve program that meets technical, schedule and cost targets
- Introduce "new ways of doing business"
- Develop effective international cooperation

The ISS will affect three major areas of science. One is life science in which the research will aid in the study of biological space effects, space environment effects, ecological life support, and life system biology engineering. Secondly, earth science in which the research will aid in the study of atmosphere protection, climate prediction, land mapping, ocean monitoring, and weather now casting. Finally, space science in which the research will aid in the study of solar physics, cosmic physics, astronomy, and astrophysics.

Along with learning about ISS itself, it was requested that an updated database of the payloads be generated. Filemaker Pro is the computer software through which this task was completed. The information for each payload was transferred from the old database to the new database. The database consisted of the payloads projected for flight during the build-up sequence. An example of this database is shown in Figure 2. In addition to understanding the payload planning process, it was imperative that the microgravity conditions under which these experiments will operate be understood. Microgravity is $9.8 * 10^{-6}$ or one millionth as strong as it is on Earth.

The Utilization Analysis Branch secured a Drop Tower facility from NASA Lewis Space Center to demonstrate the effects of microgravity. Learning this facility then became one of the tasks outlined for this position. The facility consisted of an eight foot tower apparatus, a small camera, a monitor, a video camera recorder (VCR), a trunk and six specimens as shown in Figure 3. The specimens used were a scale with a mass, oil in a tube, two magnets, a pendulum, oil mixed with water and a lit candle. The mini drop tower or free-fall tower was assembled such that a pulley could hoist the box containing a camera and the specimen to the top of the tower. The pulley was then released, thus allowing box to drop to the bottom of the trunk. During the fall the camera recorded the specimen's activity. Through this demonstration, the use of six objects was observed. A scale with a mass on it was used to show the effects of microgravity on weight or mass of an object. Oil in a tube was used to show the effects of microgravity on pipe flow, two magnets were used to show how magnetic force was effected, a pendulum was used to show how momentum was effected, oil mixed with water was used to show how two different emulsible fluids mix, and a lit candle was used to show the effects of microgravity on convection.

It was requested that a viewing analysis be performed to identify the capability to monitor the US LAB during the build-up sequence. Using the Netscape interactive software tool, results of a viewing study where cameras were used to monitor different parts of the ISS

were located. Netscape, first, provided a list of viewing equipment settings. From these findings, the pictures highlighting the US LAB were identified. The picture that provided the best viewing of the US LAB was called lower port camera looking starboard shown in Figure 4. This data was downloaded and included in a report to document that the requested capability existed.

After completing most of the tasks that were required, questions arose about fatigue that may be experienced by the ISS components. Thus, observations of the non-destructive testing of cracks were arranged. The first step in this procedure was polishing small pieces of aluminum with paste and sandpaper. These specimens were then placed in an Instron 8500 with a capacity of 22.48 Kips where they underwent extensive testing.

1.3 RESULTS/CONCLUSION

Each of these tasks, demonstrations, and experiments contributed to payload planning. The updated OSAT traffic model helped to organize Code X payloads for the current PUP. The database generated as a part of this summer program was instrumental in the development of a spreadsheet outlining the percentage of resources allocated to the payloads proposed for Station.

The results of the Drop Tower experiment were as follows. The gravitational forces were reduced as these objects were permitted to fall. The mass briefly became weightless, the oil flowed up the sides of the tube, magnetic force was reduced, momentum was either reduced or increased depending upon the position of the pendulum when it was dropped, beads of oil remained still in the water, and the shape of the flame on the lit candle took on a spherical shape versus an elongated one. These results were all documented on the VCR tape. The demonstration was performed as an exhibit at the Virginia Air and Space Museum.

The viewing analysis task was required to determine if more money needed to be allocated to provide the means to monitor the Lab. The results confirmed that the ability to monitor the US LAB during the assembly sequence already existed. Thus, only modifications to the film format need to be made.

The project involving the non-destructive testing of cracks had not been completed by the time of this report. However, scientists will be to analyze the data collected from the non-destructive testing procedures and predict any fatigue that may be caused on the ISS.

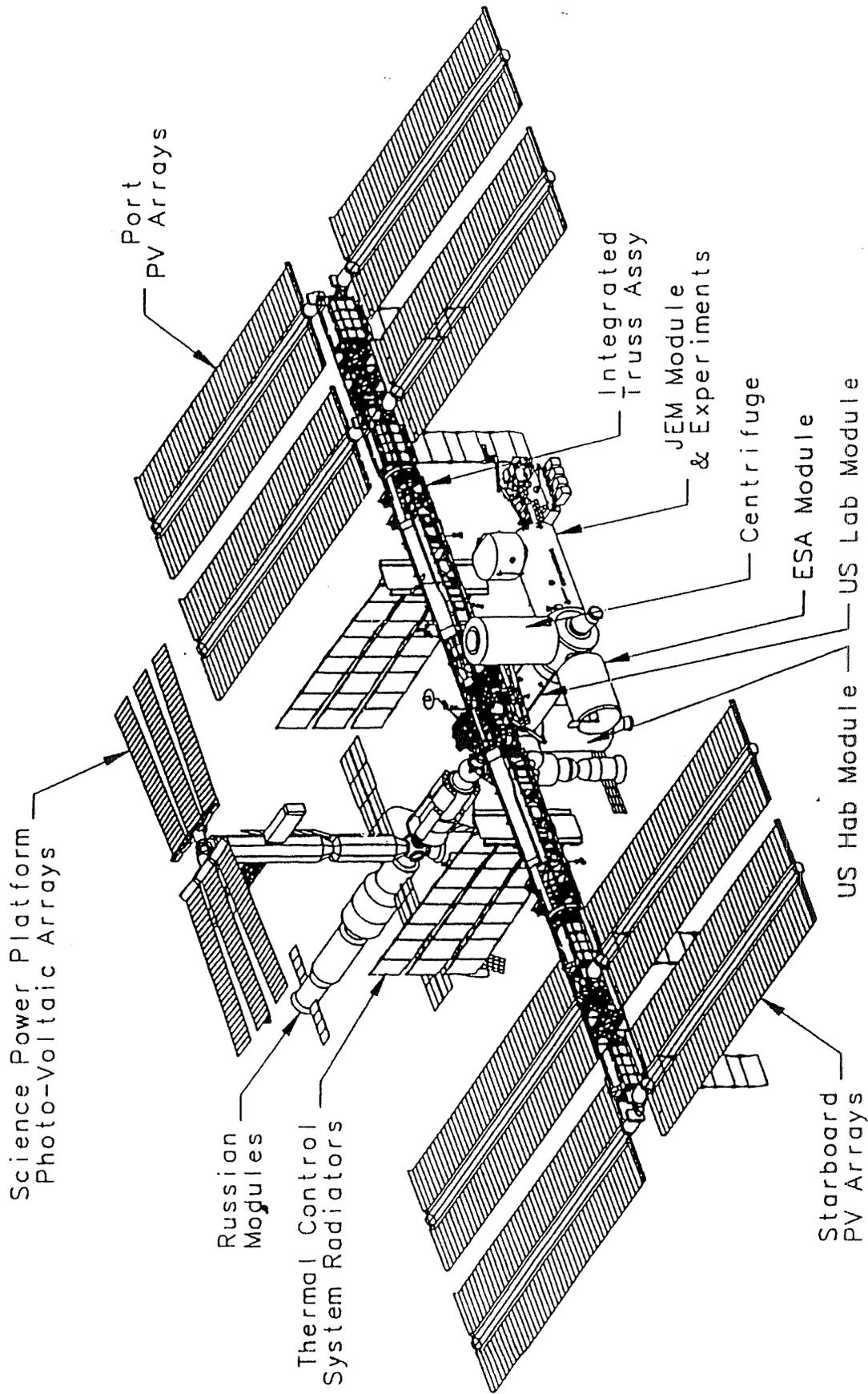


FIGURE 1 COMPONENTS OF ISS

BioServe

BITE Biomedical Isomorphisms Test Equipment			
<input type="checkbox"/> UF-3	<input type="checkbox"/> UP	July 1, 2000	6.6 runs during Increment
<input type="checkbox"/> UF-4	<input type="checkbox"/> ON-OR	February 1, 2001	4.4 runs during Increment
<input type="checkbox"/> 2E	<input type="checkbox"/> ON-OR	June 1, 2001	4.4 runs during Increment
<input type="checkbox"/> UF-5	<input type="checkbox"/> ON-OR	November 1, 2001	5.5 runs during Increment
<input type="checkbox"/> UF-6	<input type="checkbox"/> ON-OR	April 1, 2002	5.3 runs during Increment
<hr/>			
GBR Generic Bioprocessing Rack			
<input type="checkbox"/> UF-2	<input type="checkbox"/> UP	July 1, 1999	18.5 runs during Increment
<input type="checkbox"/> UF-3	<input type="checkbox"/> ON-OR	July 1, 2000	9.9 runs during Increment
<input type="checkbox"/> UF-4	<input type="checkbox"/> ON-OR	February 1, 2001	6.6 runs during Increment
<input type="checkbox"/> 2E	<input type="checkbox"/> ON-OR	June 1, 2001	6.6 runs during Increment
<input type="checkbox"/> UF-5	<input type="checkbox"/> ON-OR	November 1, 2001	8.3 runs during Increment
<input type="checkbox"/> UF-6	<input type="checkbox"/> ON-OR	April 1, 2002	8.0 runs during Increment
<hr/>			
TeMPO Test Module for Plants/Organics			
<input type="checkbox"/> UF-3	<input type="checkbox"/> UP	July 1, 2000	6.6 runs during Increment
<input type="checkbox"/> UF-4	<input type="checkbox"/> ON-OR	February 1, 2001	4.4 runs during Increment
<input type="checkbox"/> 2E	<input type="checkbox"/> ON-OR	June 1, 2001	4.4 runs during Increment
<input type="checkbox"/> UF-5	<input type="checkbox"/> DOWN	November 1, 2001	0 runs during Increment
<hr/>			
CMC			
<hr/>			
CPCG Commercial Protein Crystal Growth			
<input type="checkbox"/> UF-1	<input type="checkbox"/> UP	February 1, 1999	3.0 runs during Increment
<input type="checkbox"/> UF-2	<input type="checkbox"/> ON-OR	July 1, 1999	7.2 runs during Increment
<input type="checkbox"/> UF-3	<input type="checkbox"/> ON-OR	July 1, 2000	3.9 runs during Increment
<input type="checkbox"/> UF-4	<input type="checkbox"/> ON-OR	February 1, 2001	2.6 runs during Increment
<input type="checkbox"/> 2E	<input type="checkbox"/> ON-OR	June 1, 2001	2.6 runs during Increment
<input type="checkbox"/> UF-5	<input type="checkbox"/> ON-OR	November 1, 2001	3.3 runs during Increment
<input type="checkbox"/> UF-6	<input type="checkbox"/> ON-OR	April 1, 2002	3.1 runs during Increment
<hr/>			
XRDA X-Ray Diffraction Apparatus			
<input type="checkbox"/> UF-5	<input type="checkbox"/> UP	November 1, 2001	55.7 runs during Increment
<input type="checkbox"/> UF-6	<input type="checkbox"/> ON-OR	April 1, 2002	53.7 runs during Increment
<hr/>			
CMDS			
<hr/>			
Foam Foam Structure SS Demonstration			
<input type="checkbox"/> TBD	<input type="checkbox"/> UP	December 31, 2006	0.5 runs during Increment
<hr/>			
MD/CBAP Materials Dispersion and Cell Bioprocessing Applications Project			
<input type="checkbox"/> UF-1	<input type="checkbox"/> UP	February 1, 1999	15.3 runs during Increment
<input type="checkbox"/> UF-2	<input type="checkbox"/> ON-OR	July 1, 1999	37.6 runs during Increment
<input type="checkbox"/> UF-3	<input type="checkbox"/> ON-OR	July 1, 2000	37.6 runs during Increment
<input type="checkbox"/> UF-4	<input type="checkbox"/> ON-OR	February 1, 2001	37.6 runs during Increment

FIGURE 2 EXAMPLE OF PAYLOAD DATABASE

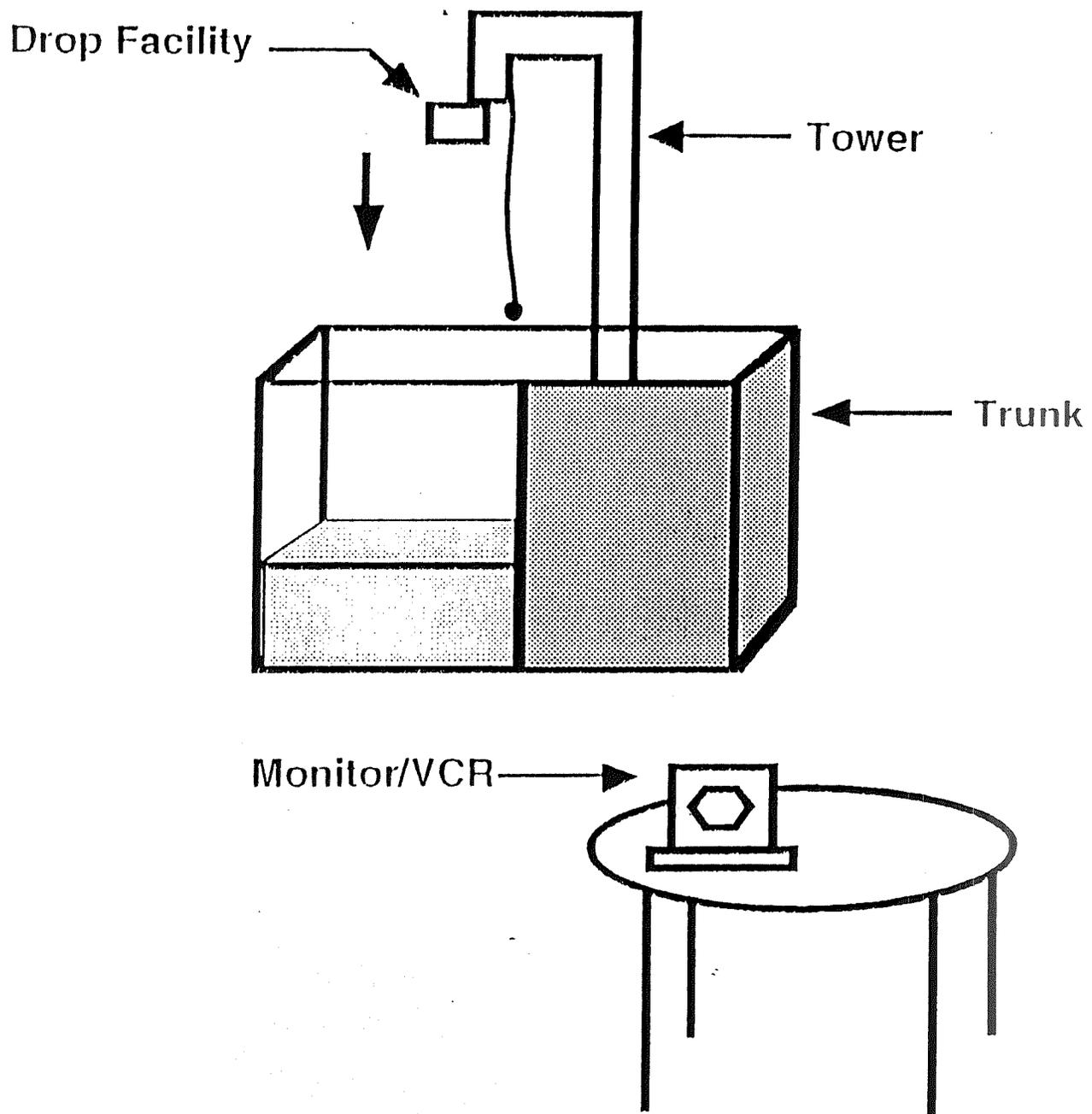


FIGURE 3 DROP TOWER FACILITY

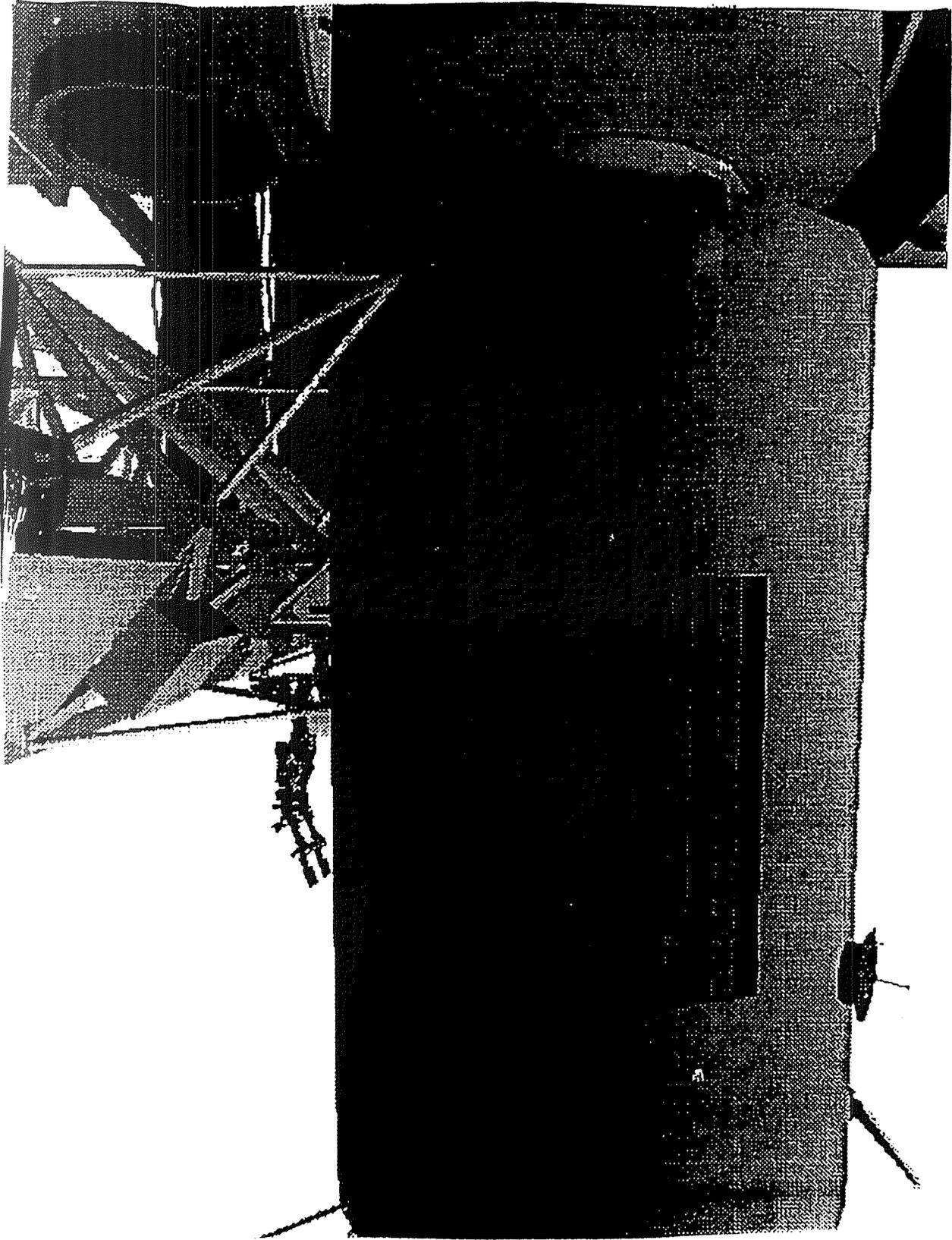


FIGURE 4 LOWER PORT CAMERA LOOKING STARBOARD

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**Free-Flight Evaluation of
Forebody Blowing for Yaw
Control at High Angles of Attack**

**Jason Kiddy
University of Maryland
at College Park**

Mentor: Jay Brandon

**Vehicle Dynamics Branch
Flight Dynamics & Controls Division
Research and Technologies Group**

July 31, 1995

Abstract

Forebody blowing is a concept developed to provide yaw control for aircraft flying at high angles of attack where a conventional rudder becomes ineffective. The basic concept is fairly simple. A small jet of air is forced out of the nose of the aircraft. This jet causes a repositioning of the forebody vortices in an asymmetrical fashion. The asymmetric forebody vortex flows develop a side force on the forebody which results in substantial yawing moments at high angles of attack.

The purpose of this project was to demonstrate the use of forebody blowing as a control device through free-flight evaluation. This unique type of testing was performed at the NASA-Langley 30- by 60- Ft Tunnel. From these tests, it could then be shown that forebody blowing is an effective method of maintaining yaw control at high angles of attack.

Prior Efforts

Before joining this project, much work had already been completed towards the same end. Primarily, the model configuration had been decided upon and constructed. Furthermore, static tests were performed to determine the aerodynamic characteristics of the model.

The configuration chosen for the model was one of a 'generic' fighter aircraft. In particular, the configuration is very similar to an old NASA design which was used to evaluate configuration effects on stability characteristics. The design features a rudder, differentially moving horizontal tails, and ailerons in addition to the blowing ports along the forebody. The model was constructed by the Eidetics Corporation and then brought to NASA-Langley's 30- by 60- Ft Tunnel for static testing.

A static test is one in which the aircraft is mounted rigidly inside a wind tunnel. By placing each of the control surfaces at different positions under various conditions, the aerodynamic qualities of the model can be determined. This is particularly important for developing a control system for an aircraft. One must know what effect each surface will have on the aircraft in order to control the aircraft.

Development of Control System

In order to actually fly the model, a suitable control system had to be developed. In particular, a control system which incorporates the effects of forebody blowing. The first step to this process is determining the stability of the aircraft. At all angles of attack, the aircraft must remain stable in both roll and yaw. Generally, the basic aircraft with no control surfaces remains stable. However this is not always the case at high angles of attack. If it is not stable, proper inputs to the control surfaces may be needed to obtain stability.

Once stability is obtained, the maximum expected roll rates can be determined. One major limiting factor to roll performance is the requirement of roll coordination. For an aircraft at a high angle of attack, it is necessary to couple yaw commands with roll commands so as to avoid undesirable sideslip. However, yaw control induced by the rudder is greatly decreased at these angles of attack. It is at this point that forebody blowing becomes necessary. However, there is generally still not enough yaw performance to match the roll capabilities and roll rate limits must be set. Using the controls available to meet the conditions of stability and roll coordination gives some idea as to the theoretical capabilities of the model and a starting point for refining the control system.

Finally, the control system was developed as a block diagram. Two separate control systems were developed. One for the lateral control system and the other for the longitudinal control system. The longitudinal control system is a fairly basic system. The only control surfaces are the horizontal tails and thrust vectoring. Thrust vectoring was being added to the original model to give added control at high angles of attack if necessary. Similarly, this system only contained three inputs. One each for the pilot's stick and trim knob and then a feedback input of pitch rate. The pitch rate feedback was used as a dampening mechanism to prevent the model from oscillating. An angle of attack feedback was originally included to limit the angle of attack but it was never employed during free-flight.

However, the lateral control system is much more complicated. This control system used the rudder, ailerons, differential tails, thrust vectoring, and forebody blowing as control surfaces. Furthermore, the pilot's stick and trim knobs were accompanied by roll rate and yaw rate dampers, sideslip feedback, and roll coordination inputs. Also, switches were required to bypass almost every feedback loop and control surface if desired. The following page illustrates this control system.

One major difficulty in developing this control system was the nature of forebody blowing. The blowing is effectively on or off which is unlike the other surfaces which can travel through a range of motion. Therefore, it is only possible to get the entire effect of blowing or no effect at all. This phenomena is produced for two reasons. First of all, the valve controlling the blowing can only be open or closed. And secondly, static data showed that the yawing moment caused by the forebody blowing was very nonlinear with respect to the air pressure.

Finally, a combiner was developed to coordinate the horizontal tail motion commanded by the longitudinal system with the differential tail motion commanded by the lateral control system. Once this was finished, the system was ready to be tested through simulation.

Simulation

In order to refine the control system, the SIMULINK toolbox for the computer program MATLAB was used. In SIMULINK it is possible to model the entire control system. Furthermore, the aircraft itself can be modeled through a series of state-space equations. These state-space equations employ the control surface deflections as inputs and output the various states of the model. In particular, the state-space equations output the roll and yaw rates, the sideslip angle and roll angle for the lateral control system. These outputs are then sent back into the control system to determine the deflection of the control surfaces.

Then, various gains can be placed into the control system for a given angle of attack and the resulting aircraft response can be determined for a given stick input. By changing the various gains in the control system, an optimal setup could be found for each angle of attack.

A similar process was repeated for the longitudinal system. Again, this was much simpler than the lateral system. Once the gain schedules were completed, the control system was turned over to the programmer who wrote the actual code to be used during free-flight.

Model Preparation

Once the control system was finished, the next stage was to finish preparing the model for free-flight. The same model that was used during the static tests was converted for free-flight. This process consisted of adding an actuator to power each control surface, installing the thrust components including thrust vectoring, and adding the data acquisition equipment. Most of this work was completed by technicians while the control system was being developed. After these components were added, the model was weighed and

balanced. The additional weight of the actuators caused the aircraft's center of gravity to shift rearward. Therefore, it was necessary to add a relatively large mass to the nose. Once this was done, the true moments of inertia along all three body axis could be determined by swinging the model and measuring the natural frequencies. The actual moments of inertia were then used to update the predicted response characteristics of the model.

The next stage was to lift the model into the tunnel and prepare it for free-flight. Air hoses and electrical wires were attached to the model at the center of gravity. Finally, each control surface was calibrated and the model was ready for free-flight.

Free-Flight

Free-flight wind tunnel testing is unique to NASA Langley's 30- by 60- Ft Tunnel. The tunnel is designed with an open test section which allows enough room and the proper facilities to actually fly a model within the tunnel. Compressed air is used to provide thrust and to power the actuators which move the control surfaces. Electrical wires are also attached to the plane to relay data between the plane and the control computers. These wires are attached to the aircraft at its center of gravity to avoid affecting the aerodynamics as much as possible.

The plane is flown by three separate pilots. One pilot is located below and behind the model. This pilot is responsible for the yaw and roll control of the plane. The other two pilots sit above and beside the model. One is the pitch pilot and the other controls the thrust. This setup allows the plane to be actually flown under controlled conditions with no risk to human life at a relatively cheap cost. Furthermore, the control system can be quickly and easily altered from the control room in case of any unexpected problems.

For this test, the free-flight program was to consist of several aspects. The primary objective was to show that the model could be flown at high angles of attack with the use of forebody blowing. To show this, the model was to be flown at a certain angle of attack with the use of thrust vectoring. Then, forebody blowing would be engaged and the thrust vectoring turned off. Finally, the blowing would be disengaged. At this point, the model would probably become unflyable. This would then show that the blowing provides enough control to fly at that angle of attack which was not possible without blowing. This was to be performed throughout a wide range of angles of attack to fully evaluate its flight envelope with and without forebody blowing.

A second object of the experiment was to determine the reaction time of the blowing. If the vortices caused by the forebody blowing took too long to form, the blowing would become impractical. To determine this, the aircraft was to be flown steadily without blowing. The blowing would then be manually engaged for a second or so and the corresponding response could be recorded.

Unfortunately, the free-flight program met with many problems. The most common problem was one where the rudder became uncontrollable. The nature of the problem was never discovered, but it caused a stop for repairs several times. Each time, the rudder resumed working properly after a short period of time for no apparent reason. Another problem was a large amount of noise in the electrical system. Again, the cause of the noise was never discovered but it was enough to cause a great deal of tail flutter and it made the data less accurate.

However, we were able to make several runs where sufficient data was obtained on the response time for the blowing. Finally, the rudder and horizontal tails were completely disconnected. This solved the noise and rudder problems. However, the plane was now flying with only thrust vectoring and ailerons. This configuration proved to be adequate since the model was still flyable. Testing was done from thirty to fifty degrees angle of attack. It was clearly shown that the plane could fly with only forebody blowing up to fifty degrees. Static data estimated the maximum angle of attack without blowing to be around 35-40 degrees. Therefore, an increase of a minimum of ten degrees was obtained with only the forebody blowing. However, expected results with the use of the conventional rudder and tails would have been around sixty degrees angle of attack, an increase of twenty-five degrees.

Data Analysis

Upon completing the free-flight testing, the next step was to analyze the flight data. There were two main objectives to be gained from the flight data. The first was a quantized value for the response time. These were obtained by looking at the instances where the blowing was turned on and then off manually. The second objective was to ensure that the forebody blowing had the same characteristics during flight as it did for the static tests. This was done by examining the periods of flight where only forebody blowing was being used. To do this, yaw velocities were differentiated to find yaw accelerations. These accelerations were then used to find the yawing moments and non-dimensionalized to find the blowing derivatives. Finally these derivatives were compared to the static derivatives found earlier.

Conclusions

Although the free-flight program experienced many problems and an inadvertent crash halted the program early, most of the original objectives were satisfied. It was clearly shown that forebody blowing is an effective control mechanism at high angles of attack. The model was able to fly at high angles of attack while using only the forebody blowing for yaw control. Unfortunately, a complete envelope expansion with and without forebody blowing was not possible. This fact makes it more difficult to analyze how great of an increase in angle of attack that forebody blowing provides over the conventional rudder and tail setup.

The experiment allowed for an accurate representation of the response time. The time from the start of blowing to the maximum acceleration due to blowing is between .1 and .25 seconds. This is an excellent result because it shows that it is quick enough to be effective.

The free flight program met with many challenges and difficulties. But, the important result of demonstrating the effectiveness of forebody blowing was successfully accomplished. The possibilities of forebody blowing are clearly evident and should be examined in greater detail.

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**Conversion of the Aerodynamic Preliminary Analysis System (APAS) to an
IBM PC-Compatible Format**

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Abstract

The conversion of the Aerodynamic Preliminary Analysis System (APAS) software from a Silicon Graphics UNIX-based platform to a DOS-based IBM PC-compatible is discussed. Relevant background information is given, followed by a discussion of the steps taken to accomplish the conversion and a discussion of the type of problems encountered during the conversion. A brief comparison of aerodynamic data obtained using APAS with data from another source is also made.

Introduction

The Aerodynamic Preliminary Analysis System (APAS) is a software package that can be used to perform a wide range of aerodynamic analyses. APAS is a family of FORTRAN programs, and is used by the Vehicle Analysis Branch of NASA Langley, among others. It allows the user to input a wide range of aerospace vehicle geometries, and can then analyze those geometries in the subsonic, supersonic, and hypersonic flight regimes. Given a set of test conditions (such as Mach number, altitude, center of gravity location, surface roughness, rotation rates, and angle of attack or sideslip sweeps), the APAS system can provide the user with all six aerodynamic force and moment coefficients, as well as estimates for a number of their derivatives. In addition, APAS also allows the user to define control surfaces and estimate their effectiveness.

The APAS system consists of three separate programs. The first program is APAS itself, which is used to create and edit geometries to be analyzed, to set up analysis runs, and to plot the results from analyzed runs. The second program is the Unified Distributed Panel (UDP) program, which is used to perform subsonic and supersonic analysis of geometries. For subsonic Mach numbers, UDP uses a combination of slender-body theory, linear source and vortex paneling methods, and empirical base drag analysis. For supersonic Mach numbers, UDP adds in the effects from an empirical wave drag analysis. The third program is the Hypersonic Arbitrary Body Program (HABP), and is used to perform analysis of the hypersonic aerodynamic characteristics of geometries. HABP uses hypersonic impact methods for its analysis. Both HABP and UDP use empirical skin friction methods to calculate skin friction forces. HABP is a modified version of the Gentry code developed in the 1960's by McDonnell Douglas, and UDP and HABP were developed in the 1970's and 1980's, respectively, by Rockwell International.¹

All three of these programs have been periodically updated to enhance their capabilities and enable them to be run on different computer systems. At one time or another, each has been run on an IBM mainframe, and Sun and VAX workstations. Currently, the Vehicle Analysis Branch runs APAS on Silicon Graphics (SGI) machines. All of the computers running APAS have had a UNIX-based operating system, and all of them have supported the Tektronics Plot10 graphics library. The Plot10 library was used by the creators of APAS to support the graphical requirements of APAS itself. Primarily, these requirements were to be able to draw and interactively edit the geometry components to be analyzed, and to display data from the analysis performed by UDP and HABP. (UDP and HABP themselves do not require any graphical support, and hence do not make use of the Plot10 library.)

Over the last few years, it has been increasingly difficult to find emulation programs that can support the interactive use of the Tektronics Plot10 library. As a result, there is a movement underway to replace the Plot10 references in APAS with a more modern standard X-based UNIX graphics package.

In addition to the increasing difficulty of finding proper emulation, the last decade has seen an explosion in the use of personal computers (PC's). There are now orders of magnitude more people who have access to PC's than to large, expensive UNIX mainframes and workstations. Accordingly, there has been an increasing call for a version of APAS that will run on a PC. This project was undertaken to fulfill that call. It was the aim of this research project to create a version of APAS system to run on a late-model IBM PC compatible, to validate the solutions given by this new version against the existing (UNIX) version, and to package this version in a form that allows the easy distribution of both the executable files and the source codes.

Approach Taken

The approach taken to this project involved a number of steps. First, the source files for APAS, UDP, and HABP were gathered and transferred over to an IBM PC compatible computer. Then, time was spent with each of the codes getting them to compile properly. At this stage it was necessary to change some calls to nonstandard FORTRAN-77 routines. Once each program was compiled and linked, APAS itself was debugged to a rough but usable level; bugs which would crash the program during normal execution were fixed, but less serious problems were left alone. It should be noted at this point that a contractor had previously written a set of routines to mimic the Plot10 library on a PC using the Watcom FORTRAN 77 compiler's graphics library. However, these routines had never been fully integrated into APAS or tested with it. It was at this point that the testing and debugging of these new Plot10-substitute routines occurred.

Once APAS had reached a level where geometries could be created and set up for analysis, the process of testing and debugging HABP and UDP began. At first, very simple geometries were created and analyzed to catch any immediate run-time errors that occurred. Then, more complex configurations such as a model of the Space Shuttle Orbiter were used for direct comparison with results obtained from the SGI versions of HABP and UDP. During this process a number a bugs were discovered, some of which were the result of errors in the original source code. These errors may need to be corrected in the current versions of the codes. This process continued until the PC and SGI versions of HABP and UDP showed identical results on multiple configurations.

Once HABP and UDP were deemed to be operating properly, work on APAS itself was finished. A number of minor, mostly cosmetic bugs were corrected. In addition, new code was written to allow the use of a mouse when using the Plot10-substitute routines. (The original APAS allows the use of the mouse.) Then, once APAS was finished, a few external utilities that typically accompany the APAS system were compiled and tested. A listing of all of the changes made to each of the APAS programs, and the reasons why the changes were made was then documented.

The final step in this project was to create a set of compressed files for easy distribution of APAS. One compressed file contains the executable files and other files

necessary to run APAS. This file also contains a README text file to explain how to run each program, as well as and other information about the PC variations from the UNIX APAS. The other compressed file contains the source codes and information about what was changed in the source files.

LaRC Equipment Used

Only a small amount of equipment was needed for this project. The primary piece of equipment used was a Dell 66 MHz Pentium computer with the Watcom FORTRAN 77 32 bit Compiler (version 9.5c) in the Vehicle Analysis Branch. The Silicon Graphics computers in the branch were used to provide the benchmark platform against which the PC version of APAS was compared. The Langley Technical Library was also used for references about programming for the mouse on a PC.

Results

Two different topics will be addressed in this section. The first will be a description of the types of corrections which needed to be made to the original APAS source codes, and what action was taken to correct them. The second will be a brief comparison of the data obtained from APAS with data from the Aerodynamic Design Data Book for the Space Shuttle Orbiter.

Problems encountered in conversion

A detailed discussion of every change made to the APAS source files is beyond the scope of this report. Instead, a general discussion of the types of problems encountered and what was done to resolve them will be included here.

The first major type of problem encountered in converting APAS was the occurrence of compiler- or platform-specific references in the original source codes. A number of these problems were quite simple, such as the use of double quotes in the INCLUDE statements in UDP, which had to be replaced by single quotes for the Watcom system. Some of these problems were caused by calls to non-standard FORTRAN 77 functions that perform system-specific tasks such as accessing the current system time or date, reading additional words used on the command line when the executable file was invoked, and exiting the program with a return code. They were fixed by replacing the SGI compiler function calls with their appropriate Watcom compiler equivalents. In addition, a number of calls to functions which did not have Watcom equivalents were encountered. These were primarily trigonometric functions using degrees instead of radians. The prevalence of these functions in the source codes made it simpler to create a few additional functions with a radians to degrees conversion than it would have been to replace all of the calls to them in the source files. A final change in this category in the handling of files. On previous systems where APAS was used, the limits on the number of files open and the numbers of characters in a filename were much larger than on the PC. It was necessary to add a statement to HABP and UDP which increased the number

of files that could be opened by the programs, and to truncate any filenames that were too long.

For the most part, these types of problems were relatively quick and easy to solve (although INCLUDE statements with double quotes appeared in about three fourths of the UDP subroutines, and were time-consuming to replace). Once aware of them, they did not present much difficulty to correct. However, the use of compiler-specific routines in the source codes will continue to present a barrier when taking the software from one platform or compiler to another.

The second major class of problems encountered was errors in the original source codes. A few of these errors, such as incorrect FORMAT statements, were easy to spot and relatively harmless, but most caused substantial problems and were hard to find. Most of the errors centered around the definition, typing, and initialization of variables. In a few cases, it was obvious that an INCLUDE file containing a needed common block was missing. In these cases, the required INCLUDE statements were added. In a larger number of cases, an apparent typographical error led to using a variable that was never defined or initialized in a particular routine. Most of these cases were remedied by replacing the variable with another variable in the routine which seemed like the one that original programmers must have intended. A number of errors were also caused by differences in the arguments of COMMON blocks in different routines, or by assigning variables different data types as they are passed from one routine to the next. These errors were corrected when they seemed to cause a problem. Lastly, a couple of coding errors were discovered that resulted when the code was prepared for use with the SGI compiler. Apparently, the SGI compiler cannot handle using nested exponents on a single line. In a couple of instances in HABP, the lines replacing the original nested exponentiation were mathematically different from the originals, and hence generated incorrect results. These lines were changed to restore the original mathematical expressions.

This class of problems was far more insidious than the first class and occupied a large portion of the time spent testing and debugging the APAS programs. The instances of errors that seemed to be causing problems appear to have been fixed. But there is no guarantee that errors of this type will not resurface. There are still quite a number of common blocks that have multiple type definitions, and quite a number of variables with multiple types, that were left in place. The potential exists for many more errors of this type to surface in the future if the code is moved to other systems or if more thorough testing is done.

The last major type of problem encountered when converting APAS to run on a PC was the difference in graphical formats used in the PC and Plot10 systems. These problems were only encountered in APAS, since HABP and UDP do not have any graphics. A number of problems were caused by what appeared to be errors in the Plot10-substitute library code. They were most likely the result of not fully integrating and testing the new library with APAS, and all of them that were found were fixed. In a few cases, minor errors in text or symbol positions had to be corrected. They were probably caused by the differences in a PC screen resolution, which is 1024x768 pixels and the Tektronics terminal, which was 4096x3180 pixels. A final problem of this type was the difference in the use of graphical and text-based text between the two systems. On a Tektronics terminal, both graphically drawn text and regular text could be positioned in

the same fashion. The PC uses a different means to position each kind of text. In cases where the text position was considered critical, graphical text reads and writes were substituted for text-based ones in the PC version.

Most of these types of issues were not absolutely critical to the functioning of APAS, but correcting them made APAS a much nicer program to use. The most serious problems of this type were actually errors in the original source code (such as multiply-typed variables) which did not cause problems for Plot10 graphics, but could cause the Watcom PC graphics to crash the program.

One additional issue that needed to be addressed in this area was the use of a mouse to move the cursor when viewing or editing the geometry components of a vehicle. The original Plot10 library supported the use of the mouse, since it was directly supported by the keyboard interface. (Originally, before the use of the mouse became prevalent, keyboard thumbwheels were used.) The Plot10 replacement routines for the PC did not include mouse support, instead relying on the keyboard cursor keys to move the cursor around the screen. While this performs adequately, it was desirable to have mouse support on the PC as well in order to more closely copy the "feel" of the original APAS. To do this on a PC, a few additional lines of code had to be written to issue calls to DOS assembly language interrupts to position and reposition the mouse cursor. Unfortunately, the resulting mouse movement seemed jerky and was hard to position precisely. As a result, a dual-movement method was used. The user can move the cursor with the mouse and then press the mouse button, which will allow the user to either reposition the cursor with the cursor keys or to enter a desired keyboard command.

APAS comparison for Space Shuttle Orbiter configuration

Comparisons of the results obtained from APAS analysis of the longitudinal aerodynamic characteristics of the Space Shuttle Orbiter with the values contained in the Shuttle's Aerodynamic Design Data Book (ADDB) will now be discussed. The comparisons have been made for varying angles of attack at two Mach numbers, one subsonic (Mach = 0.6) and one hypersonic (Mach = 15). It should be noted that many more comparisons and validations of the code than those discussed here were made. However, in the interest of space, only these two cases will be discussed.

The APAS model of the Shuttle Orbiter used for this comparison is shown in Figure 1. The data for the subsonic comparison is shown in Figure 2. The values of the lift, drag, and pitching moment coefficients (C_l , C_D , and C_m) are shown as functions of angle of attack (α). The results obtained from the APAS (UDP) analysis are shown as straight lines, and values from the Aerodynamic Design Data Book are shown as "+" characters. From Figure 2 it can be seen that the lift and drag curves are generally in fairly good agreement with the values from the ADDB. UDP slightly overpredicted the slope of the lift curve and slightly underpredicted the drag, but these differences are small. The pitching moment curve, however is significantly different from the values in the ADDB. This is probably due to the fact that only linear terms were used in this particular analysis. Other studies done with APAS have shown considerably better agreement.

The data for the hypersonic comparison is shown in Figure 3. As in Figure 2, the values of the lift, drag, and pitching moment coefficients (C_l , C_D , and C_m) are shown as

functions of angle of attack (α), and the results obtained from APAS (HABP) are shown as straight lines. The lift and drag curves show even better agreement with the ADDB data for this case than they did for the subsonic case. The pitching moment curve shows somewhat better agreement in this case than in the subsonic case, although it is largely in error in some places. This is most likely due to an error in the prediction in the center of pressure in HABP. For the shuttle, this error has been shown to be about two percent of the body length. If the center of gravity in APAS were to be moved forward by two percent, it is likely that the discrepancy between the APAS data and the data from the ADDB would be substantially less.^{2,3}

Conclusions

The Aerodynamic Preliminary Analysis System (APAS) software has been converted from a Silicon Graphics UNIX-based platform to run on a DOS-based IBM PC-compatible. The APAS software has been tested, debugged and validated for a number of representative cases. APAS has now been packaged in a way that it is easy to distribute both the executable files and the source files, and in such a way that it is easy for whoever receives the distribution files to install and run them. A discussion of the relevant background information, the steps taken to accomplish the conversion and the types of problems encountered during the conversion has been made. A brief comparison of data obtained using APAS with data from another source has also been made. The following conclusions are drawn:

- 1) The types of problems encountered in converting APAS to a run on a PC included those caused by compiler-specific references, those caused by errors in the original source codes, and those due to differences between the PC and Tektronics Plot10 graphics formats.

- 2) A number of errors in the original source codes still exist. Care must be taken to insure that these errors do not cause problems in the future.

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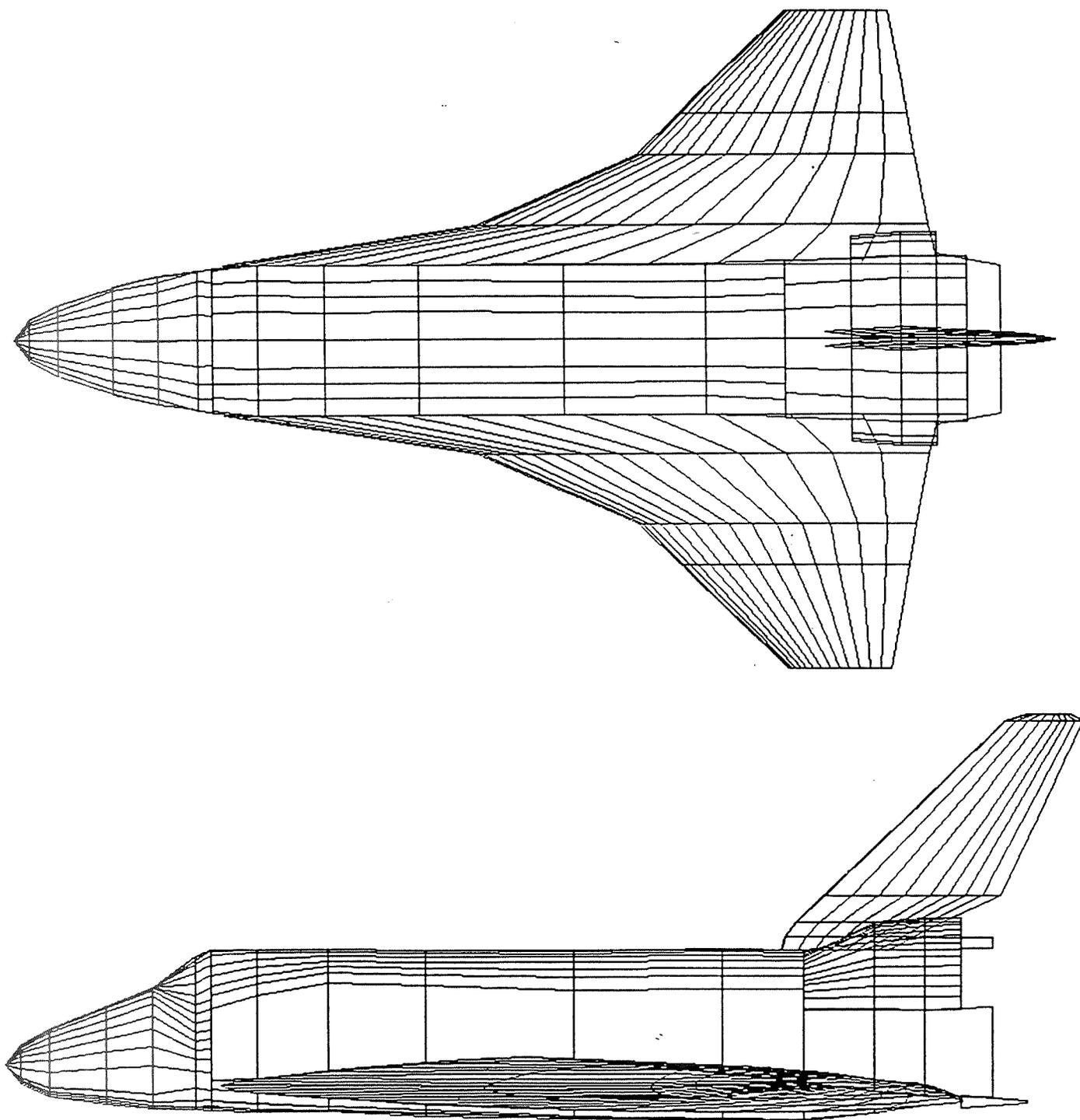


Figure 1. APAS model of Space Shuttle Orbiter, top view (top) and side view (bottom).

Subsonic Longitudinal Data

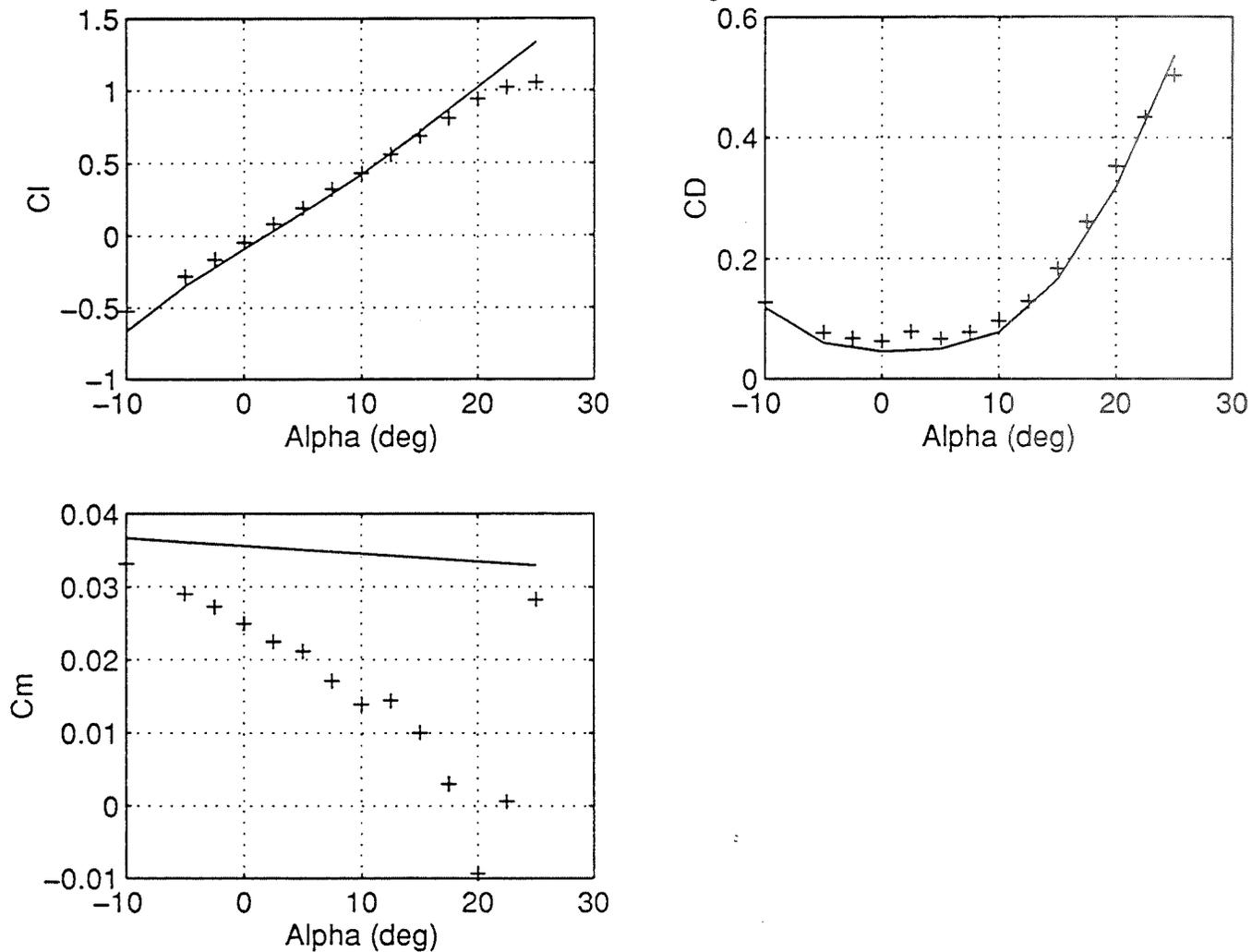


Figure 2. Subsonic longitudinal aerodynamic data.

Hypersonic Longitudinal Data

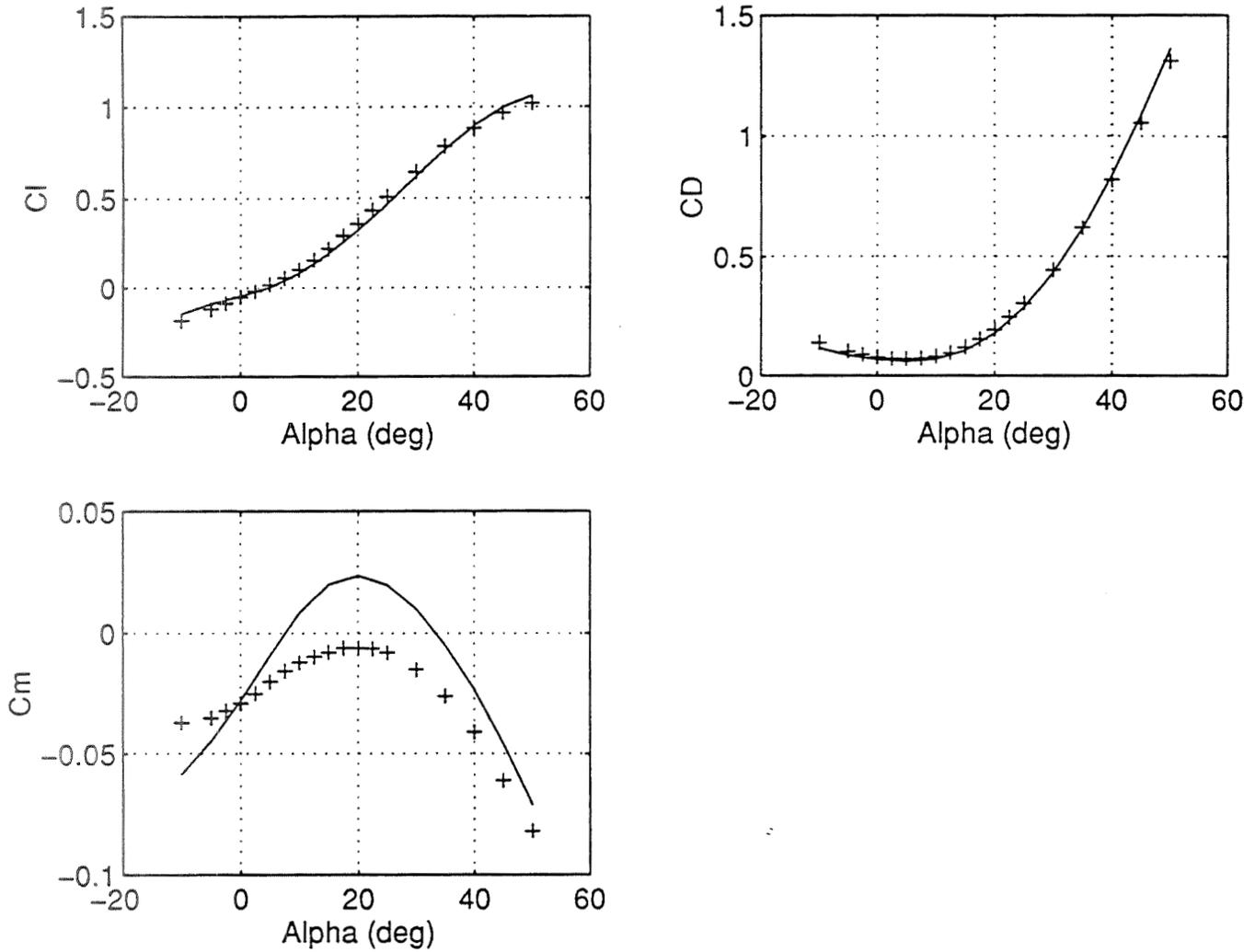


Figure 3. Hypersonic longitudinal aerodynamic data.

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**Modeling of the Expected Lidar Return Signal for
Wake Vortex Experiments**

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Abstract

A computer program that models the Lidar return signal for Wake Vortex experiments conducted by the Aerosol Research Branch was written. The specifications of the program and basic theory behind the calculations are briefly discussed. Results of the research and possible future improvements on it are also discussed.

Introduction

Recently, the Aerosol Research Branch of the Atmospheric Sciences Division at Langley Research Center began undertaking Lidar based measurements of the Wake Vortex regime of an airplane. This research is of significant interest for many reasons. First, the entrainment of the exhaust plumes by the wingtip vortices of the airplane effects the dilution of the exhaust gases into the atmosphere. It can also result in chemical reactions that can lead to the formation of highly reactive species such as sulfur oxides and nitrogen oxides. These can in turn effect the atmosphere. Increased knowledge of wake vortex phenomena is also of interest for airplane safety since aircraft vortices have been linked to several airplane crashes. Much of the work done on vortex phenomena has been in the area of numerical modeling, such as Continuum Dynamics' UNIWAKE program. There has been very little experimental verification of these models. The Lidar based investigations hope to provide such verification, as well as other information such as the types and sizes of exhaust particles. In conducting these experiments it is obviously useful to know how high the quality of the data can be expected to be for different experimental setups. For this reason it is useful to have a working model that can provide such information and which agree well with experimental data.

Summary of Research

The goal of this research has been to create a computer program that would produce a theoretical Lidar return signal that is as realistic as possible. It is hoped that this can provide information about the experimental setups that will yield the best data, and what kind of data quality can be expected from them. The program models the scattering of a laser pulse off atmospheric molecules and the exhaust particles of the aircraft plume, which has been entrained into the wingtip vortices. The program is written in the Interactive Data Language (IDL) version 3.6.1 for use on a PC.

The problem is approached primarily from a theoretical standpoint. Given a laser with a certain wavelength and power, the power elastically backscattered off the atmospheric molecules into a particular light detector is calculated using the formulae for Rayleigh backscattering coefficients as provided in Raymond Measure's, Laser Remote Sensing: Fundamentals and

Applications. The amount of backscattered light is sampled every 1.5m, which is the same sampling interval the detectors in the actual experiments use. The molecular density of atmospheric molecules is also required for this calculation. This is calculated for the different altitudes using the methods described in U.S Standard Atmosphere, 1976. The program also calculates the amount of Mie backscattered power scattered off the particles in the exhaust plume of an aircraft. The plume is assumed to have a gaussian vertical distribution with a full width half maximum given by the program user and centered about an altitude also given by the user. The particle size distributions are taken from previous work done by June E. Rickey, but the program allows for other size distributions to be used. The amount of Mie backscattered power is calculated using a Mie scattering program from C.F. Bohren and D.R. Huffman's Absorption and Scattering of Light by Small Particles. To determine how much of the backscattered radiation is detected the radius of the telescope is required, as well as the reflectances and transmissions of the various mirrors and beam splitters in the detector system. These can all be entered and altered by the user.

Once the amount of backscattered power is known, this can be converted to the number of photons per second detected by dividing by the individual photon energy. Also, the total number of photons detected in each 1.5m range bin can be calculated. Multiplying this number by the efficiency of the Photomultiplier tubes in the detector assembly yields the number of photoelectrons detected in each range interval. At this point, synthetic noise is added to make the model more realistic. This is done using the random number generator provided by IDL. The resulting model return signal looks qualitatively like an actual return signal.

This signal is then compared with an actual return signal to determine how realistic the model is. The model is found to give a significantly higher signal to noise ratio than the experimental signal. Thus an additional factor must be added to the model to downgrade the performance of its detector assembly. This is still in the process of being done.

In conclusion, this program produces model Lidar return signals that qualitatively resemble experimental Lidar return signals. With further work the programs output will more closely resemble an experimental signal and hence will be more useful. There are many improvements that can still be made to it. For example, a more user-friendly interface is being added making the program easier, as well as simplifying the process of changing the different input values. Also, better results might be obtained by changing the vertical plume distribution from a gaussian to one predicted by the UNIWAKE model or some similar one. Unfortunately, time has run out to incorporate this into the program.

omit

Langley Sign Language Home Page

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Abstract:

I designed a sign language home page for Langley that is easy to navigate through. The home page is made by using the World Wide Web, for those who are interested in learning sign language. In the home page, I linked the pictures to the clickable words so that when the words are clicked with a mouse, there is a picture of the proper sign for each word. When that picture is clicked again, a written description of how to sign that word would appear. I used the language, Hypertext Markup Language (HTML), for the home page. It will be available soon for Langley access.

The Internet plays a significant role in shaping the Information Age that we live in today. There is a wealth of information available today that are being used and exchanged everyday, thanks to the Internet. Today people can write to other people quickly anywhere around the world, people can get the specific information they want with the click of a mouse, or people can simply explore the world sitting down, all of it through the Internet. The Internet is a "global network of networks," connecting to thousands of computers and more than 35 million users around the world. Electronic mail is the most widely used in the Internet. Sending a fax is cheaper and quicker through the use of the Internet. The cost is the same, whether you are communicating from Boston to New York, or Boston to Singapore. So with access to thousands of networked computers worldwide, possibilities for the mutual exchange of ideas and collaborative cooperation are limitless.

The Internet is well-known for its user-friendly information portion, the World Wide Web. In WWW, it's easy to access and retrieve information instantly wherever the Internet location. The WWW is based on a client/server architecture, as are all other Internet applications. It is accessed from the client, called a browser, which can be a PC, Macintosh, or UNIX platform, but you don't have to connect directly to the server to find what you need. From a user's perspective, the connection is completely transparent. The WWW uses interactive, graphical links that form a web of connections across a worldwide computer network. Called the "Killer Application," the WWW supports hypertext and hypermedia documents, including graphics, audio, and video. Each WWW page is linked to other WWW pages with hyperlinks-words, phrases, and/or graphics. Each hyperlink is linked to the WWW address of a page containing additional information on the particular subject. The first document that generally appears upon accessing a WWW server is the "home page." A typical home page contains current information about a company, organization, or individual. It provides instant access, 24 hours a day to company background information, press releases, and data sheets, all presented in easy-to-read graphics format. Anyone can create a home page complete with text, graphics, sound and scanned photographs. Home pages of universities, government agencies,

museums, libraries, public officials, and even private individuals can be found on the Internet.

I designed the sign language home page using Netscape 1.1N. First, I had to think of what signs to put in my home page. After thinking a list of commonly used words, I used a sign language book called "The Joy of Signing" to scan the pictures of the signs using a scanner, SHARP Scanner V3.01, in the Data Visualization and Animation Lab, and converted it into a gif format so that the computer can read the text and change it to a picture of the sign. Using the software GIF Coverter in my Power PC, I resized the signs to make the squares of the signs all even. Using SimpleText and Microsoft Word from the computer, I wrote the language for the home page, Hypertext Markup Language (HTML), to embed the images and put in text in the document. HTML does not specify how the final document should look, it just specifies the document's structure. I input the text so that there was a list of common words, and linked them to the right signs using the link tag <A HREF>. That way when someone clicks a word, it links to a picture of the sign for the word and that person would see the sign. I again linked those pictures to written descriptions for more information, in which I also wrote the text, in case someone is not sure if he/she is following the signs right Next, I added some graphics to make the front page stand out with a big picture of a finger pointing out, along with the words, "You too can learn sign language" and colorful dots, taken from another home page in the WWW. The sign language home page will be put in a server soon, and everybody from Langley can access it.

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**A Variational Formulation for the Finite Element Analysis of
Sound Wave Propagation in a Spherical Shell**

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Abstract

Development of design tools to furnish optimal acoustic environments for lightweight aircraft demands the ability to simulate the acoustic system on a workstation. In order to form an effective mathematical model of the phenomena at hand, we have begun by studying the propagation of acoustic waves inside closed spherical shells. Using a fully-coupled fluid-structure interaction model based upon variational principles, we have written a finite element analysis program and are in the process of examining several test cases. Future investigations are planned to increase model accuracy by incorporating non-linear and viscous effects.

Introduction

An important problem in the design of commercial aircraft is noise reduction in both the cabin and the outside environment. The need for a low level of noise both inside and outside the airplane must be balanced with the need to maintain a light structure. We have undertaken a program of computational modeling of this system in order to develop the modeling tools necessary for design optimization of future aircraft.

A favorite computational scheme for studying problems of this type is the finite element method. The finite element method was first used for multi-disciplinary applications in the 1960's, when it was found to be appropriate for issues including heat conduction, hydrodynamic lubrication, and eigenvalue solutions of the Helmholtz equation for fluids vibrating in closed spaces [1], p. 274. One of the earliest instances of the employment of finite elements in structural-acoustic problems was by the automotive industry. In 1982, Nefske et al. [2] performed this kind of analysis for passenger car and truck cabins. In this work they present representations of the acoustic modes within the compartments as well as frequency response computations using modal synthesis.

Much other research has been done to establish a method of coupling the behavior of an enclosed fluid to the dynamics of the surrounding structure. Usually this is simply done by requiring that no fluid enters the solid surface. This implies that the surface normal component of the relative velocity between the fluid and the structure must equal zero. The equations of the solid and the fluid are thus solved separately, and the matching of the normal velocities at the surface forms the coupling. It is done this way because to start with the equations of motion for the whole system and simply try to apply a finite element method (such as a Galerkin method) results in difficult, asymmetric matrices. However, the problem with separate solution of the equations is that certain terms drop out which in fact would not drop out if a more complicated model of the interaction between fluid and structure was used. These terms are the mass terms, and their inclusion would make for more precise mathematical predictions.

Instead of starting from the equations of motion, we have started from a variational formulation of Hamilton's principle, and included the fluid-structure interaction as a constraint on the system. This formulation is based upon the work of Kock and Olson [3]. In our first case we have ignored gravitational and viscous effects. Though this is not an improvement upon previous methods, we wanted to use this simplest case as a method of comparison. It should produce exactly the same result as solving the equations separately and matching velocities. If it does so, the stage is set for the inclusion of additional terms into the statement of Hamilton's principle which will improve the accuracy of the model.

Variational Formulation

Hamilton's principle is a general statement about the conservation of energy of a system of particles (see, e.g. Bedford [4]). It states that the value of the integral over time of the kinetic minus potential energy of the system takes a minimum value. Using the common notation of variational calculus (see e.g. Courant and Hilbert [5]), this can be written as

$$\delta \int_{t_0}^{t_1} (T - U) dt = 0$$

in the case of a conservative system, where T is the kinetic energy and U is the internal energy. By using the principle of virtual work, Hamilton's principle is easily extended to apply to nonconservative systems (in which some force adds energy to the system), and also to systems where the generalized coordinates are not independent. Physically, this corresponds to the case where the quantities in question are related by some equations, and those equations are known as constraints. With the addition of constraints C and virtual work terms W , Hamilton's principle becomes

$$\delta \int_{t_0}^{t_1} (T - U + W + C) dt = 0. \quad (1)$$

For the problem at hand, we will use equation 1, with a virtual work term supplied by a surface force on the sphere, a constraint that enforces velocity matching on the boundary, and constraints that enforce local and global conservation of mass.

The solid shell contributes kinetic energy, potential energy and a surface force term.

$$T_s = \int_{\Omega_s} \frac{1}{2} \rho_s \left(\frac{\partial \bar{U}}{\partial t} \cdot \frac{\partial \bar{U}}{\partial t} \right) d\Omega_s, \quad U_s = \int_{\Omega_s} \frac{1}{2} \bar{\epsilon} \mathbf{C} \bar{\epsilon} d\Omega_s$$

$$W_s = \int_{\Gamma_s} \bar{U} \cdot \bar{f}_s d\Gamma_s. \quad (2)$$

Here Ω_s is the solid volume, Γ_s , the solid boundary, \bar{U} , the displacement vector, $\bar{\epsilon}$, the strain vector, \mathbf{C} , the material stiffness tensor, and \bar{f}_s is the surface force acting on the solid.

By taking into account the assumption that the shell is thin, we can change the volume integrals to surface integrals. This is due to the fact that we assume the displacements are linearly distributed throughout the thickness of the shell, so that the normal to the element is preserved – it remains normal and does not change in length under the deformation. Then the displacement components $\bar{U} = (U_1, U_2, W)$ can be written as

$$U_1(\alpha_1, \alpha_2, \zeta) = u_1(\alpha_1, \alpha_2) + \zeta \beta_1(\alpha_1, \alpha_2, 0),$$

$$U_2(\alpha_1, \alpha_2, \zeta) = u_2(\alpha_1, \alpha_2) + \zeta \beta_2(\alpha_1, \alpha_2, 0),$$

$$W(\alpha_1, \alpha_2, \zeta) = w(\alpha_1, \alpha_2),$$

where $\alpha_1, \alpha_2, \zeta$ are general curvilinear coordinates, u_1, u_2, w are the components of the displacement of a point on the reference surface and β_1, β_2 are rotations. The thin shell assumptions also allow us to write the rotations in terms of u_1, u_2 , and w . We can write the strain vector $\bar{\epsilon}$ in terms of the displacements \bar{u} by using the strain-displacement relations in general curvilinear coordinates. These relations will not be reproduced here as they are lengthy and can be found in many references, see e.g. Kraus [6], p. 31. We will write them as $\bar{\epsilon} = \mathbf{A}\bar{u}$, where \mathbf{A} is a matrix operator.

We now substitute all of these relations into equations 2 and integrate over the normal component ζ . Then the contributions of the solid become

$$T_s = \int_{\Gamma_s} \frac{h\rho_s}{2} \left(\frac{\partial \bar{u}}{\partial t} \cdot \frac{\partial \bar{u}}{\partial t} \right) d\Gamma_s, \quad U_s = \int_{\Gamma_s} (\mathbf{A}\bar{u})^T \mathbf{Q} \mathbf{A}\bar{u} d\Gamma_s.$$

\mathbf{Q} is the matrix \mathbf{C} after the integration – it is multiplied by some combinations of powers of h . This h is the thickness of the sphere, and W_s , of course, is unchanged. The solid functional, then, is

$$\Pi_s = \int_{t_0}^{t_1} \left[\int_{\Gamma_s} (\mathbf{A}\bar{u})^T \mathbf{Q} \mathbf{A} \bar{u} d\Gamma_s - \int_{\Gamma_s} \frac{h\rho_s}{2} \left(\frac{\partial t\bar{u}}{\partial t} \cdot \frac{\partial \bar{u}}{\partial t} \right) d\Gamma_s - \int_{\Gamma_s} \bar{u} \cdot \bar{f}_s d\Gamma_s \right] dt.$$

Taking the first variational, and integrating by parts in the T_s term gives

$$\delta\Pi_s = \int_{\Gamma_s} (\mathbf{A}\bar{u})^T \mathbf{Q} \mathbf{A} \delta\bar{u} d\Gamma_s + \int_{\Gamma_s} \frac{h\rho_s}{2} \frac{\partial^2 \bar{u}}{\partial t^2} \cdot \delta\bar{u} d\Gamma_s - \int_{\Gamma_s} \bar{f}_s \cdot \delta\bar{u} d\Gamma_s = 0. \quad (3)$$

The fluid contributes the following terms:

$$T_f = \int_{\Omega_f} \frac{1}{2} \rho_f \bar{v} \cdot \bar{v} d\Omega_f, \quad U_f = \int_{\Omega_f} \rho_f e d\Omega_f,$$

where Ω_f is the volume of the fluid, and e is the specific internal energy of the fluid. The constraints of local and global conservation of mass, as well as the fluid-structure interaction, are part of the fluid functional. Hence, this functional is of the form

$$\begin{aligned} \Pi_f = \int_{t_0}^{t_1} \left[\int_{\Omega_f} \left\{ \rho_f e - \frac{1}{2} \rho_f \bar{v} \cdot \bar{v} - \lambda_1 \left(\frac{\partial \rho_f}{\partial t} + \nabla \cdot (\rho_f \bar{v}) \right) - \lambda_2 \rho_f \right\} d\Omega_f \right. \\ \left. + \int_{\Gamma_s} \lambda_3 \left(-\frac{\partial u_n}{\partial t} + v_n \right) d\Gamma_s + \lambda_2 M_f \right] dt \end{aligned}$$

where $\lambda_1, \lambda_2, \lambda_3$ are Lagrange multipliers, u_n is the normal displacement of the fluid boundary, v_n is the normal velocity of the fluid boundary, and M_f is the mass of the fluid.

Taking the first variation with respect to \bar{v} and setting each integral to zero gives a series of equations. These equations reveal the true meanings of the Lagrange multipliers. This has been done in detail by Kock and Olson [3], p. 467. We will reproduce only their results. The Lagrange multiplier $\lambda_1 = \varphi$, where φ is the scalar potential (that is, $\bar{v} = \nabla\varphi$). In addition, $\lambda_3 = \rho_f \varphi$, and λ_2 is still unknown, so it shall be renamed λ . After integration by parts, the fluid functional becomes

$$\begin{aligned} \Pi_f = \int_{t_0}^{t_1} \left[\int_{\Omega_f} \left\{ \rho_f e - \frac{1}{2} \rho_f (\nabla\varphi)^2 - \varphi \left(\frac{\partial \rho_f}{\partial t} + \nabla \cdot (\rho_f \nabla\varphi) \right) \right. \right. \\ \left. \left. - \lambda \rho_f + \rho_f \frac{\partial \varphi}{\partial t} \right\} d\Omega_f + \lambda M_f \right] dt. \end{aligned}$$

In the linearized case it is assumed that the change in fluid density is only a small perturbation from the initial density ρ_0 . By taking $\rho_f = \rho_0 + \rho$ and linearizing about the initial domain, that is, $\Omega_f \Rightarrow \Omega_{f_0}$ and $\Gamma_f \Rightarrow \Gamma_{f_0}$, the functional simplifies further. Following Kock and Olson ([3], p. 485), the expression becomes

$$\begin{aligned} \Pi_f = \int_{t_0}^{t_1} \left[\int_{\Omega_{f_0}} \left\{ -\frac{1}{2} \frac{\rho_0}{c_0} \left(\lambda - \frac{\partial \varphi}{\partial t} \right)^2 + \frac{1}{2} \rho_0 (\nabla\varphi)^2 \right\} d\Omega_{f_0} \right. \\ \left. + \int_{\Gamma_{f_0}} \rho_0 \left(\frac{\partial \varphi}{\partial t} - \lambda \right) u_n d\Gamma_{f_0} \right] dt, \end{aligned}$$

where c_0 is the speed of sound. In this case taking the first variation and setting each part to zero gives

$$\begin{aligned} \int_{\Omega_{f_0}} \left[\frac{\rho_0}{c_0^2} \left(\frac{\partial^2 \varphi}{\partial t^2} - \frac{\partial \lambda}{\partial t} \right) - \nabla \cdot (\rho_0 \nabla \varphi) \right] \delta \varphi d\Omega_{f_0} + \int_{\Gamma_{f_0}} \left[\rho_0 \left(-\frac{\partial u_n}{\partial t} + \frac{\partial \varphi}{\partial n} \right) \right] \delta \varphi d\Gamma_{f_0} = 0, \\ \int_{\Gamma_{f_0}} \rho_0 \left(\frac{\partial \varphi}{\partial t} - \lambda \right) \delta u_n d\Gamma_{f_0} = 0, \\ \left[\int_{\Omega_{f_0}} -\frac{\rho_0}{c_0^2} \left(\lambda - \frac{\partial \varphi}{\partial t} \right) d\Omega_{f_0} - \int_{\Gamma_{f_0}} \rho_0 u_n d\Gamma_{f_0} \right] \delta \lambda = 0. \end{aligned} \quad (4)$$

Finite Element Analysis

We implement the finite element approximation using standard isoparametric elements (see, e.g., Huebner et al. [1], Ch. 5) to discretize the domain. Since the boundaries of each element will, of necessity, be curved, the boundary itself must be approximated. For each coordinate we will write an expression of the form

$$x(\eta, \xi, \zeta, t) = \sum_{i=1}^m N_i(\eta, \xi, \zeta) x_i(t). \quad (5)$$

Here η, ξ, ζ are the natural coordinates of the element. N_i are the interpolation functions, in natural coordinates, and m is the number of nodes per element. We approximate all of the coordinates in this way. In addition, we use the same interpolation functions N_i to approximate the variables in the problem, that is, u, v, w, φ , and λ . Displacement coordinates are now (u, v, w) instead of (u_1, u_2, w) to prevent confusion.

We will use two-dimensional elements to model the sphere, and three-dimensional elements for the fluid. The approximations are of the form

$$\begin{aligned} \bar{u}(\eta, \xi, t) &= \sum_{i,j=1}^m N_{ij}(\eta, \xi) u_j(t), \\ \varphi(\eta, \xi, \zeta, t) &= \sum_{i=1}^m N_i(\eta, \xi, \zeta) \varphi_i(t), \\ \lambda(t) &= \sum_{i=1}^m \lambda_i(t). \end{aligned} \quad (6)$$

where N_{ij} is the $3 \times 3m$ matrix of interpolation functions

$$\mathbf{N} = \begin{pmatrix} N_1 & 0 & 0 & \dots & N_m & 0 & 0 \\ 0 & N_1 & 0 & \dots & 0 & N_m & 0 \\ 0 & 0 & N_1 & \dots & 0 & 0 & N_m \end{pmatrix}$$

and \bar{u} is the vector

$$\bar{u} = [u_1 \quad v_1 \quad w_1 \quad \dots \quad u_m \quad v_m \quad w_m].$$

The choice of Lagrange polynomials as interpolation functions allows the nodal values $u_i, v_i, w_i, \varphi_i, \lambda_i$ to have the physical meaning of being the value of the function at that node. In our problem the nodal values are functions of time. Since we will be forcing the sphere sinusoidally, we will use Fourier transforms to transform out time and solve the problem in the frequency domain. This will, of course, have no effect on the spatial integrals.

To substitute the approximations into the variational principles derived, it is necessary to address the issue of differing coordinate frames. The interpolation functions are in local coordinates η, ξ, ζ , whereas the variational form is in global coordinates – cartesian x, y, z in the case of the fluid, and a generalized curvilinear α_1, α_2 for the solid. To compound the problem, in our case all of the nodal coordinates and element information is obtained from the neutral file output of the commercial finite element code PATRAN. The PATRAN output has the coordinates of all nodes listed in a global cartesian system. So it is necessary to undertake various coordinate transformations before the integrals in the variational expressions can be evaluated.

The fluid expressions give no difficulty in this area. Equation 5 gives the form of the transformation from cartesian to natural coordinates. It is known from calculus that $dx dy dz = |J| d\eta d\xi d\zeta$, where $|J|$ is the determinant of the Jacobian matrix of partial derivatives. Thus the integrals will transform in the following manner:

$$\int_V f(x, y, z) dx dy dz = \int_{V'} f'(\eta, \xi, \zeta) |J| d\eta d\xi d\zeta,$$

$$J = \begin{pmatrix} \frac{\partial x}{\partial \eta} & \frac{\partial x}{\partial \xi} & \frac{\partial x}{\partial \zeta} \\ \frac{\partial y}{\partial \eta} & \frac{\partial y}{\partial \xi} & \frac{\partial y}{\partial \zeta} \\ \frac{\partial z}{\partial \eta} & \frac{\partial z}{\partial \xi} & \frac{\partial z}{\partial \zeta} \end{pmatrix}.$$

where the primes denote the transformed function and volume. Substituting equations 6 into the fluid equations 4 yields the following expressions.

$$\sum_{i,j=1}^m \left[\frac{d^2 \varphi_i}{dt^2} \int_V \frac{\rho_0}{c_0^2} N_i N_j |J| d\eta d\xi d\zeta + \varphi_i \int_V \rho_0 \nabla N_i \nabla N_j |J| d\eta d\xi d\zeta \right. \\ \left. - \frac{d\lambda_i}{dt} \int_V \frac{\rho_0}{c_0^2} N_i |J| d\eta d\xi d\zeta - \frac{du_i^n}{dt} \int_S \rho_0 N_i(\eta, \xi) N_j(\eta, \xi) |J| d\eta d\xi \right] \delta \varphi_j = 0,$$

$$\sum_{i,j=1}^m \left[\frac{d\varphi_i}{dt} \int_S \rho_0 N_i(\eta, \xi) N_j(\eta, \xi) |J| d\eta d\xi - \lambda_i \int_S \rho_0 N_i(\eta, \xi) |J| d\eta d\xi \right] \delta u_j^n = 0,$$

$$\sum_{i,j=1}^m \left[\lambda_i \int_V -\frac{\rho_0}{c_0^2} |J| d\eta d\xi d\zeta + \frac{d\varphi_i}{dt} \int_V \frac{\rho_0}{c_0^2} N_i |J| d\eta d\xi d\zeta \right. \\ \left. - u_i^n \int_S \rho_0 N_i(\eta, \xi) |J| d\eta d\xi \right] \delta \lambda_j = 0.$$

Note that this integration is over the area or volume of the element in natural coordinates, so that the range of each variable is $(-1, 1)$. Following Kock and Olson [3], we will write these integrals in shorthand, where subscripts denote vector and matrix components:

$$\begin{aligned} \sum_{i,j=1}^m \left[\frac{d^2 \varphi_i}{dt^2} M_{ij}^\varphi + \varphi_i K_{ij}^\varphi - \frac{d\lambda_i}{dt} C_i^{\varphi\lambda} - \frac{du_i^n}{dt} C_{ij}^{\varphi u} \right] &= 0, \\ \sum_{i,j=1}^m \left[\frac{d\varphi_i}{dt} C_{ij}^{\varphi u} - \lambda_i K_i^{\lambda u} \right] &= 0, \\ \sum_{i,j=1}^m \left[-\lambda_i K^\lambda + \frac{d\varphi_i}{dt} C_i^{\varphi\lambda} - u_i^n K_i^{\lambda u} \right] &= 0. \end{aligned}$$

The solid elements demand an additional coordinate transformation. This will not be written out in detail here. The strain-displacement relations written in generalized curvilinear coordinates are first transformed to a local arc length coordinate system. Then they are fairly simple to transform into natural coordinates using a Jacobian matrix. The final result is that equation 3 written with indicial notation in terms of a finite element approximation becomes

$$\begin{aligned} \sum_{i,j=1}^m \left[u_i \int_S N_{ki} A_{pk} Q_{pq} A_{qr} N_{rj} |J| d\eta d\xi + \frac{d^2 u_i}{dt^2} \int_S \frac{h \rho_s}{2} N_{ki} N_{kj} |J| d\eta d\xi \right. \\ \left. - \int_S f_i N_{ij} |J| d\eta d\xi \right] \delta u_j = 0. \end{aligned}$$

where \mathbf{A} is the matrix of strain-displacement relations in natural coordinates. We can write this as

$$\sum_{i,j=1}^m \left[u_i K_{ij}^u + \frac{d^2 u_i}{dt^2} M_{ij}^u - F_i \right] = 0.$$

Then, putting all of these equations together and taking the Fourier transform of both sides, the linear system to solve becomes

$$\begin{aligned} -\omega^2 \begin{pmatrix} \mathbf{K}^u & 0 & -\mathbf{K}^{\lambda u^T} \\ 0 & -\mathbf{K}^\varphi & 0 \\ -\mathbf{K}^{\lambda u} & 0 & -\mathbf{K}^\lambda \end{pmatrix} \begin{pmatrix} \bar{u} \\ \varphi \\ \lambda \end{pmatrix} + i\omega \begin{pmatrix} 0 & \mathbf{C}^{\varphi u^T} & 0 \\ \mathbf{C}^{\varphi u} & 0 & \mathbf{C}^{\varphi\lambda^T} \\ 0 & \mathbf{C}^{\varphi\lambda} & 0 \end{pmatrix} \begin{pmatrix} \bar{u} \\ \varphi \\ \lambda \end{pmatrix} \\ + \begin{pmatrix} \mathbf{M}^u & 0 & 0 \\ 0 & -\mathbf{M}^\varphi & 0 \\ 0 & 0 & 0 \end{pmatrix} \begin{pmatrix} \bar{u} \\ \varphi \\ \lambda \end{pmatrix} = \begin{pmatrix} \mathbf{F} \\ 0 \\ 0 \end{pmatrix} \end{aligned}$$

where the vector $[\bar{u} \ \varphi \ \lambda]$ is the vector of nodal values. The next step is to use a complex solver suitable to this system of equations to solve for the nodal variables. We will use a linear system solver taken from the fortran subroutine library LAPACK.

Summary and Conclusions

We have formulated and begun to implement a finite element analysis program based on variational principles for the problem of sound wave propagation in a spherical shell. At the time of the writing of this report results were not yet available. The program has yet to be completely debugged, and several more weeks of work are necessary before accurate, complete solutions can be obtained. This work will continue over the course of the next year as we incorporate additional effects into our model in our effort to develop an improved computational method for structural acoustics problems.

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Synthesis and Characterization of Poly(Arylene Ether Benzimidazole) Oligomers

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Abstract

Several poly(arylene ether benzimidazole) oligomers were prepared by the nucleophilic aromatic substitution reaction of a bisphenol benzimidazole and various alkyl-substituted aromatic bisphenols with an activated aromatic dihalide in *N,N*-dimethylacetamide. Moderate to high molecular weight terpolymers were obtained in all cases, as shown by their inherent viscosities, which ranged from 0.50 to 0.87 dL g⁻¹. Glass transition temperatures (T_g s) of polymer powders ranged from 267-280°C. Air-dried unoriented thin film T_g s were markedly lower than those of the powders, whereas T_g s of films dried in a nitrogen atmosphere were identical to those of the corresponding powders. In addition, air-dried films were dark amber and brittle, whereas nitrogen-dried films were yellow and creasable. Nitrogen-dried films showed slightly higher thin-film tensile properties than the air-dried films, as well.

Introduction

Polybenzimidazoles (PBIs) are heterocyclic polymers which exhibit high chemical, physical, and mechanical properties. They are generally prepared via the two-phase melt condensation reaction of a tetrafunctional bis(*o*-diamine) with a dicarboxylic acid, or derivatives thereof, at temperatures around 260°C¹. This reaction can also be carried out in polyphosphoric acid². The polymers are well known for their thermal stability, which is derived from the high resonance energy of the aromatic and heterocyclic groups incorporated into the chain¹, as well as from intermolecular hydrogen bonding effects. Also characteristic of PBIs are their excellent solvent resistance, resistance to acid/base hydrolysis, and hydrophilicity. However, despite their advantages, PBIs are notoriously difficult and expensive to process, requiring extremely high molding temperatures and pressures. As a result, these materials are not extensively used. Some PBI applications include: nose cones for airborne projectiles, heat-resistant *o*-rings and gaskets, and varnishes³. PBI is commercially sold under the name of Celazole^{®3}.

Poly(arylene ether)s (PAEs) are a class of engineering thermoplastics which show great potential for use in high-performance applications. They are generally synthesized by the nucleophilic aromatic substitution reaction of an activated aromatic dihalide and the alkali metal salt of an aromatic bisphenol in polar, aprotic solvents⁴. Other methods of PAE preparation include electrophilic Friedel-Crafts processes⁵, macrocyclic ring cleavage⁶, and oxidative coupling reactions⁷. Since PAEs are thermoplastic materials, they are much easier to process than the thermoset-like polybenzimidazoles, and their low flammability/low gas emission during thermal stresses make them well-suited for high-performance aerospace applications. These materials generally show excellent solvent resistance, with the exception of their characteristic swelling in chlorinated solvents. This susceptibility to chlorinated substances, which are commonly used in the aerospace industry, have prevented the widespread use of PAEs in this area. However, PAEs are quite common commercially, with applications that include artificial heart casings, pin grid array sockets, molded circuit boards, fiber optic connectors, and cable insulation⁸.

By incorporating heterocyclic units into PAEs, it is possible to obtain a combination of the high chemical and thermal resistance of heterocyclic polymers with the ease of processability of PAEs. Two routes have been established to these materials. The first route involves the nucleophilic aromatic displacement reaction of a heterocyclic-containing, activated aromatic dihalide with the alkali metal salt of an aromatic bisphenol in polar, aprotic solvents^{9,10}. The

second method involves the reaction of the alkali metal salt of a heterocyclic-containing aromatic bisphenol with an activated aromatic dihalide under similar conditions^{11,12}. Examples of heterocyclic units which have previously been incorporated into PAEs include: quinoxalines⁹, imidazoles¹², 1,3,4-oxadiazoles¹³, and 1,2,4-triazoles¹³.

The objective of this study is to prepare high-temperature, chemically resistant, and potentially photopatternable poly(arylene ether benzimidazole)s for potential aerospace and microelectronics applications.

Approach

Synthesize controlled molecular weight poly(arylene ether benzimidazole) (PAEBI) random terpolymers via the nucleophilic aromatic displacement of 5,5'-bis[2-(4-hydroxyphenyl) benzimidazole] and various alkyl-substituted aromatic bisphenols with 4,4'-difluorobenzophenone, using 4-fluorobenzophenone as the endcapping agent.

Experimental

Starting materials

4,4'-Difluorobenzophenone (m.p. 103-106°C, Lancaster Synthesis) was recrystallized from absolute ethanol. 4-Fluorobenzophenone (m.p. 46-48°C, Lancaster Synthesis) and 5,5'-bis[2-(4-hydroxyphenyl) benzimidazole] (m.p. 389°C, Technically) were used as received. Tetramethyl bisphenol A (TM-BPA, m.p. 163-166°C), dimethyl bisphenol A (DM-BPA, m.p. 137-139°C), bisphenol E (BPE, m.p. 122-126°C), tetramethyl bisphenol F (TM-BPF, m.p. 174-175°C), bisxylenol P (m.p. 159-161°C), hexamethyl biphenol (HM-BPL, m.p. 225-228°C), and tetramethyl biphenol (TM-BPL, m.p. 219-224°C) were obtained from Ken Seika Corp., and were used as received. Other reagents were obtained from commercial sources and used as received.

Polymer Synthesis

Poly(arylene ether benzimidazole)s (PAEBIs) were prepared by reacting a 6% excess of a 3:1 molar ratio of 5,5'-bis[2-(4-hydroxyphenyl) benzimidazole] (75 mol %) and alkyl-substituted bisphenol (25 mol %) with 4,4'-difluorobenzophenone (94 mol %) in the presence of pulverized potassium carbonate in anhydrous N,N-dimethylacetamide (DMAc) at 15% solids (wt/wt). 4-Fluorobenzophenone (12 mol %) was used as the endcapper. The water generated during the alkali metal formation of the bisphenate was removed as an azeotrope with toluene. The reaction mixture was stirred at 155-160°C under a nitrogen atmosphere for 12-16 hours to afford dark brown, viscous solutions. The reaction mixtures were precipitated into a water/acetic acid mixture (~10/1), washed successively in hot water and methanol to remove trapped salts, and dried at ~90°C for ~12 hours to afford the off-white polymers in nearly quantitative yields.

Films

DMAc solutions (10-25% solids wt/vol) of the polymers were centrifuged for approximately 1 hour, and the decantate was doctored onto clean, dry plate glass. The films were dried to a tack-free form in a low-humidity chamber, and subsequently dried at 100, 200, and

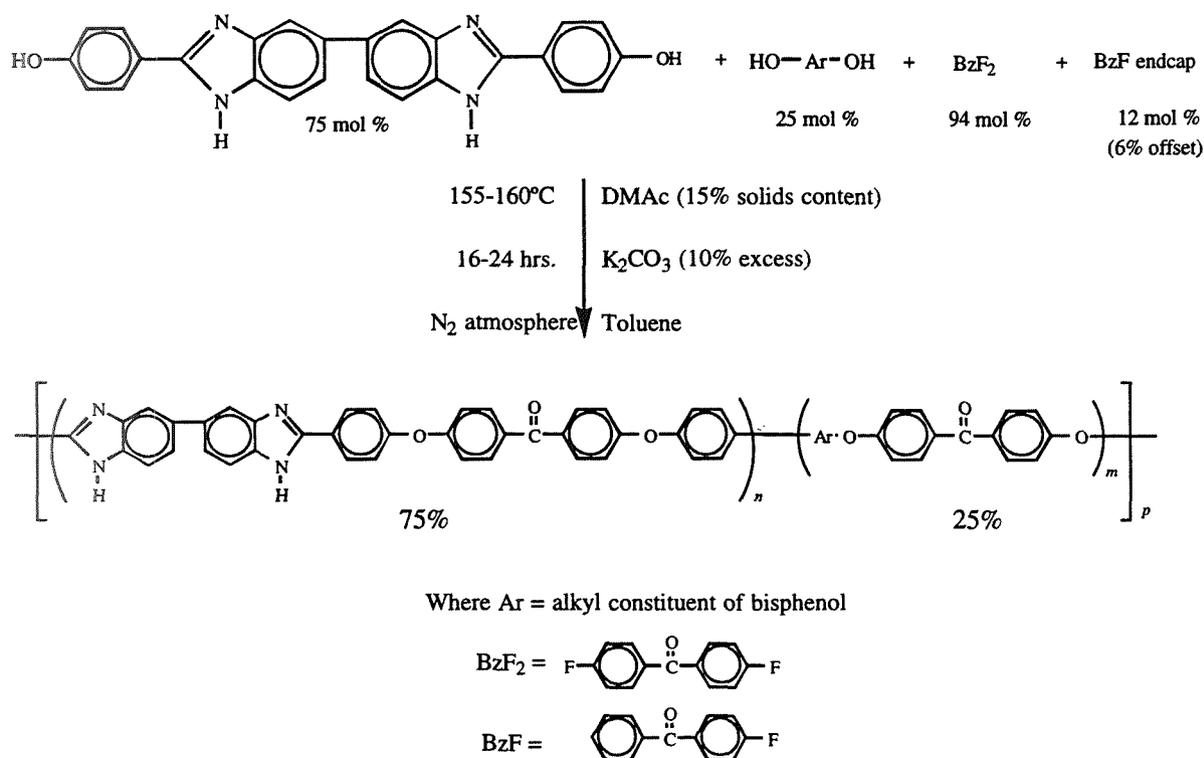
300°C in both air and nitrogen for 1 hour at each temperature. Unoriented thin-film mechanical tests were performed according to ASTM D882 at 23°C, using four specimens per test.

Other Characterization

Glass transition temperatures (T_g s) were determined from a Shimadzu DSC-50 differential scanning calorimeter (DSC). T_g values were taken as the inflection point of the ΔT vs. temperature curve at a heating rate of 20°C min⁻¹. Inherent viscosities (η_{inh}) were determined on 0.5% polymer solutions (wt/vol) in DMAc at 25°C, using a Cannon Instruments single-bulb viscometer.

Results and Discussion

Moderate to high-molecular weight polymers were prepared as depicted in Scheme 1 by the nucleophilic displacement reaction of 5,5'-bis[2-(4-hydroxyphenyl) benzimidazole] and alkyl-substituted aromatic bisphenols with 4,4'-difluorobenzophenone in DMAc at 155-160°C in the presence of potassium carbonate under nitrogen. The ratio of 5,5'-bis[2-(4-hydroxyphenyl) benzimidazole] and alkyl-substituted aromatic bisphenols employed was 3:1 so as to obtain polymers with T_g s > 250°C.



Scheme 1

The molecular weights of the polymers were controlled by offsetting the stoichiometry in favor of the bisphenols and endcapping with 4-fluorobenzophenone. The alkyl-substituted aromatic bisphenols (Ar) used in the preparation of the terpolymers are shown in Figure 1.

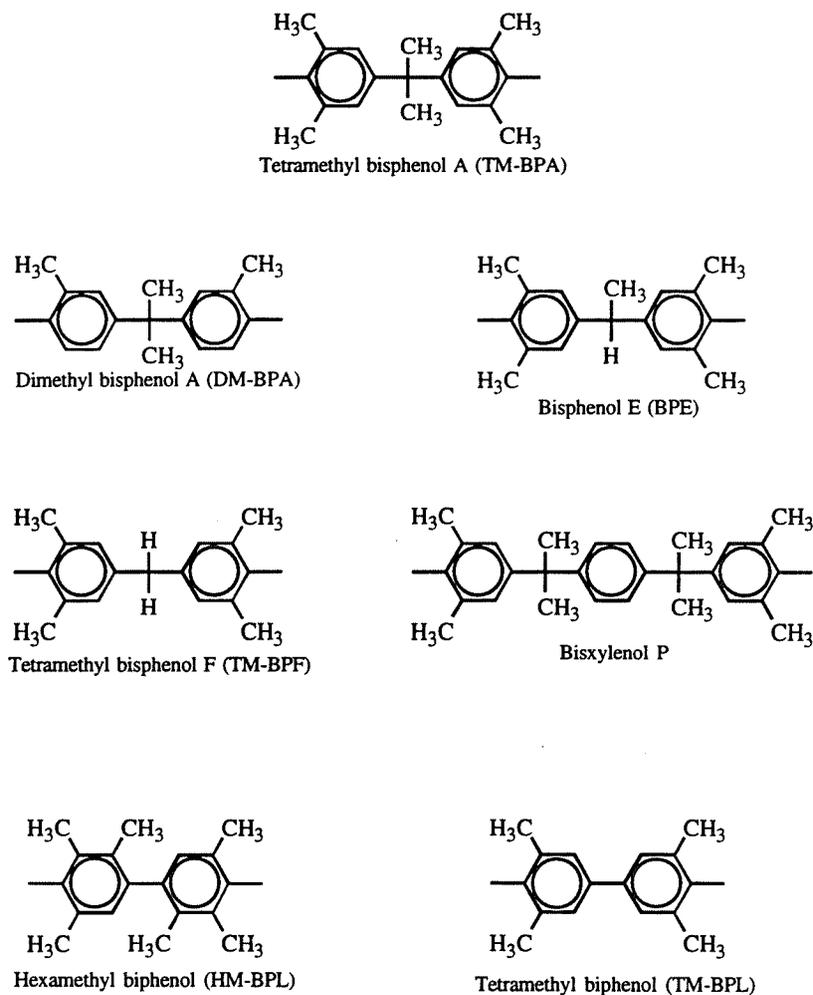


Figure 1

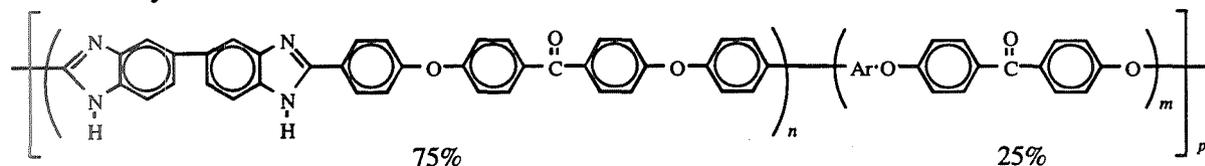
Generally, polymerizations required the full 16-24 hours to reach completion, as the reaction mixtures did not become significantly viscous before this time. Nearly quantitative yields were obtained for all the polymers, except for the TM-BPF-containing terpolymer, which was obtained in 63% yield. The low yield of this material was due to the formation of insoluble material (gel) in the extremely viscous reaction mixture, presumably due to hot spots in the reaction medium which form as a result of inefficient heat transfer in viscous solutions¹⁴. Employing a higher degree of stoichiometric offset or a lower solids content of the reaction mixture would probably solve this problem. Subsequent preparation of the TM-BPF-containing PAEBI at an 8% stoichiometric offset afforded the same results with an overall yield of 46%. Polymer characterization is presented in Table 1.

Glass transition temperatures ranged from 261-280°C, and inherent viscosities ranged from 0.47 to 0.87 dL g⁻¹, which indicates that moderate to high-molecular weights were obtained. These values compare well with results obtained from similar PAEBIs previously prepared¹⁴.

Trends in PAEBI T_gs can be based on three characteristics of the alkyl-substituted aromatic bisphenols: (1) the presence and substitution of the linkage unit joining the two phenyl rings, (2) the methyl substitution on the phenyl rings of DM-BPA and TM-BPA, and (3) the methyl substitution on the phenyl rings of the biphenol structures, TM-BPL and HM-BPL. In the first case, the observed T_g trend with respect to the linkage unit is nil > CH₂ > CH-CH₃ > C(CH₃)₂ > 1,4-disopropylidylphenylene (TM-BPL > TM-BPF > BPE > TM-BPA > Bisxylenol P). Since the inherent viscosities of the materials being compared are dissimilar, and consequently the molecular weights of the polymers, the trends observed here could be due in part to molecular weight effects.

Regarding the second category, the tetramethyl substitution on TM-BPA as opposed to the dimethyl substitution on DM-BPA may affect the T_g in terms of steric effects between polymer chains. The more sterically hindered TM-BPA may show a higher T_g due to a lesser degree of chain mobility versus DM-BPA. Thirdly, the hexamethyl substituted HM-BPL may give a higher T_g than the less hindered TM-BPL for similar steric reasons. However, for both cases, no T_g was detected for either the TM-BPA or HM-BPL-containing PAEBIs by DSC.

Table 1 Polymer Characterization



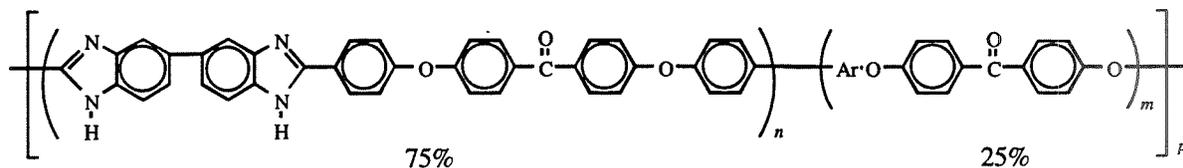
Ar	η_{inh} (dL g ⁻¹) ^a	T _g (°C) ^b
TM-BPL	0.87	280
TM-BPF ^c	0.82	271
BPE	0.47	267
DM-BPA	0.50	261
HM-BPL	0.73	Not Detectable by DSC
TM-BPA	0.64	Not Detectable by DSC
Bisxylenol P	0.61	TBD ^d

^a Inherent viscosity measured in DMAc on 0.5% (wt/vol) solutions at 25°C

^b Glass transition temperature determined by DSC at heating rate of 20°C min⁻¹

^c Polymerization carried out at 8% stoichiometric offset

^d TBD = to be determined

Table 2 Unoriented Thin-Film Characterization: Air-Dried

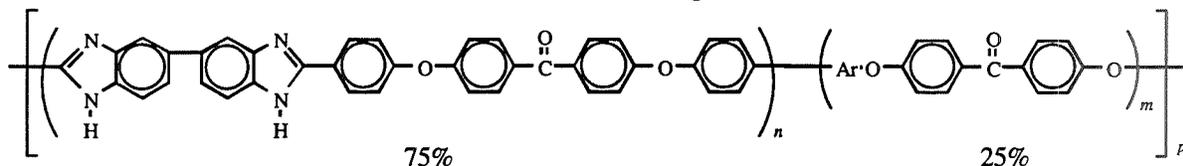
Ar	T _g (°C) ^a	Color, texture ^b
TM-BPL	234	Amber, not creasable
TM-BPF ^c	239	Amber, not creasable
BPE	230	Amber, not creasable
DM-BPA	TBD ^d	Amber, not creasable
HM-BPL	Not Detectable by DSC	Amber, not creasable
TM-BPA	TBD	TBD
Bisxylenol P	TBD	TBD

^a Glass transition temperature determined by DSC at heating rate of 20°C min⁻¹

^b All films dried at 100, 200, and 300°C for 1h at each temperature

^c Polymerization carried out at 8% stoichiometric offset

^d TBD = to be determined

Table 3 Unoriented Thin-Film Characterization: Nitrogen-Dried

Ar	T _g (°C) ^a	Color, texture ^b
TM-BPL	281	Light yellow, creasable
TM-BPF ^c	277	Light yellow, creasable
BPE	270	Light yellow, creasable
DM-BPA	271	Light yellow, creasable
HM-BPL	280	Light yellow, creasable
TM-BPA	TBD ^d	TBD
Bisxylenol P	TBD	TBD

^a Glass transition temperature determined by DSC at heating rate of 20°C min⁻¹

^b All films dried at 100, 200, and 300°C for 1h at each temperature

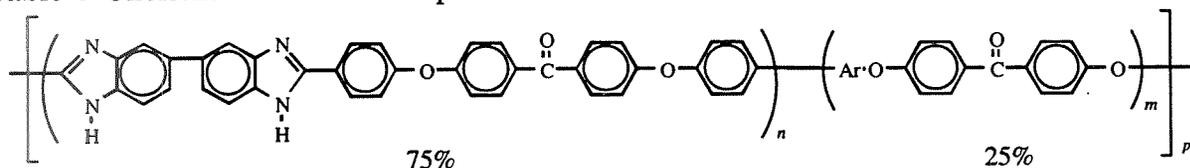
^c Polymerization carried out at 8% stoichiometric offset

^d TBD = to be determined

Unoriented thin-film properties are presented in Tables 2-5. Polymer films dried in air afforded amber, brittle films. However, drying films cast from the same polymer solutions in a nitrogen atmosphere, under the same temperature profile, yielded light yellow, creasable films. In addition, the T_gs of the air-dried films were considerably lower (~31-47°C) than those of the respective as-isolated powders, whereas the nitrogen-dried film T_gs correlated well with the as-isolated powder T_gs. This decrease in the thermal stability of the air-dried films was surprising,

and may be due to some oxidative degradation; since the films dried in an inert atmosphere showed no T_g decrease.

Table 4 Unoriented Thin-Film Properties^a: Air-Dried



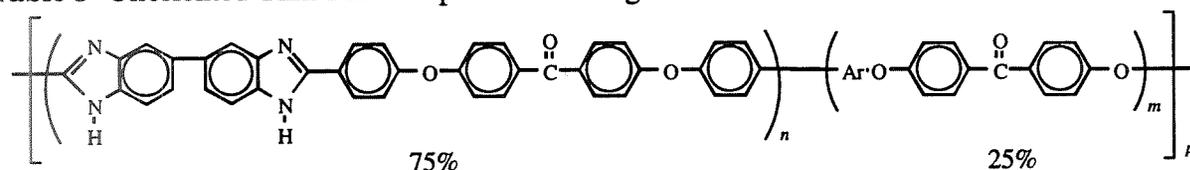
Ar	Tensile Strength (ksi)	Tensile Modulus (ksi)	Elongation at Break (%)
TM-BPL	17.7	484	7
TM-BPF ^b	TBD ^c	TBD	TBD
BPE	14.5	467	4
DM-BPA	TBD	TBD	TBD
HM-BPL	TBD	TBD	TBD
TM-BPA	TBD	TBD	TBD
Bisxylenol P	TBD	TBD	TBD

^a Films tested according to ASTM D882 at 23°C using four specimens per test

^b Polymerization carried out at 8% stoichiometric offset

^c TBD = to be determined

Table 5 Unoriented Thin-Film Properties^a: Nitrogen-Dried



Ar	Tensile Strength (ksi)	Tensile Modulus (ksi)	Elongation at Break (%)
TM-BPL	18.9	494	10
TM-BPF ^b	TBD ^c	TBD	TBD
BPE	17.7	475	10
DM-BPA	TBD	TBD	TBD
HM-BPL	TBD	TBD	TBD
TM-BPA	TBD	TBD	TBD
Bisxylenol P	TBD	TBD	TBD

^a Films tested according to ASTM D882 at 23°C using four specimens per test

^b Polymerization carried out at 8% stoichiometric offset

^c TBD = to be determined

This degradation could be due to the presence of abstractable primary benzylic hydrogens, which could be induced to form free radicals upon heating in the presence of oxygen. If this is the case, events such as α -chain scission adjacent to carbonyl groups or radical recombination to form lower molecular weight polymer chains could occur. Further investigation will be required before a more definitive conclusion can be drawn.

Unoriented thin-film properties of the nitrogen-dried films were slightly greater than those for films dried in air under similar conditions. As previously mentioned, films dried in air were darker in color and not creasable, whereas nitrogen-dried films were light yellow and creasable.

Conclusions

Moderate to high molecular weight poly(arylene ether benzimidazole) terpolymers were synthesized via the nucleophilic aromatic displacement reaction of 5,5'-bis[2-(4-hydroxyphenyl)benzimidazole] and various alkyl-substituted aromatic bisphenols with 4,4'-difluorobenzophenone. Air-dried polymer films exhibited more color, lower T_g s, and slightly lower unoriented thin-film tensile properties as compared to nitrogen-dried films. Characterization studies are still in progress, the results of which will be reported in future work.

The use of tradenames of manufacturers does not constitute an official endorsement of such products or manufacturers, either expressed or implied, by the National Aeronautics and Space Administration.

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**Importance of the Office of Inspector General
to the efficient operation of
Langley Research Center**

Student
Anthony L. Linton

Mentor
Lee Ball

Office of Inspector General

During my time in the office of Inspector General my task was to assist the investigators in the office with investigations concerning operations on the center. I helped with gathering and organization of information relevant to specific cases. However, due to the sensitive nature of the cases I am not at liberty to discuss their topics.

The office of Inspector General (IG) investigates possible crimes against the government. The IG at LaRC handles cases such as possible fraud that might cause unnecessary monetary losses to the center. For example, if an employee were stealing computer components from the work place and the IG were to receive a tip about these illegal actions, they would run an investigation on the matter and decide what steps were necessary to remedy the situation.

The IG usually receives information about possible infractions from other NASA employees. If an employee believes that possible infractions are being committed then they can go to the IG and discuss the situation. Many times the investigations turn up no violation, however, when there is a crime being committed the IG takes the necessary actions.

My job was to assist those conducting the investigations wherever they deemed necessary. My responsibilities ranged from gathering information about past cases to creating charts and graphs that could be used to present the case, in a simplified and organized manner, to other supervisors.

While I was there, I became familiar with software applications that could be used to increase the efficiency of an office. I was given the task of learning Microsoft Project in an attempt to apply its specialized features to the IG. The primary goal was to organize cases in a manner that would show the possible length of a case, so that gaps in

productivity could be identified. This would allow the investigator to use their time more effectively.

One of the most important things that I learned while at the IG was the importance of good management. There are certain skills and abilities that a manager must develop and being around a person with those skills allowed me see which areas I needed to develop. The ability to communicate information in a simple yet effective manner is necessary. Also the capability to organize operations in a fashion that will most effectively run the organization is vital.

During my tenure in the Office of Inspector General I became familiar with an organization that is vital to NASA. Without the IG the widespread abuse of LaRC monies and materials would become a serious problem. The importance of a policing system in any large organization essential.