Technology Reinvestment Project
Manufacturing Education and Training

Final Report

PRACTICE ORIENTED MASTER'S IN OPTICS

Center for Applied Optics
The University of Alabama in Huntsville
Huntsville, AL

in Collaboration with

Alabama A&M University
Normal, AL

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I. Project Summary: An interdisciplinary Masters Program with a concentration in Optics and Photonics Technology has been developed under the U.S. Manufacturing Education and Training Activity of the Technology Reinvestment Project. This development has been a collaboration between the University of Alabama in Huntsville, Alabama A&M University, Northwest Shoals Community College, the NASA Marshall Space Flight Center, the U. S. Army Missile Command, Oak Ridge National Laboratory, Advanced Optical Systems Inc., Dynetics, Inc., Hughes Danbury Optical Systems, Inc., Nichols Research and Speedring Inc. These organizations as well as the National Institute for Standards and Technology and SCI, Inc. have been participating fully in the design, development and implementation of this program. This program will produce highly trained graduates who can also solve practical problems, and includes an on-site practicum at a manufacturing location.

The broad curriculum of this program emphasizes the fundamentals of optics, optical systems manufacturing and testing, and the principles of design and manufacturing to cost for commercial products.

The MS in Physics and MSE in Electrical Engineering Degrees with concentration in Optics and Photonics Technology are offered by the respective UAH academic departments with support from and in consultation with a Steering Committee composed of representatives from each of the participating organizations, and a student representative from UAH.

The origins of the new Master's of Science and Master's of Science in Engineering program with Concentration in Optics and Photonics Technology go back to early 1993 when a group of scientists and engineers representing mostly Huntsville area government, industry and academic organizations started meeting to discuss the possibility of forming an alliance focused on defense conversion and the possible commercialization of their largely defense and government oriented technologies and business strategies. At that time the group consisted of representatives of The University of Alabama in Huntsville (UAH), Northwest Shoals Community College, the NASA Marshall Space Flight Center (MSFC), the U. S. Army Missile Command (MICOM), the Army Space and Strategic Defense Command (SSDC), the Oak Ridge National Laboratory (ORNL) and about a dozen mostly local companies involved in optical technology. This group shared a common objective in working together on defense conversion and the pursuit of dual-use technologies for the benefit of all participants.

The result of these early discussions was an agreement, in May of 1993, to form the Alliance for Optical Technology. The Memorandum of Agreement, which was effected on March 16, 1994, stipulates that the signatory organizations "...desire to form a strategic alliance to advance the development and transfer of technologies in the interest of enhancing the global competitiveness of the industrial members while facilitating the effectiveness of the public sector members in meeting their mission objectives particularly in the area of strengthening the technological competitiveness of the United States." The stated purpose of the Alliance is for "...coordinating ... precompetitive activities in optical technology, sharing controlled access to each other's facilities, ... , exchanging and/or sharing personnel resources ... , providing advanced education and training in applied optical technology and manufacturing, seeking funds for cooperative projects, identification of common technical and manufacturing deficiencies, pooling, ... of internal and external information, providing

controlled access to the technology of Alliance members, providing links to new market sectors, and providing a shared electronic design system for project support."

Of these noble and ambitious objectives, the one that the Alliance decided to pursue first was that of developing an advanced education and training program in applied optical technology and manufacturing. A proposal to develop a new Practice-oriented Master's in Optics program was submitted to the U.S. Manufacturing Education and Training Activity of the Technology Reinvestment Project (TRP) in July 1993. It was selected for funding in the fall of 1993 and the award was made in March 1994. The proposal stipulated that "Industry and government organizations will participate fully in the design, development and implementation of this program. The program will be designed to produce highly-trained graduates, who have an optimum combination of skills in the areas of manufacturing engineering, science, management and business-practices, and who can solve practical problems. The program will include an on-site practicum at a manufacturing industry. The program will enable the defense workforce and industry transition to commercial manufacturing, enhance their competitiveness in global marketplace, and expand the US job base and economy." Again, very noble and ambitious objectives.

A Steering Group for the development and implementation of the program was set up in the fall of 1993 consisting of representatives of a subset of the Alliance membership and additional university faculty from UAH and Alabama A&M University (AAMU). A student representative was added in the fall of 1994 when the first class was matriculated. The current project team is indicated in Table 1 with a total of 45 representatives on the Steering Committee. This would be completely unwieldy should everyone show up at any one meeting. Most Steering Committee meetings consist of about fifteen representatives with all sectors of the project team community reasonably well represented.

MS/MSE Concentration in Optics and Photonics Technology
Table 1 - Project Team

Academic Institutions
University of Alabama in Huntsville
Alabama A&M University
Northwest Shoals Community College

Industrial Affiliates
Advanced Optical Systems
Dynetics Inc.
Hughes Danbury Optical System
Nichols Research
SCI Inc.
Speedring, Inc.

Government Institutions
NASA Marshall Space Flight Center
U.S. Army Missile Command
Oak Ridge National Laboratory
National Institute of Standards & Technology

Advisory
Space & Systems Defense Command
Boeing
Mason and Hanger International
Morgan Research
Teledyne Brown Engineering
WIT, Inc.

This group worked through April 1994 to define a program and curriculum which met their diverse requirements and expectations. It was decided that the program would be offered in two tracks under

existing UAH master's degrees with special concentrations: one as a Master's in Science with Concentration in Optics and Photonics Technology under the UAH Physics Department and the other as a Master's of Science in Engineering with Concentration in Optics and Photonics Technology under the UAH Electrical and Computer Engineering Department. A sense of the challenge of reconciling very disparate viewpoints is captured in the UAH Physics Department internal memorandum of February 7, 1994, recommending approval of the program "on a trial basis". This memorandum states, in part, that "... there was some concern ... that the proposed degree program did not have sufficient core physics graduate courses." The recommendation was made that, with the addition of pairs of electives from the physics core program, the program would be satisfactory provided that it "... be viewed as an *'experimental'* terminal Masters program with an emphasis on a particular specialty. While this is a significant departure from our current program, the success of the program should provide our department with a means of addressing (through a reexamination of our graduate program) the national concern that many physics graduates are lacking the necessary qualifications demanded by modern industry (see *Physics Today,* January 1994). The Graduate Committee will examine the success of the program after 2-3 years and in the meantime our current program will be reviewed. Should the optics MS degree prove a success, the question of such a graduate program based on focused areas of specialization is appropriate and ... (should) ... be seriously considered..."

The program was also accepted on a trial basis by the UAH Department of Electrical and Computer Engineering and the two departments worked with the Center for Applied Optics and the Steering Group to formulate the curriculum and course content for the new courses that needed to be developed.

II. Fulfillment of the Scope of Work: Table 2 indicates the resultant Curriculum Requirements. Table 3 gives a Typical Course Schedule although the program also supports alternative and nontraditional schedules. Four new courses were developed specifically for this program. These are the three listed in Table 2 Optics Design and Manufacturing Technology, namely "Optics and Photonics System Design," "Optomechanical Design and Manufacturing" and "Optical Fabrication and Testing;" and the "Integrated Production and Process Design" course under Engineering Management. Syllabi for these courses are included in Tables 4 - 7. As of this writing, the first class, which matriculated in the fall of 1994, is anticipating graduation at the end of this semester. As noted below, this is over a year later than expected. However, the next two classes which matriculated in the fall of 1995 and 1996 are making more rapid progress and should graduate in close to two years rather that the originally expected sixteen months.

In the early planning stages it was decided that the degree should require a practicum/thesis and that these would be conducted at non-university locations. A number of the organizations involved in the development of the program volunteered to offer support for students pursuing their practicum at their locations. The list of such opportunities is given in Table 8. The students are now engaged in their on-site practicum summer thesis work in accordance with Table 3.

As we are approaching the end of the TRP support it appears that the program has been a success and will become self sustaining with about ten to twelve students per class. So far the graduating students have been successful in finding industrial positions as noted below.

Table 2
Curriculum Requirements

21 Hours Required Core Courses

- 6 credit hours in Optics Principles:
  (a) Geometrical Opt./(b) Physical Optics
- 9 credit hours in Optics Design and Manufacturing Technology:
  - Optics and Photonics Systems Design
  - Optomechanical Design/Manufacturing
  - Optical Fabrication and Testing
- 6 credit hours in Engineering Management:
  Integrated Production and Process
  Design plus one course from area k or l.

6 Hours Required in Elective Courses (two courses to be taken in <u>one</u> of the following lettered areas):

a. Optical Systems and Engineering
- Coherent Opt. Sys./Holography
- Electro-Optical Engineering
- Optoelectronics
- Lens Design
- Non-Linear Optics
- Laser Electronics
- Introduction to Lasers
- Radiometry

b. Quantum Optics
- Quantum Optics
- Laser Physics
- Special Topics in Optics - Nonclassical States
- Quantum Mechanics for Optics/Solid State
- Lasers
- Optical Properties of Matter

c. Optical signals
- Random Signals and Noise
- Linear Systems
- Digital Image Processing
- Fourier Optics
- Signal Processing
- Special Topics in Optics - Optical Computing

d. Optical Communications
- Communication Theory
- Detection of Opt/Infrared Radiation
- Optical Communications
- Statistical Optics
- Fiber Optics
- Optical Phase Conjugation

Table 2
Curriculum Requirements (Con't)

e. Optical Materials
   - Elements of Material Science
   - Crystal Physics & Crystal Growth
   - Magnetic and Optical Properties of Materials
   - Materials for Radiation Detectors
   - Optical Properties of Matter

f. Manufacturing Technology, Systems
   - Introduction to Systems Engineering
   - Engineering Economic Analysis

g. Manufacturing Technology, Quality
   - Statistical Quality Control
   - Advanced Statistical Applications

h. Manufacturing Technology, Stat.
   - Statistical Methods for Engineers
   - Advanced Statistical Applications

i. Manufacturing Techn., Reliability
   - Engineering Reliability
   - Reliability, Availability, and Maintainability

j. Physics
   - Introduction - Quantum Mechanics II
   - Quantum Mechnics for Opt../Solid State
   - Introduction -Solid State Physics I
   - Classsical Dynamics I
   - Statistical Mech. & Kinetic Theory I

k. Engineering Management Integrated Production & Process
   - Engineering Management Theory
   - Foundations - Total Quality Mgt
   - Financial Methods for Engineers
   - Engineering Project Management
   - Labor Relations for Engineers

- Organization Structure and Motivation
- Productivity and Quality Engineering
- Implementation of Technology
- Marketing/Management
- Management Science
- Introduction to Management of Technology
- Marketing - High Technology Environment
- Managing Technical Professionals
- New Product Development
- Marketing Emerging Technologies

6 Hours of On Site Practicum and Thesis required:

Table 3
Typical Course Schedule

Fall Semester:
- Geometrical Optics
- Physical Optics
- Engineering Management Elective

Spring Semester:
- Optics and Photonics System Design
- Optomechanical Design and Manufacturing
- Elective 1

Summer:
- On Site Practicum Thesis

Fall Semester:
- Integrated Product and Process Design
- Optical Fabrication and Testing
- Elective 2

Table 4
Optics and Photonics Systems Design

Course Outline:

1. **Components**
   - 1.1 Light Sources
   - 1.2 Detectors
   - 1.3 Modulators
   - 1.4 Lenses and Mirrors
   - 1.5 Diffractive Optical Elements
   - 1.6 Fibers and Fiber Components
2. **Subsystems**
   - 2.1 Transmitters
   - 2.2 Receivers
   - 2.3 Detector Arrays and Drive Electronics
   - 2.4 Optical Correlators
   - 2.5 Post Processing
3. **Systems**
   - 3.1 Telescopes
   - 3.2 Optical Pattern Recognition
   - 3.3 Adaptive Signal Processing
   - 3.4 Laser Radars
   - 3.5 Infrared Systems
   - 3.6 Fiber Communication Networks
   - 3.7 Fiber Imaging
   - 3.8 Fiber Sensors

Table 5
Optomechanical Design and Manufacturing

Course Outline

1. Optomechanics fundamentals and CAD
2. Optical mounts for mirrors, lenses, prisms & filters
3. Adjustment mechanisms (linear, tilt and rotary)
4. Dimensional stability, thermal and environmental considerations
5. Material selection for optical and structural parts
6. Fabrication methods (tolerances, machining, HT & chemical processes)
7. Advanced topics (IR systems, DM optics, biomedical and environmental monitoring applications, optical methods for non-destructive testing)
8. Computer-aided design and analysis project

Table 6
Optical Testing and Fabrication

Course Outline

1 Optical Bench Measurements Nodal Slide, focal lengths, cardinal points
2 Component Measurements Radius of curvature, refractive index, surface roughness
3 General Light Field Measurements
4 Aberrations Wavefront aberrations, transverse aberrations, MTF
5 Geometrical Tests Knife-edge, Hartman, Ronchi
6 Interferometric and Wavefront Tests Fizeau, Twyman-Green, lateral shearing,
7 Grinding and Polishing
8 Optical Coatings
9 Remote Optical Diagnostics Holographic interferometry, Moire Tests
10 Fabrication and testing techniques of optical components and systems
11 Components measurements
12 Lecture and "*Hands-on*" Laboratory Grind and polish 8" f/10 mirror Test with WYCO, ZYGO, Foucault Reflective Coating

Table 7
Integrated Product and Process Design

Course Description:
Introduces the concepts and tools which support integrated product and process design (IPPD). Particular attention will be paid to multi-functional teams and their value in promoting the concept of life-cycle engineering. Students will also gain experience with tools and technologies that support the IPPD philosophy and allow them to implement "*real*" product programs and to address the design-to-cost and performance issues that will arise.

Course Outline:
1. Introduction to the IPPD philosophy
2. Managing the Change to IPPD
3. Building Effective Teams
4. Managing Multi-Functional Teams
5. Designing for Performance
6. Computer Aided Engineering & Test Considerations
7. Design for Manufacturability
8. Design for Reliability & Serviceability
9. Design for Testability
10. Design for Optimization
11. Program Cost and Schedule Development issues
12. Project Management Issues Case Study
13. Implementation Case Studies

Table 8
Samples of On-Site Practicum

NASA Marshall Space Flight Center, Huntsville, AL
(a) Diamond Turning; (b) Ion Figuring; (c) Diffractive Optics; (d) Coherent Optics; (e) Video/Imaging Systems; (f) Optical Design

U.S. Army Missile Command, Redstone Arsenal, AL
(a) Guided Wave Optical Devices; (b) Integrated Optical Components; (c) Electro-Optical Polymer Devices; (d) microfabrication for Electro-Optical Devices and Integration; (e) Diffractive and Binary Optics

Oak Ridge National Laboratory, Oak Ridge, TN
(a) Evaluation of prototype metrology instruments for optical scatter and figure; (b) Interpreting power spectrum measurements of deterministically fabricated surfaces; (c) Finite element analysis approaches to distortion-free mounting in fabrication, testing, and end-use; (d) Single point diamond turning; (e) Ion beam milling; (f) Ductile mode grinding of brittle materials; and (g) Selected topics in photonics.

National Institute of Standards & Technology (NIST), Gaithersburg, MD
(a) Laser Ranging for Remote Sensing; (b) Ultrafast Lasers; (c) Absolute Cryogenic Radiometry; (d) Parametric Down Conversion; (e) Thermal Imaging

Advanced Optical Systems, Huntsville, AL
Optical Image Processing

Dynetics Inc., Huntsville, AL
Wideband High-Speed Signal Processing and Microwave Device Development based on Acousto-Optic Technology

Hughes Danbury Optical Systems, Danbury, CT
(a) White Light Interferometer for Coarse Metrology; (b) Caustic Scanning Interferometer for Testing Aspheric Optics

Nichols Research Corporation, Huntsville, AL
(a) Passive Ice Detection System for Flight Safety; (b) Advanced Optical Instrumentation

SCI Systems, Huntsville, AL
Fiber Position Sensor - Testing of the prototype of a high accouracy position sensor for fiber optic cable winding, perform additional analyses, and make design improvements.

Speedring, Cullman, AL
Precision Optical Manufacturing

III. Curricular Reform: The combination of courses in fundamental optics with courses in manufacturing technology and engineering management encompassed in this program was new at UAH and certainly not common in the United States. As noted in section I, this is considered as a trial to be possibly adopted in other disciplines by the UAH academic departments. Although this program has had outstanding success in placing its graduates in industry it is felt that this is still a nice area in general academic science and engineering education. Even after four years, we consider that this program is still in its infancy, and, though it is growing steadily, it is still too early to determine if its principles should be more broadly adopted by the university.

IV. Participation of Active and Displaced Defense Workers: Currently we have six students in our program who work in defense related positions.

V. Project Evaluation and Assessment (*See Lessons Learned):*

VI. Dissemination: The first of the materials developed to disseminate information about the program was an 11"X14" color flyer (Attachment 1 is a copy). In May 1994, approximately 300 copies were sent to universities and industries with interest in optics with the request that the flyers be distributed and posted in strategic places. The final version (Attachment 2) of our advertising brochure, a fourteen page in-depth description of the program, was completed in February 1995 and distributed to universities, industries and government laboratories, presidents of student chapters of the Optical Society of America and to individual students who had inquired about the program. We have also developed a tri-fold brochure, (Attachment 3), that is taken to all optics-related meetings and conferences for distribution. Attachment 4 is a flyer developed in 1996 that replaced the 1994 flyer and has become the initial advertising mail-out with a follow-up of the in-depth brochure to direct inquiries about the program. Our last mailing was done in December, 1997 and included 393 industries, university student chapters, university physics and electrical engineering departments across the country.

The availability of the program and financial laid was included in the UAH web site in 1995 with links to the NSF/MET site as well as the web sites of the optics and photonics professional societies. The web site was regularly updated and completely redesigned in 1997.

Attachment 5 is an advertisement of the program that was placed in SPIE's *OE Reports* in December 1996. The same advertisement was placed in the December issues of *Physics Today* and *Optics and Photonics News*. We plan to continue our yearly mail-outs to the same groups; however, we have decided that SPIE's *Optics Education* has the targeted readership for our program and will advertise in this publication in the future.

The program was highlighted at a booth which was acquired by UAH at the 11th Annual Technical and Business Exhibition and Symposium held at the von Braun Civic Center on May 16-17, 1995. The symposium was attended by over 5,000 and many picked up mateials available at the booth describing the program.

Invited talks on the program include:

a) 1995 International Conference on Education in Optics associated with the Annual Meeting of the International Society for Optical Engineering on July 10, 1995 and published in proceedings of the conference, SPIE Proceedings Volume 2525, paper 35, pgs. 370-378.

b) Optical Society of America Forum on Education and included in their proceedings, October 1996.
c) 96 Annual Conference on the Graduate Studies Division of the American Society of Engineering Education, June 1996.
d) NSF Engineering Education Innovator's Conference, April 1996

VII. Leadership and Management: The leadership of this program has been under Dr. John O. Dimmock, Director of the Center for Applied Optics at The Univesity of Alabama in Huntsville. A faculty advisory committee was established consisting of representatives of the UAH departments of Physics, Electrical and Computer Engineering, Mechanical and Aerospace Engineering, Industrial and Systems Engineering, Chemical Engineering and Chemistry. The outside academic, industrial and govoernmental advisory board member institutions are listed in Table I. A student representative was appointed to the advisory board and individual and group meetings were held with the students on at least a biannual basis. The advisory board has served to develop and review the curriculum and assess student progress.

VIII. Resources: Salaries were the single largest expenditure of the program both in TRP funds as well as cost sharing. The TRP program funded the development of the six new courses and the Physics and Electrical Engineering Departments cost-shared the teaching/mentoring time for their faculty members after the courses were developed. As the Center for Applied Optics traditionally has not had an academic budget, their faculty and staff were paid by TRP funds in the first three years, although in the last year most of this time was cost-shared from their research budget. The next largest expenditure for TRP and cost sharing was for students, their tuition and practicum support. Travel and costs associated with advertisement of the program accounted for almost all of the remaining expenditures (Attachment 6).

Dynetics, Inc. was the major cost-sharing partner in this program with staff involvement as well as a large equipment cost share (Attachment 7) for the students in this program. Hughes-Danbury, NASA and Nichols have also cost-shared the cost of students as well as their staff time in mentoring. Although not formally cost-sharing, many members of the Steering Committee (Attachment 8) have given their time for meetings and to develop practicum topics for students who may have an interest in their area of optics.

The UAH labs used in this program are housed in our 110,000 square foot optics building which was specifically designed for state-of-the-art optics research. It contains four floors of vibrationally-isolated and environmentally-shielded lab core, which includes over 6, 000 square feet of cleanroom space.

The labs that are used are the Virtual Prototyping Laboratory and the Optical Design Laboratory. A variety of capabilities exist to perform virtual prototyping of complex off-axis asheric optical systems, direct transfer of optical ray races and surfaces to AutoCAD Finite Element Analysis (FEA) programs, and CNC machines for optical parts fabrication. Software includes: AutoCAD release 14 with mechanical Desks Top 2.0 capability, mechanical fasteners and geometric dimensioning and tolerancing symbols libraries, Autospell and a text editor. Hardware includes 486 and Pentium computers and a Hewlett-Packard Draftpro EXL color pen plotter (A-E size). The Optical Design Laboratory contains the best commercial optical design programs (CODE V, SYNOPSYS, ZEMAX, and others), in addition to a unique link to CAD and Finite Element Analysis, resulting in the ability to:

1) design leading-edge optical systems with tolerancing and fabrication specifications;
2) download to CAM; and
3) optimize the optical systems for manufacturability and performance.

IX. Lessons Learned: These lessons may not be all that surprising to those who have developed new curricula in the past yet they may be useful for others.

First, it was an interesting challenge to develop and get Steering Committee agreement on a new curriculum with as diverse a group as we had, but it can be done. This took about three months of fairly steady effort. Initially there was a significant difference of viewpoint between the academic and the government/industry representatives with the academic representatives stressing fundamentals and the industry stressing practical training. What resulted, of course, was a mix.

Second, it takes a considerable amount of time to get a new set of courses and curriculum approved by the academic organizations involved once they wee approved by the Steering Committee. This also took about three months.

Third, even with reasonable extensive advertising, it takes time for the student community to realize that there is a new program available. All reasonable avenues for advertising should be pursued and a process should be established to ensure that all inquiries and applications get communicated promptly to the program office. A considerable amount of time should be set aside by the program office to discuss the program with prospective students.

Fourth, nearly every prospective student either requires or expects financial support. This needs to be budgeted and a process established to determine who gets supported. A time-line for this needs to be established and communicated in advertising and to the prospective students.

Fifth, it is taking longer for the students to complete the program than the originally planned sixteen months. The average time appears to be closer to two years. This is because it is taking longer than the planned three months to complete the practicum.

Sixth, although we have been able to place all students with a practicum, so far, at the appropriate time, the opportunities have come from many directions not originally anticipated.

Seventh, we have found that our graduating students are in high demand and, so far, all have received industrial offers. However, it is still too early to really declare a success. Nevertheless, at this stage it appears optimistic.

X. Acknowledgments: Obviously the development and implementation of this program has required the support and participation of many individuals and organizations. First, we would like to acknowledge Jeff Bennett, U.S. Army Missile Command; Jim Bilbro, NASA Marshall Space Flight Center; Gordon Emslie, Chairman of the UAH Physics Department; Darell Engelhaupt, UAH Center for Applied Optics; Dick Hartman, Advanced Optical Systems; Gary Kammerman, Teledyne Brown Engineering; Neil Mohon, Dynetics; and David Olson, Hughes Danbury Optical Systems; who, among other members of the Alliance for Optical Technology, were very effective in the initial definition and development of the program. Second, we would like to thank the NASA Marshall Space Flight Center, the U.S. Army Missile Command, the Oak Ridge National Laboratory, Advanced Optical Systems, Inc., Dynetics Inc., Hughes Danbury Optical Systems, Nichols Research, the National Institute for Standards and Technology, SCI Inc., and Speedring for offering support for the student on-site practicum thesis projects. Third, we would like to thank Bob Berinato,

Dynetics, Inc. for his continued support and for teaching several of the Optomechanical Design and Manufacturing classes. Classes were also taught by Ned Bragg, OETC, Inc.; David Pollock, UAH; and Jim Spann, NASA/MSFC. Finally we would like to acknowledge support of the Technology Reinvestment Project, and thank John Jennings, ARPA, and John Carlisle and Sally Little, NASA/MSFC, for their interest and support.

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Table 2
Project Activity Summaries

The University of Alabama in Huntsville
John O. Dimmock

Project Title	Lev.	Investigator	Site	Test	Impl.	Del	Description
Optomechanical Design and Manufacturing Course	☐ T ☐ L ☐ U ☐ A ☒ G ☐ P ☐ O	Dr. B. Peters/ Mr. Darell Engelhaupt	UAH	◉ Yes ○ No	○ Yes ○ No ◉ Cont.	○ M ◉ C ○ W ○ Y ○ D ○ S ○ I ○ T ○ O	Course was developed and offered for the first time in Spring 1995 semester. Currently five students are enrolled in this class.
Optics and Photonics Systems Design	☐ T ☐ L ☐ U ☐ A ☒ G ☐ P ☐ O	Dr. V. Riasatti	UAH	◉ Yes ○ No	○ Yes ○ No ◉ Cont.	○ M ◉ C ○ W ○ Y ○ D ○ S ○ I ○ T ○ O	Course covers Optoelectronic Components, Subsystems & Systems. Currently four students are enrolled in the class.
Optical Testing and Fabrication	☐ T ☐ L ☐ U ☐ A ☒ G ☐ P ☐ O	Dr. L. Hillman	UAH	◉ Yes ○ No	○ Yes ○ No ◉ Cont.	○ M ◉ C ○ W ○ Y ○ D ○ S ○ I ○ T ○ O	Fabrication Testing and Coating of Optical Coatings. In the fall of 1997, eight students took this course.

Table 2
Project Activity Summaries

The University of Alabama in Huntsville
John O. Dimmock

Project Title	Lev.	Investigator	Site	Test	Impl.	Del	Description
Integrated Product and Process Design (IPPD)	☐ T ☐ L ☐ U ☐ A ☒ G ☐ P ☐ O	Dr. P. Farrington	UAH	◉ Yes ○ No	○ Yes ○ No ◉ Cont.	○ M ◉ C ○ W ○ Y ○ D ○ S ○ I ○ T ○ O	Concepts & tools for IPPD Life-Cycle Engineering & Real Product Programs. In the fall of 1997, eight students took this course.
On-site Practicum & Thesis	☐ T ☐ L ☐ U ☐ A ☒ G ☐ P ☐ O	Dr. D. Gregory Dr. G. Nordin Dr. L. Hillman Dr. P. Banerjee Dr. C. Vikram	NASA/MSFC, UAH, McDonnell Douglas, DARPA Nichols, UAH UAH UAH UAH	◉ Yes ○ No	○ Yes ○ No ◉ Cont.	○ M ○ C ○ W ○ Y ○ D ○ S ○ I ◉ T ○ O	Students to work on a real project at an Industry/Government Organization. Currently there are 11 students involved in practicums.
Lens Design	☐ T ☐ L ☐ U ☐ A ☒ G ☐ P ☐ O	Dr. Joe Geary	UAH	◉ Yes ○ No	○ Yes ○ No ◉ Cont.	○ M ◉ C ○ W ○ Y ○ D ○ S ○ I ○ T ○ O	Lens Design Course with hands-on, practical application with theory to backup design examples. The optical design and analysis code ZEMAX was used. Fifteen students took the course in the fall of 1997.

Table 3: Personnel

The University of Alabama in Huntsville

John O. Dimmock

Personnel Classification	Total	Sex		Race/Ethnicity							Foreign	Disabled
		F	M	US	NA	AA	C	H	PI	A		
Faculty	9		9	7			7			2		
Management Staff	4	1	3	4			4					
Experts in the Classroom												
Other Educational Personnel	1		1							1	1	
Visiting Faculty												
Stud. in Short-term Technician Training												

Notes: Students in Short-term Technician Training Activities and Students in Short-term Professional Training Activities must be formally enrolled in MET training or education activity.

Enter Race/Ethnicity for U.S. citizens and permanent residents only: (NA) Native American; (AA) African American, not of Hispanic origin; (C) Caucasian, not of Hispanic origin; (H) Hispanic; (PI) Pacific Islander; (A) Asian. All entries are whole numbers and count each individual ONCE, except as noted.

Table 3: Personnel

The University of Alabama in Huntsville

John O. Dimmock

Personnel Classification	Total	Sex		Race/Ethnicity							Foreign	Disabled
		F	M	US	NA	AA	C	H	PI	A		
Stud. in Short-term Professional Training												
Stud. in Experimental Lower Division UG (Undergraduate)												
Stud. in Experimental Upper Division UG (Undergraduate)												
Students in Experimental Master's Degree Program	15	1	14	14		1	13			1	1	
Graduate TAs												
Undergraduate TAs												

Notes: Graduate TAs and Undergraduate TAs must be paid by with MET funds to assist MET award faculty in the delivery of MET training or education.

Enter Race/Ethnicity for U.S. citizens and permanent residents only: (NA) Native American; (AA) African American, not of Hispanic origin; (C) Caucasian, not of Hispanic origin; (H) Hispanic; (PI) Pacific Islander; (A) Asian. All entries are whole numbers and count each individual ONCE, except as noted.

Table 3: Personnel

The University of Alabama in Huntsville

John O. Dimmock

Personnel Classification	Total	Sex		Race/Ethnicity							Foreign	Disabled
		F	M	US	NA	AA	C	H	P I	A		
Students Doing Internships in Industry												
Active Defense Workers	6		6	6			6					
Displaced Defense Workers												

Notes: Displaced Defense Workers are participants who lost defense-related manufacturing jobs prior to participation. NOTE: The proportion of participants that fits into these categories varies greatly across MET awards due to the wide variety in the nature of MET awards.

Enter Race/Ethnicity for U.S. citizens and permanent residents only: (NA) Native American; (AA) African American, not of Hispanic origin; (C) Caucasian, not of Hispanic origin; (H) Hispanic; (PI) Pacific Islander; (A) Asian. All entries are whole numbers and count each individual ONCE, except as noted.

Table 4: Functional Expenditures

The University of Alabama in Huntsville
John O. Dimmock

Functional Category	Current Award Year
Faculty Salaries	8433
Student Salaries	6039
Research Staff Salaries (Full-time (non-teaching) research scientists and technical support)	
Post-Doc Salaries	
Administration Management Salaries (clerical support, contracts officer,etc.)	2674
Other Salaries	
General Operating Expenses	535
Facilities	
Travel	599
Equipment	
University Overhead-Indirect Costs	7860
Total	26140

Table 5: Matching Funds by Source of Support

The University of Alabama in Huntsville
John O. Dimmock

Type	TRP/MET Award	Industry	Univ.	Other Federal Agencies	State	Other Support	Total
Cash-Unrestricted							
Cash-Restricted	26,140						26,140
In-Kind Equipment, Materials and Supplies		117,632					117,632
In-Kind Personnel			90,685				90,685
In-Kind Software							
Other							
Total	26,140	117,632	90,685				234,457

Table 6: Industrial Participation

The University of Alabama in Huntsville
John O. Dimmock

Company	Type of Support	Type of Part.	Size	Foreign	Representative(s)	Hire or Supervise	Engineering Production
McDonnell Douglas	☐ CA ☐ SE ☐ IP ☒ OS ☐ IE ☐ NA ☐ IS	☐ A ☐ F ☒ L	○ S ○ M ◉ L	○ Yes ◉ No		○ H ○ S ○ N	○ Yes ○ No ○ Unkn
Remarks Supports one student involved in the Practice Oriented Masters Program							
Dynetics, Inc.	☐ CA ☐ SE ☒ IP ☐ OS ☒ IE ☐ NA ☐ IS	☒ A ☒ F ☐ L	◉ S ○ M ○ L	○ Yes ◉ No	Dr. Bob Berinato	◉ H ○ S ○ N	◉ Yes ○ No ○ Unkn
Remarks Serves on the Steering Committee, provides in-kind equipment to the program for hands-on experience for students							
Nichols Research	☒ CA ☒ SE ☐ IP ☒ OS ☐ IE ☐ NA ☐ IS	☒ A ☒ F ☐ L	○ S ◉ M ○ L	○ Yes ◉ No	Mike Jones Blair Barbour	○ H ◉ S ○ N	◉ Yes ○ No ○ Unkn
Remarks Provides financial support and practicum topic for one student. Hired a POMO student who has graduated from the program. Serves on the Steering Committee.							
Advanced Optical Systems	☐ CA ☐ SE ☐ IP ☒ OS ☐ IE ☐ NA ☐ IS	☒ A ☐ F ☐ L	◉ S ○ M ○ L	○ Yes ◉ No	Dr. Richard Hartman	○ H ○ S ○ N	○ Yes ○ No ○ Unkn
Remarks Serves on Steering Committee							
Boeing	☐ CA ☐ SE ☐ IP ☒ OS ☐ IE ☐ NA ☐ IS	☒ A ☐ F ☐ L	○ S ○ M ◉ L	○ Yes ◉ No	Mr. Ralph Reinhold	○ H ○ S ○ N	○ Yes ○ No ○ Unkn
Remarks Serves on Steering Committee							
Teledyne Brown Engineering	☐ CA ☐ SE ☐ IP ☒ OS ☐ IE ☐ NA ☐ IS	☒ A ☐ F ☐ L	○ S ○ M ◉ L	○ Yes ◉ No	John Yanosky	○ H ○ S ○ N	○ Yes ○ No ○ Unkn
Remarks Serves on Steering Committee							

Table 6: Industrial Participation

The University of Alabama in Huntsville
John O. Dimmock

Company	Type of Support	Type of Part.	Size	Foreign	Representative(s)	Hire or Supervise	Engineering Production
Morgan Research	☐ CA ☐ SE ☐ IP ☒ OS ☐ IE ☐ NA ☐ IS	☒ A ☐ F ☐ L	◉ S ○ M ○ L	○ Yes ◉ No	Timothy Morgan	○ H ○ S ○ N	○ Yes ○ No ○ Unkn
Remarks Serves on Steering Committee							
ADTRAN	☐ CA ☐ SE ☐ IP ☒ OS ☐ IE ☐ NA ☐ IS	☐ A ☐ F ☒ L	○ S ◉ M ○ L	○ Yes ◉ No		◉ H ○ S ○ N	○ Yes ○ No ○ Unkn
Remarks Provides support for employee to attend program and work on practicum topic.							

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Record 8

Table 6: Industrial Participation

The University of Alabama in Huntsville
John O. Dimmock

Company	Type of Support	Type of Part.	Size	Foreign	Representative(s)	Hire or Supervise	Engineering Production
McDonnell Douglas	☐ CA ☐ SE ☐ IP ☒ OS ☐ IE ☐ NA ☐ IS	☐ A ☐ F ☒ L	○ S ○ M ◉ L	○ Yes ◉ No		○ H ○ S ○ N	○ Yes ○ No ○ Unkn
Remarks Supports one student involved in the Practice Oriented Masters Program							
Dynetics, Inc.	☐ CA ☐ SE ☒ IP ☐ OS ☒ IE ☐ NA ☐ IS	☒ A ☒ F ☐ L	◉ S ○ M ○ L	○ Yes ◉ No	Dr. Bob Berinato	◉ H ○ S ○ N	◉ Yes ○ No ○ Unkn
Remarks Serves on the Steering Committee, provides in-kind equipment to the program for hands-on experience for students							
Nichols Research	☒ CA ☒ SE ☐ IP ☒ OS ☐ IE ☐ NA ☐ IS	☒ A ☒ F ☐ L	○ S ◉ M ○ L	○ Yes ◉ No	Mike Jones Blair Barbour	○ H ◉ S ○ N	◉ Yes ○ No ○ Unkn
Remarks Provides financial support and practicum topic for one student. Hired a POMO student who has graduated from the program. Serves on the Steering Committee.							
Advanced Optical Systems	☐ CA ☐ SE ☐ IP ☒ OS ☐ IE ☐ NA ☐ IS	☒ A ☐ F ☐ L	◉ S ○ M ○ L	○ Yes ◉ No	Dr. Richard Hartman	○ H ○ S ○ N	○ Yes ○ No ○ Unkn
Remarks Serves on Steering Committee							
Boeing	☐ CA ☐ SE ☐ IP ☒ OS ☐ IE ☐ NA ☐ IS	☒ A ☐ F ☐ L	○ S ○ M ◉ L	○ Yes ◉ No	Mr. Ralph Reinhold	○ H ○ S ○ N	○ Yes ○ No ○ Unkn
Remarks Serves on Steering Committee							
Teledyne Brown Engineering	☐ CA ☐ SE ☐ IP ☒ OS ☐ IE ☐ NA ☐ IS	☒ A ☐ F ☐ L	○ S ○ M ◉ L	○ Yes ◉ No	John Yanosky	○ H ○ S ○ N	○ Yes ○ No ○ Unkn
Remarks Serves on Steering Committee							

Table 6: Industrial Participation

The University of Alabama in Huntsville
John O. Dimmock

Company	Type of Support	Type of Part.	Size	Foreign	Representative(s)	Hire or Supervise	Engineering Production
Morgan Research	☐ CA ☐ SE ☐ IP ☒ OS ☐ IE ☐ NA ☐ IS	☒ A ☐ F ☐ L	◉ S ○ M ○ L	○ Yes ◉ No	Timothy Morgan	○ H ○ S ○ N	○ Yes ○ No ○ Unkn
Remarks Serves on Steering Committee							
ADTRAN	☐ CA ☐ SE ☐ IP ☒ OS ☐ IE ☐ NA ☐ IS	☐ A ☐ F ☒ L	○ S ◉ M ○ L	○ Yes ◉ No		◉ H ○ S ○ N	○ Yes ○ No ○ Unkn
Remarks Provides support for employee to attend program and work on practicum topic.							

Table 7: Non-Industrial Participation

The University of Alabama in Huntsville
John O. Dimmock

Organization	Type of Support	Type of Part.	Size	Foreign	Representative(s)	Hire or Supervise	Engineering Production
NASA/MSFC	☒ CA ☒ SE ☒ IP ☒ OS ☒ IE ☐ NA ☐ IS	☒ A ☒ F ☒ L	○ S ○ M ◉ L	○ Yes ◉ No	Jim Bilbro	○ H ◉ S ○ N	◉ Yes ○ No ○ Unkn
Remarks Provides practicum opportunity for two students, serves on Advisory Board							
DARPA	☐ CA ☐ SE ☐ IP ☒ OS ☐ IE ☐ NA ☐ IS	☐ A ☒ F ☐ L	○ S ○ M ○ L	○ Yes ◉ No		○ H ○ S ○ N	○ Yes ○ No ○ Unkn
Remarks Provides practicum support for one student							

ATTACHMENTS 1 - 5

ADVERTISEMENTS

TECHNOLOGY REINVESTMENT PROJECT

ARPA

THE MS/MSE DEGREE PROGRAM WITH CONCENTRATION IN OPTICS AND PHOTONICS TECHNOLOGY

Center for Applied Optics

NASA

MICOM

NIST

SCI

HUGHES

AOS

Dynetics, Inc.

A Practice-oriented Master's Program in Optics offered in collaboration with industry and government organizations, sponsored by ARPA under the Technology Reinvestment Project.

NRC

ALABAMA AGRICULTURAL AND MECHANICAL UNIVERSITY

ornl

UAH

The University of Alabama in Huntsville

Huntsville, Alabama 35899

INTRODUCTION

An interdisciplinary Master's Program with a concentration in Optics and Photonics Technology is offered under the U.S. Manufacturing Education and Training Activity of the Technology Reinvestment Project (TRP).

A number of industries, government and academic organizations, as shown in Table 1, are participating fully in the design, development and implementation of this program. The program will produce highly trained graduates who can solve practical problems. It includes an on-site practicum at a manufacturing location.

This program is designed to uniquely prepare and qualify students to enter active careers in industry and/or government in the business of technology development and manufacturing. It is also designed for those working scientists and engineers seeking professional growth and career advancement opportunities. Some significant features of this program, which distinguish it from the traditional master's programs in physics and electrical engineering, are:

1. A balanced mix of science, engineering and management courses for a well rounded multi-disciplinary background, which will give the graduates a competitive edge in the job market.
2. Applications oriented courses have a significant design and hands-on laboratory content to provide the background and knowledge directly applicable to the workplace needs.
3. An on-site praticum at an industry or government research laboratory under the supervision of a senior manager will provide valuable practical training of working on a real hardware-based project.

The graduate of this program will require significantly less on the job training to become a productive employee.

Table of Content

The program is designed to enable full-time students and the government and industrial defense work force to transition to commercial manufacturing, enhancing their competitiveness in the global marketplace, and to expand the U.S. job base and economy.

The broad spectrum curriculum of this program emphasizes the fundamentals of optics, optical systems manufacturing and testing, and the principles of design and manufacturing to cost for commercial products. The participating organizations are providing extensive personnel and laboratory facilities to ensure successful implementation and sustainment of the program.

The MS in Physics and MSE in Electrical Engineering Degrees with concentration in Optics and Photonics Technology are offered by the respective University of Alabama in Huntsville (UAH) academic departments under the auspices of the UAH Graduate School, with support from and in consultation with the Steering Committee chaired by Dr. John O. Dimmock, Director of the Center for Applied Optics. The committee is composed of representatives from each of the participating academic and industrial organizations, as well as a student representative from UAH.

The degree consists of thirty-three credit hours, of which twenty-seven are classroom hours in new and existing courses offered by UAH and Alabama A&M University (AAMU), and six credit hours consisting of a practicum and thesis to be executed at one of the on-site locations.

Academic Institutions

The University of Alabama in Huntsville
Alabama A&M University
Northwest Shoals Community College

Government Institutions

NASA Marshall Space Flight Center
National Institute of Standards and Technology (NIST)
U.S. Army Missile Command
Oak Ridge National Laboratory

Industrial Affiliates

Advanced Optical Systems (AOS)
Dynetics, Inc.
Hughes Danbury Optical Systems, Inc.
Nichols Research Corporation
SCI Systems, Inc.
Speedring, Inc.

Table 1. Program Affiliates

ADMISSION REQUIREMENTS

For unconditional admission to the School of Graduate Studies, an applicant must hold a bachelor's degree in science or engineering from an accredited institution. The following minimum requirements are acceptable to the graduate school; individual departments may require higher averages or additional requirements.

- A minimum average of B (GPA of 3.0) on the undergraduate record, and
- A score of 1500 on the aptitude test (verbal, quantitative, and analytical) portion of the GRE

The applicant whose native language is not English is required to take the Test of English as a Foreign Language (TOEFL) and score at least 500.

CURRICULUM REQUIREMENTS

21 Hours Required Core Courses

- 6 credit hours in Optics Principles:
  (a) Geometrical Optics (OSE541 - UAH, or PHY649 - AAMU); and (b) Physical Optics (OSE542 -UAH, or PHY657 - AAMU)
- 9 credit hours in Optics Design and Manufacturing Technology:
  - Optics and Photonics Systems Design (EE570/PH570 - UAH)
  - Optomechanical Design and Manufacturing (EE670/ PH670 - UAH)
  - Optical Fabrication and Testing (OSE654 - UAH)
- 6 credit hours in Engineering Management:
  Integrated Production and Process Design (ISE570 - UAH) plus one course from area k or l.

6 Hours Required in Elective Courses (two courses to be taken in <u>one</u> of the following lettered areas):

a. Optical Systems and Engineering
- Coherent Optical Systems and Holography (OSE632 - UAH)
- Electro-Optical Engineering (EE633 - UAH)
- Optoelectronics (PH544 -UAH)
- Lens Design (PHY 665 - AAMU)
- Non-Linear Optics (PH746 - UAH; or PHY670 - AAMU)
- Laser Electronics (EE613 - UAH)
- Introduction to Lasers (PH545 - UAH; or PHY671 - AAMU)
- Radiometry (PH546 - UAH)

b. Quantum Optics
- Quantum Optics (PHY660 - AAMU)
- Laser Physics (PHY 671 - AAMU)
- Special Topics in Optics - Nonclassical States (PHY 784 - AAMU)
- Quantum Mechanics for Optics and Solid State (OSE555 -UAH)
- Lasers (OSE645 - UAH)
- Optical Properties of Matter (OSE655 -UAH)

c. Optical Signals
- Random Signals and Noise (OSE500 -UAH)
- Linear Systems (OSE601 - UAH)
- Digital Image Processing (EE604 - UAH)
- Fourier Optics (PH673 - UAH)
- Signal Processing (PHY771 - AAMU)
- Special Topics in Optics - Optical Computing (PHY 780 - AAMU)

d. Optical Communications
- Communication Theory (EE506 - UAH)
- Detection of Optical and Infrared Radiation (EE531 - UAH)
- Optical Communications (EE634 - UAH)
- Statistical Optics (EE735 - UAH)
- Fiber Optics (Phy715 - AAMU) or (EE734 - UAH)
- Optical Phase Conjugation, (PHY 712 - AAMU)

e. Optical Materials
- Elements of Material Science (PHY632 - AAMU)
- Crystal Physics and Crystal Growth (PHY634 -AAMU)
- Magnetic and Optical Properties of Materials (PHY635 - AAMU)
- Materials for Radiation Detectors (PHY735 - AAMU)
- Optical Properties of Matter (OSE655 - UAH)

f. Manufacturing Technology, Systems
- Introduction to Systems Engineering (ISE627 - UAH)
- Engineering Economic Analysis (ISE723 - UAH)

g. Manufacturing Technology, Quality
- Statistical Quality Control (ISE523 - UAH)
- Design and Analysis of Experiments (ISE526 - UAH)

h. Manufacturing Technology, Statistics
- Statistical Methods for Engineers (ISE690 - UAH)
- Advanced Statistical Applications (ISE790 - UAH)

i. Manufacturing Technology, Reliability
- Engineering Reliability (ISE638 - UAH)
- Reliability, Availability, and Maintainability (ISE738 - UAH)

j. Physics
- Introductory Quantum Mechanics II (PH552 - UAH; or PHY521 - AAMU)
- Quantum Mechanics for Optics and Solid State (OSE555 - UAH)
- Introduction to Solid State Physics I (PH560 - UAH; or PHY525 - AAMU)
- Classical Dynamics I (PH601 - UAH)
- Statistical Mechanics and Kinetic Theory I PH621 - UAH)

k. Engineering Management Integrated Production and Process
- Engineering Management Theory (EM660 - UAH)
- Foundations of Total Quality Management (EM662 - UAH)
- Financial Methods for Engineers (EM665 - UAH)
- Engineering Project Management (EM666 - UAH)
- Labor Relations for Engineers (EM667 - UAH)

- Organization Structure and Motivation (EM760 -UAH)
- Productivity and Quality Engineering (EM762 - UAH)
- Implementation of Technology (EM766 - UAH)

1. Marketing/Management/Management Science
   - Introduction to Management of Technology (MGT601 - UAH)
   - Marketing in a High Technology Environment (MKT606 - UAH)
   - Managing Technical Professionals (MGT622 - UAH)
   - New Product Development (MSC690 - UAH)
   - Marketing Emerging Technologies (MKT514 - UAH)
6. **Hours of On Site Practicum and Thesis required:** (sample practicum opportunities are listed on page 8).

Students interested in pursuing a doctoral degree in optics or physics should discuss those plans with the faculty advisor before selecting a program of study.

TYPICAL COURSE SCHEDULE

Fall Semester:
- Geometrical Optics (OSE541 - UAH)
- Physical Optics (OSE542 - UAH)
- Engineering Management Elective

Spring Semester:
- Optics and Photonics System Design (EE570 - UAH)
- Optomechanical Design and Manufacturing (EE670 - UAH)
- Elective 1

Summer:
- On-Site Practicum/Thesis (OSE699 - UAH)

Fall Semester:
- Integrated Product and Process Design (ISE570 - UAH)
- Optical Fabrication and Testing (OSE671 - UAH)
- Elective 2

PARTICIPATING ACADEMIC ORGANIZATIONS

UAH CENTER FOR APPLIED OPTICS

The Center for Applied Optics (CAO) was established in 1985 to provide a focal point for the optical science and engineering programs at UAH and to stimulate and support greater industry and government research and development in optics. The CAO meets the equipment and personnel needs of researchers in optics, including faculty members from other departments, besides working on several research projects funded federally as well as from the private sector. Some of the unique equipment available at the CAO includes a state of the art diamond turning optics fabrication machine, and a well equipped metrology laboratory. The CAO possesses about $3 million worth of specialized optics equipment.

Approximately 60% of the Center's activities address such basics as the design, fabrication and testing of optics and optical systems. About 20% of its activities are directed to industrial applications such as optical sensing and metrology. The remaining 20% are devoted to the application of optical technology to other areas of science and engineering.

The Center currently consists of a staff of 20 professionals including 6 Senior Research Scientists, 8 Research Scientists and Optical Technologists, and 6 support staff. The current activities and capabilities of the CAO include: computer aided optical component and system design; optomechanical engineering; optical system materials and process development; optical system modeling and analysis; optical coating, fabrication and metrology; rapid prototyping; electro-optical materials and device modeling; holography, holographic interferometry, speckle metrology; and coherent laser infrared systems analysis and development.

UAH DEPARTMENT OF ELECTRICAL & COMPUTER ENGINEERING

This department is the largest on campus, enrolling 660 undergraduates and 300 graduate students, of whom almost half work in local industrial or government facilities. The ECE faculty has 29 full-time members, with specialization in optics, solid state, electro-magnetics, communications/signal processing and computers. The department offers a large number of graduate and undergraduate courses. During a typical quarter, it offers 37 undergraduate class sections, 17 laboratory sections, and twenty-six graduate course sections.

During 1992-93, the ECE Department granted 55 MSE degrees, and 6 PhD degrees. The instructional staff consists of 29 full-time faculty, eight part-time lecturers, twenty-six graduate teaching assistants, and nine graduate research assistants.

The ECE Department features many laboratories devoted to teaching and research in optics. The Optical Computing laboratory is devoted to the analysis, design and testing of optical computing and signal processing systems. A new instructional laboratory in Optical Engineering features

experiments in holography, interferometry and optical communication. The Optical Information Processing laboratory is devoted to research in acousto-optics, photorefractives and nonlinear materials characterization. The Optical Computing laboratory performs the analysis, design and testing of optical computing and signal processing systems. The Optoelectronics laboratory is devoted to design, fabrication and testing of liquid crystal-based diffractive optics.

UAH DEPARTMENT OF PHYSICS

The physics faculty at UAH consists of 14 full-time professors and 7 research professors. All faculty members are involved in research, working in solid-state physics, laser physics, optics, general relativity, solar physics, and space physics.

The department's research activities are broadly categorized into four main areas: Optics, Space Plasma Physics, Astrophysics/General Relativity, and Solid State Materials/ Materials Science.

With the combined resources of the Physics Department, CAO and external agencies (e.g. NASA, local industry), we offer graduate students opportunities to work on many research topics of contemporary interest. The University has laboratory facilities for such diverse topics as thin film optics, integrated optics, optical design, space optics, fiber optic sensors, optical surface properties, high energy lasers, polarimetry, infrared science, quantum optics, nonlinear optics, four wave mixing, holography, optical image processing, optical computing and optical signal processing.

UAH DEPARTMENT OF MECHANICAL & AEROSPACE ENGINEERING

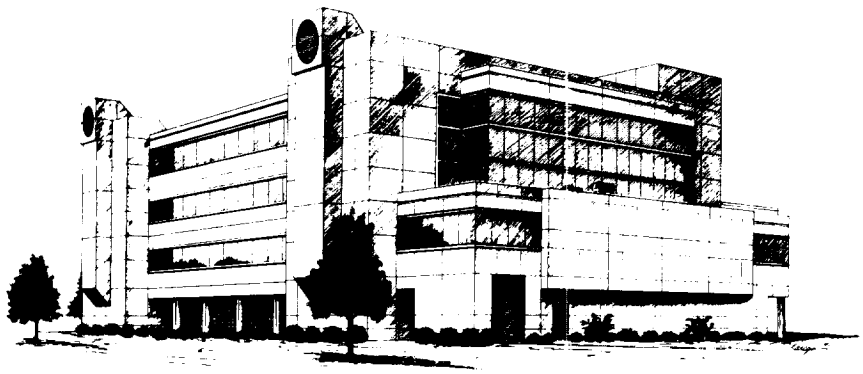
The department has 17 full-time faculty members. Thirty percent of the PhD degrees awarded by the department during the past five years have involved research in applied optics. The range of research interests of the faculty in the department is quite broad, affording graduate students excellent opportunities for optics-related research in fluid and solid mechanics, heat transfer, aerodynamics, thermodynamics, transport phenomena, applied optics, experimen-tal mechanics, space plasma, controls, and combustion and propulsion.

UAH INDUSTRIAL AND SYSTEMS ENGINEERING DEPARTMENT

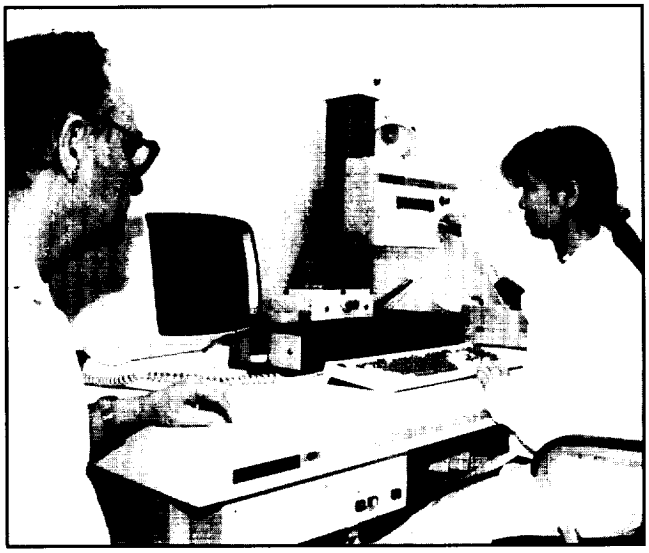
In support of this Program, the Department of Industrial and Systems Engineering offers courses and associated minors in engineering management, systems engineering, statistics, quality control, manufacturing systems, quality assurance, systems simulation and operations research. The department is currently supported by eleven full-time faculty members and six part-time faculty members. Of particular interest to the Optics student is the department's Engineering Management option, which has been developed to meet the needs of practicing engineers who find themselves performing engineering management functions without the benefit of formal management education. As our society becomes more and more dependent upon technology, more engineers are moving into management positions. The Engineering Management option is designed to build upon the mathematical and analytical expertise gained from both a formal engineering education and professional experience. The curriculum contains courses in project management, appropriate organization structure for knowledge workers, motivation of technically trained workers, TQM, financial methods for engineers, how to assimilate technology from research and development to industry, integrated product and process design and productivity and quality issues.

ALABAMA A&M UNIVERSITY PHYSICS DEPARTMENT

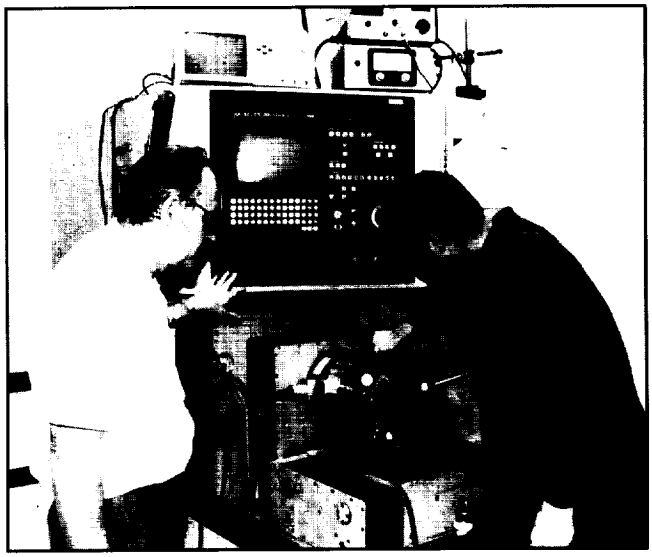
The physics department at Alabama Agricultural and Mechanical University (AAMU) is a dynamic and progressive department with fifteen (15) tenured and sixteen (16) research faculty members. The department offers a B.S. degree in physics and applied physics, M.S. and Ph.D. degrees in Optics, Lasers and Materials Science. The department is the seat of a National Science Foundation (NSF) Center of Nonlinear Optics and Materials and Howard J. Foster Center for Irradiation of Materials. The annual research funding of the department from agencies like NASA, NSF, DoD, DoE, etc., is over $5M. The department is housed in the recently constructed V. M. Chambers Science Building.



The optics building, completed in 1991, is the focal point of all optics research at UAH



Darell Engelhaupt and Donquing Cao of CAO are preparing the Form Talysurf profilometer to perform dimensional inspection of some mirrors.



Darell Engelhaupt and Ye Li of CAO are calibrating the single-point diamond turning machine prior to the fabrication of metal mirrors.

FACILITIES

Optics Building

The optics building contains 118,000 square feet and was completed in November 1991. The CAO, Physics Department, and elements of the College of Engineering are located in this new Optics Building. The laboratories are placed in the central core of the structure which is actually a separate building surrounded by the office and support portion of the facility. This allows the laboratories to be more effectively isolated from vibration and other environmental effects. The Optics Building has over 20 advanced optics laboratories specializing in optical signal processing, nonlinear optics, fiber optics, etc., administered by faculty from the Physics, ECE, Mechanical Engineering and Chemical Engineering Departments, and researchers from the CAO.

Some unique laboratories existing in the Optics Building are described on the following pages.

Optical Metrology Laboratory

The Optical Metrology laboratory contains a Zygo interferometer and Form Talysurf profilometer for surface figure/shape, Wyko TOPO-3D and Talystep profilometers for surface finish/roughness and step height, custom BSDF and TIS instruments for surface scattering, a Normaski microscope for examining fine details on glass and coated optics, and a Klinger measuring microscope for dimensional metrology. All equipment is located in vibrationally isolated and environmentally controlled 100K cleanrooms. In this lab, NASA space flight hardware has been successfully inspected for surface figure and finish; a wide variety of optical systems have been assembled, aligned and tested by CAO experts; materials exposed to the space environment as well as candidate materials for Space Station Freedom have been tested; and numerous analyses of the scattering properties of materials for military and space applications have been performed.

Optical Fabrication Laboratory

Current areas of concentration include rapid and low-cost prototyping and optical fabrication methodology research. The equipment includes a Pneumo Ultra 2000 single point diamond turning (SPDT) machine with 12" diameter swing, which is capable of turning non-ferrous metals, plastics, and crystalline materials (Ge, ZnSe, etc.) for fabrication of mirrors, lenses, molds, and high precision non-optical components. The SPDT machine is located in a vibrationally isolated and environmentally controlled lab. There is a class 100K clean inspection area within the lab. One-, two- and four-spindle Strausbaugh polishers, with up to 16" diameter swing, are available for conventional polishing of mirrors and lenses. Also, metrology and coating facilities are available in these optical fabrication areas. Past accomplishments include fabrication of space-qualified optics for NASA (mirrors for ultra-violet imager, transparent solid telescope, CO_2 LIDAR); lightweight metal matrix composite collimator for the Army; compact focal plane image coupler for the Navy; Mach 5 to 8 wind tunnel components for NASA; four-mirror reflective zoom telescope for Boeing; multifocal intraocular lenses; and diffractive lens molds.

J. Kim of Optical Aeronomy Lab is coating indium tin oxide on the fiber optic tapers for the camera assembly of a solar telescope.

Optical Coatings Laboratory

The Optical Coatings laboratory contains five high vacuum systems with base pressure of 10^{-7} torr, cryogenic pumping, resistive evaporation, RF sputtering, ion milling and deposition; and 10K and 100K clean areas for ultra-high vacuum work. Accomplishments to date include deposition of all types of metal coatings, protective layers, superconducting thin films, dielectric films, conductive coatings, and surface patterning.

The CVC-18 resistive evaporator includes an 18" diameter bell jar, six sources for depositing various material layers in a single run, glow discharge cleaning, substrate heating to 300°C, cryocoil for directing evaporation and quartz crystal thickness monitoring. The Veeco single-source resistive evaporator is used for quick metal coatings on parts up to 6" in diameter.

The RF system includes a 3" planar magnetron source, 600-watt RF power supply, automatic impedance matching network, dual process gas capabilities, substrate rotation and heating; and quartz crystal monitor for thickness control. An additional source can be added, if desired. The Balzers 710 coating unit has a 29" bell jar for large substrates and a capability for adding two four-pocket electron-beam evaporators for co-evaporation and multi-layer dielectric films. Accomplishments include 1-2-3 super-conducting thin films for infrared detection, indium-tin-oxide transparent conductive films and protective coatings.

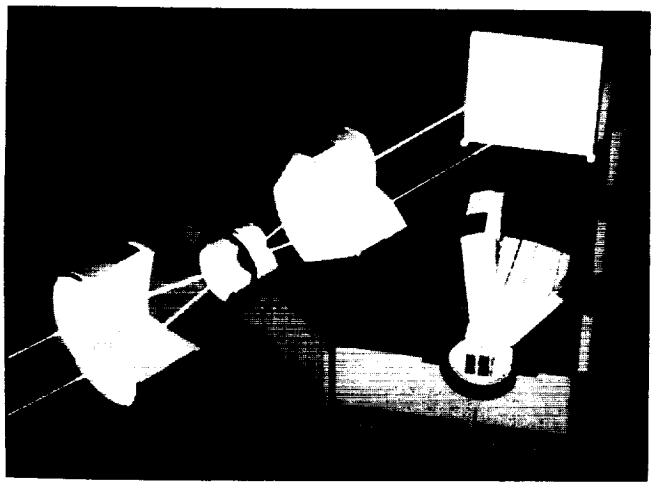
Optical Design Laboratory

The Optical Design Laboratory contains the best commercial optical design programs (CODE V, SYNOPSYS, and others), in addition to a unique link to CAD and Finite Element Analysis, resulting in the ability to:

1) design leading-edge optical systems with tolerancing and fabrication specifications;
2) download to CAM; and
3) optimize the optical systems for manufacturability and performance.

Numerous optical systems have been designed and modeled in this lab, including:

- Solar vector magnetograph for NASA
- ISTP/UV-Imager for NASA
- Scanning micro-lens array for Lockheed
- Compact HOE spectrometer for NASA
- All reflective zoom telescope for Boeing
- High-resolution EUV/X-ray telescopes for NASA
- UV-VIS-IR imaging spectrometer for NSF



A broad spectrum imaging spectrometer designed by using the optical design and modeling software available at CAO.

Anees Ahmad of CAO and Steve McClain of Physics Department are testing the prototype of a multispectral zoom telescope fabricated at CAO.

- Scanning IR telescope for MICOM
- Retinal reflex camera and an in-vivo corneal microscope for opthalmological research applications

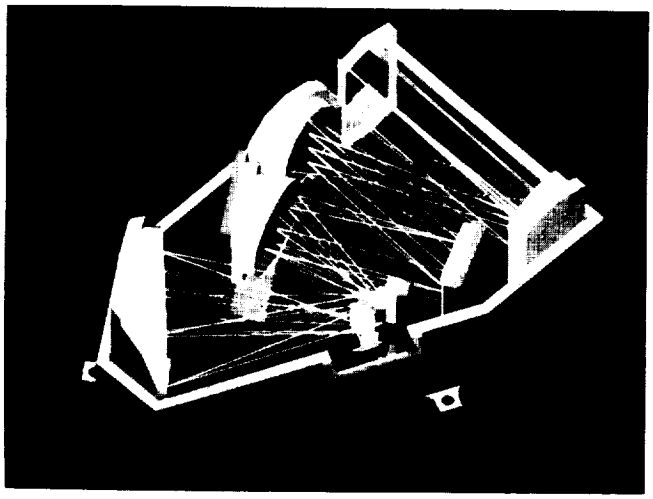
System Prototyping Laboratory

This lab is used for the rapid feasibility demos using extensive inventory of optical components such as optical tables, mounts, stages, etc. Rapid prototyping with in-house fabrication of special components is performed in this lab. The lab is used for integration, test and evaluation of optical components and systems. Some of the systems prototyped in this lab include: Ultraviolet imager; all-reflective zoom telescope; one-piece Ritchey-Chretien telescopes; and total integrated scatter instrument for space-flight.

Virtual Prototyping Laboratory

A variety of capabilities exist in this lab to perform virtual prototyping of complex off-axis aspheric optical systems, direct transfer of optical ray traces and surfaces to AutoCAD, Finite Element Analysis (FEA) programs, and CNC machines for optical parts fabrication.

Software includes: AutoCAD release 13 with AME (Advanced Modeling Extension) capability, mechanical fasteners and geometric dimensioning and tolerancing symbols libraries, Autospell and a text editor. Hardware includes 486 and Pentium computers and a Hewlett-Packard Draftpro EXL color pen plotter (A-E size). Some of the systems designed and modeled in this lab include the Ultraviolet Imager (UVI), Solar X-ray Imager (SXI), ultra-lightweight collimators, and a number of compact imaging spectrometers.



The virtual prototype of a compact imaging spectrometer showing the actual raytrace and aspheric optics.

Optical Information Processing

The optical information processing laboratory is devoted to the areas of optical signal processing, acousto-optics, nonlinear optics and photorefractive materials. The facilities include two optics tables, 15 mW He-Ne lasers, a 4W argon laser, a dye laser, acousto-optic cells and photorefractive crystals and a state of the art beam analyzer, complete with computer interface. Typical work involves the measurement of optical nonlinearities, study of the physics of the photorefractive effect, beam fanning, characterization of photorefractive crystals, and image processing and novel phase conjugation geometries using these materials, and the study of hybrid acousto-optic bistable devices.

Opto-electronics Research Laboratory

This laboratory is devoted to the design, fabrication, and testing of opto-electronic devices and systems. Tables and optical components are available for holography and image processing. Extensive facilities have been developed for fabricating and testing liquid crystal spatial light modulators and adaptive lenses. Nonlinear organic materials and devices, especially etalons, are fabricated and tested as modulators on glass and silicon integrated circuits. Applications in holographic television, very large optical memories, and global optical interconnects are being studied.

Experimental Mechanics and Applied Optics

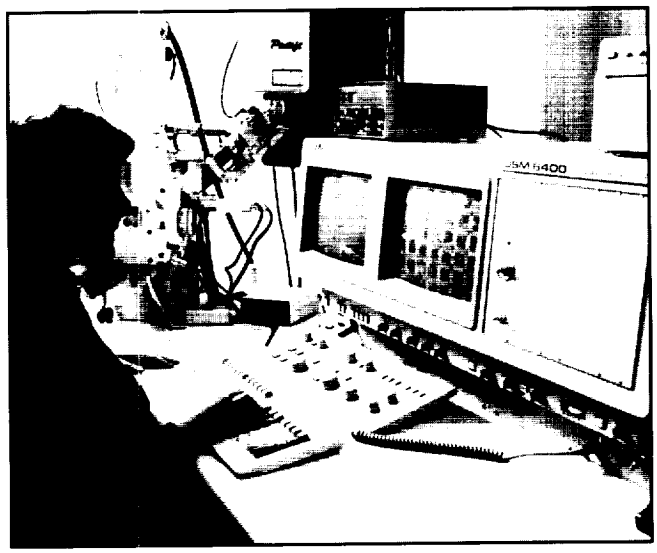
This laboratory complex is located on the ground floor of the Optics Building and occupies approximately 3000 square feet. It consists of eight fully outfitted laboratories including two panoramic imaging system laboratories, an optical metrology laboratory, an applied mechanics laboratory, a fiber optic sensing laboratory, a holography laboratory, an image processing and computer laboratory, and a photo processing dark room. Research efforts are currently concentrated in the development of imaging systems utilizing panoramic annular lenses, wave guide holography, experimental mechanics, optica metrology, fiber optic sensing technologies, and image processing.

ISE/EM Distance Learning Program

To meet the needs of the working professional, a state-of-the-art video classroom has been designed and built in order to make graduate programs available to students with heavy travel schedules, those students located in remote areas, and students requiring a maximum of flexibility in balancing family, career, and educational responsibilities.

The classroom is operated by a full-time media technician and makes use of a three camera system: one focusing on the professor and lecture board; an over-head camera to display graphs, charts, text, etc.; and a student camera which picks up visual images of the in-class students as they ask questions and participate in class. A bank of 12 VCRs record the lecture in real time. The completed tapes are sent, via 2-day air, to as many as 40 Industry Partner locations. Students

Video equipment in the control room of Distance Learning Program is used to record the lectures in real time.



Scanning Electron Microscope in Materials Characterization Lab of AAMU.

view the lecture tapes as a class, receive the handouts with each tape, and contact the professor with questions or comments via phone, fax, e-mail, or during a faculty visit to the Industry Partner. Exams are proctored by approved industry personnel.

Advantages to this delivery method include:

- No conflict with company travel or business
- Allows multiple review of lecture material
- Program can follow relocated student.

AAMU Laboratories

Crystal Growth: Solution Crystal Growth; Growth from Melt (Czochralski, Bridgmann); Organic Crystal Growth; Top Seeded Flux, Physical; Vapor Transport.

Microgravity Space Experiments: Solution Crystal Growth; Growth of Optical Crystals.

Materials Characterization: Crystal cutting and polishing; X-ray diffraction, Scanning Electron Microscopy (SEM); Dielectric and Electrical Measurements; I.R. Detector Characteristics; Thermal Measurements (DSC, DTA), FTIR, EPR hardness testing.

Optical In-situ Crystal Growth Rate Measurement: Interferometric, Heterodyne Detection, Mach-Zehnder, Ellipsometry.

High Temperature Furnace: Furnaces up to 3000° C; Growth of superalloys

Glassy Carbon Manufacturing: Glassy carbon for crystal growth crucibles.

Materials Irradiation Center: RBS, Optical Device Fabrication, Nanostructures, Ion Implantation.

Fiber Optics: SRS in Optical Fibers.

Laser Labs: Laser Spectroscopy, NLO Optical Phase Conjugation; Frequency Upconversion, Optical Thin Films and Integrated Optics; Optical Materials Diagnostic Lab (Pico second and Nano second Nd:YAG laser, Nitrogen laser, Argon Ion laser, Excimer laser, CO_2 laser, He-Ne lasers).

Holography: Holographic storage, Realtime holography.

SAMPLES OF ON-SITE PRACTICUM

NASA/MSFC - (a) Diamond Turning; (b) Ion Figuring; (c) Diffractive Optics; (d) Coherent Optics; (e) Video/Imaging Systems; (f) Optical Design

MICOM - (a) Guided Wave Optical Devices; (b) Integrated Optical Components; (c) Electro-Optical Polymer Devices; (d) Microfabrication for Electro-Optical Devices and Integration; (e) Diffractive and Binary Optical Devices

ORNL - (a) Evaluation of prototype metrology instruments for optical scatter and figure; (b) interpreting power spectrum measurements of deterministically fabricated surfaces; (c) finite element analysis approaches to distortion-free mounting in fabrication, testing, and end-use; (d) selected topics in single point diamond turning; (e) selected topics in ion beam milling; (f) selected topics in ductile mode grinding of brittle materials; and (g) selected topics in photonics.

Advanced Optical Systems - Optical Image Processing

Dynetics - Wideband High-Speed Signal Processing and Microwave Device Development based on Acousto-Optic Technology

Hughes Danbury - (a) White Light Interferometer for Coarse

Metrology; (b) Caustic Scanning Interferometer for Testing Aspheric Optics

Nichols Research - (a) Passive Ice Detection System for Flight Safety; (b) Advanced Optical Instrumentation

NIST - (a) Laser Ranging for Remote Sensing; (b) Ultrafast Lasers; (c) Absolute Cryogenic Radiometry; (d) Parametric Down Conversion; (e) Thermal Imaging.

SCI - Fiber Position Sensor - Testing of the prototype of a high accuracy position sensor for fiber optic cable winding, perform additional analyses, and make design improvements.

Speedring - Precision Optical Manufacturing

GOVERNMENT & INDUSTRY AFFILIATES

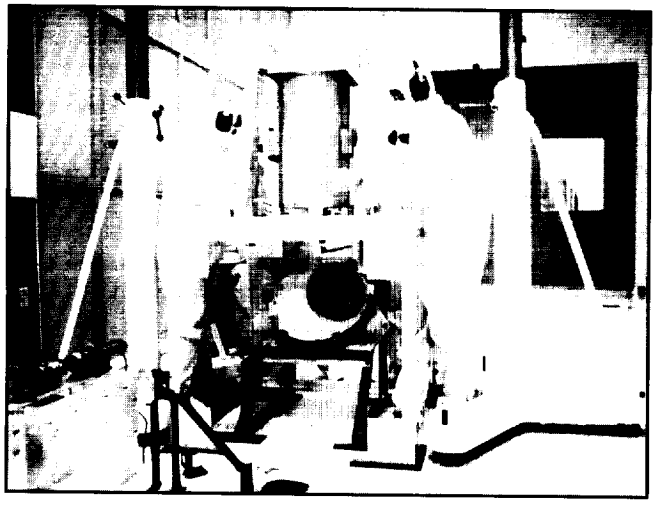
NASA Marshall Space Flight Center

The Optics and RF division at Marshall Space Flight Center (MSFC) performs research and development in the areas associated with optical system design, fabrication, test and analysis, and provides technical support to projects involved in the development and/or application of these systems.

The goals of the division are to foster research and development, to advance the state-of-the-art in optics, to serve as a repository of technical knowledge, and to serve as a focal point for technology transfer between industry, government, and university communities.

Current projects/technology investigations include AXAF-I, laser atmospheric wind sounder, space laser energy, lidar technology, optical technology and solar X-ray imager.

The Optical Systems Branch currently has over 14,700 square feet of laboratory space and contains several unique facilities including binary optics, coating, optical design and analysis, optical fabrication, optical metrology, precision optical fabrication, laser characterization and a one-of-a-kind straylight test facility. Plans are underway to increase laboratory space by adding several new facilities including an expanded optical shop and metrology lab, a 30 meter test tower and a precision optical fabrication facility.



AXAF-S mirror testing in the straylight test facility

U.S. Army Missile Command

The Missile Research, Development, and Engineering Center (MRDEC) is the Army's lead organization for technologies for missile systems located on Redstone Arsenal in Huntsville, Alabama. MRDEC is comprised of 18 Directorates and Offices, a workforce of over 2,000 people, and a yearly budget of over $450 million. MRDEC plans, manages, and conducts research, exploratory and advanced development for guided missile and rocket weapon systems, unmanned vehicles, and related components; and provides scientific, engineering, and technical support for weapon system programs over the complete life cycle.

The primary products are technologies for missiles and related systems, e.g., propulsion, guidance and control, simulation, structures, and materials. This includes specific enabling technologies as well as new concepts for entire new systems such as the Fiber Optics Guided Missile.

Facilities include optical sensor and propagation range (1/2 Km), airborne seeker measurement tower w/turntable, IR imaging sensor test facility, infrared simulation system (IRSS), Electro-optical simulation system (EOSS), scanning electron microscope, thin film deposition lab, photolithography lab, IOC microfabrication lab and optical correlator test lab.

Advanced Optical Systems (AOS)

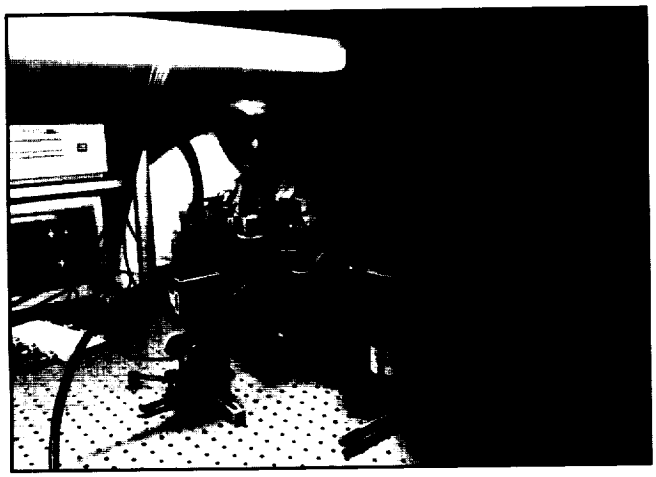
AOS is a small business that was formed to seek optical solutions to military and civilian problems. AOS personnel have over fifty years of experience in the science and management of optics. The president of the company invented and managed the fabrication of the country's premiere indoor laser radar range, the Army Missile Optics Range. He also invented and managed the development of the U.S.'s smallest optical correlation image processor, featured on the cover of SPECTRUM magazine. He also managed the development of an optical processor system for missile guidance.

Some business interests of AOS are aided target recognition, cuing for ATR systems, seekers, optical correlation, diffraction pattern sampling, neural networks, optical processing of radar imagery and laser radar.

Facilities include 1500 sq. ft. laboratory, mobile optical correlation laboratory; opto-electronic ATR cuing system, optical correlator with video/digital input of target scene and filter, digital video acquisition and editing system, computer controlled Hi-8 video acquisition and editing system and compact disc writer.

Dynetics, Inc.

Dynetics is an employee-owned business with offices in Huntsville, AL, Detroit, MI, Dayton, OH, and Ft. Walton Beach, FL. In 1994, Dynetics was recognized as National Small Business Prime Contractor of the Year. The company has offered engineering solutions and services for 20 years. Dynetics has over 280 skilled analysts, scientists, and engineers involved in advanced engineering, research and development. They provide customers with high-quality and innovative support in electro-optics, signal processing, flight technology, hardware development, sensor systems technology, software engineering, systems analysis, high-fidelity system simulation, industrial automation systems, and test



Dynetics is developing an acousto-optical processor for challenging radar applications.

and evaluation. Specific areas of research are Optical Signal Processing, EO/IR Sensors, Sensor Signal Processing, Electronic Interfaces and Mechanical Design and Fabrication.

Hughes Danbury Optical Systems, Inc.

Hughes Danbury Optical Systems (HDOS), located in Danbury, Connecticut, is at technology's leading edge in the design, development and manufacturing of precision optical and electro-optical systems. HDOS provides new and advanced developments for the Department of Defense, NASA, the aerospace and semiconductor industries and to scientific institutions. HDOS is a wholly owned subsidiary of Hughes Aircraft Company.

HDOS facilities are capable of producing four meter class optics of virtually any geometry, large precision structures, holographic optics and gratings, system wavefront correctors, beryllium and silicon carbide mirrors and binary optical systems. Other facilities permit full scale manufacturing of EO/IR sensors, optical assemblies and unique electro-optical systems for space science instruments. HDOS has integrated design, manufacturing, assembly and test facilities that are configured to meet today's requirements for total quality management.

Approximately 60% of the employees at HDOS are involved in some form of research and development efforts within the organization. Their engineering skills are highly specialized within their fields of expertise.

Space Programs - HDOS is currently fabricating four nested, cylindrical, grazing incidence mirror pairs for NASA's Advanced X-ray Astrophysics Facility (AXAF). The first and largest pair was successfully completed in 1991, surpassing customer acceptance specifications. Other efforts include electro-optic and spectrometric sensor and scientific instruments, Small Explorer class payloads, star trackers, payload pointing systems, and related optical and optomechanical subsystems.

Strategic Systems - HDOS is a leader in the field of visible light sensors, optical systems for surveillance and directed energy, star sensors, and various multi-spectral electro-optical sensors. For our nation's important Ballistic Missile Defense Organization (BMDO) programs, including Brilliant Eyes, Brilliant Pebbles, FEWS and others, HDOS is supplying the key technology to produce surveillance and tracking sensors.

Tactical Systems - HDOS designs and builds high performance electro-optical and infrared (EO/IR) sensors and subsystems for tactical ground and airborne vehicles. A unique laser threat detection and warning system for helicopters was developed by HDOS. The AN/AVR- 2 Laser Detecting Set is now in production for the U.S. Army, Navy and Marine Corps.

Precision Materials Operations - HDOS launched a new commercial venture in 1992, and is now a supplier of precision-thinned bonded Silicon-on-Insulator (SOI) wafers to the semiconductor industry. HDOS markets this new family of products under the AcuThin trade name. Starting with AcuThin wafers, integrated circuit manufacturers will be able to design faster, smaller electronic components and fabricate them in less time. This is due to the superior flatness and uniformity that Hughes Danbury builds into the SOI wafers.

Nichols Research Corporation

Nichols Research Corporation (NRC) is a Huntsville-born and grown high technology corporation. Since its inception in 1976, NRC has stressed the importance of being a multi-service company with an increasing customer and technology base. This goal has enabled NRC to become a multi-million dollar company with over 20 technical offices located throughout the nation.

NRC is now a recognized leader in the realm of high technology professional services and for specializations in numerous areas including systems engineering, smart sensors, information and computer technology, modeling and simulation, software environments, advanced materials, and intelligence.

Optical systems analyses are a major product area and constitute the origin of NRC's hardware development support products. NRC provides technical requirements, system

NRC's Automated EO Test System

analyses, program planning, technology assessment, and test planning for space-based surveillance, airborne surveillance, missile-borne tracking, and laser and radar subsystems. The advancements made by NRC in electro-optics, combined with the application of this technology to numerous programs for military and space systems, have distinguished NRC as a leader in high technology research and development in Huntsville and throughout the United States.

The National Institute of Standards and Technology (NIST)

The Radiometric Physics Division is the primary unit within NIST in Gaithersburg, Maryland for carrying out the basic mission of promoting accurate and useful optical radiation measurements in the ultraviolet, visible and infrared spectral regions. The Division's activities support industrial and national needs and seek to achieve three primary goals:

- To develop, improve, and maintain the national standards and measurements techniques for radiation thermometry, spectroradiometry, photometry, and spectrophotometry,
- To disseminate these standards by providing measurement services to customers requiring calibrations of the highest accuracy,
- To conduct fundamental and applied research to develop the scientific and technical basis for future measurement services.

The Division employs research scientists, engineers, technicians, and calibration specialists, and maintains a balanced mix of research, development, and measurement services. It is organized into three operational groups,

- Infrared Radiation
- Detector Metrology
- Thermal Radiometry

Specific projects include: establishing a facility to provide long-term measurements for space-based remote sensing programs; operating a solar ultraviolet monitoring research station at NIST; establishing an infrared radiation beamline at the NIST synchrotron radiation facility; characterizing the optical properties of materials to support the development of new optical devices; and establishing standards of measurement for characterizing flat-panel displays.

Oak Ridge National Laboratory
Advanced Photonics & Optical Fabrication Technology

The Oak Ridge complex consists of 3 sites (the Oak Ridge National Laboratory, the Y-12 plant, and the K-25 site) with over 15,000 employees and capabilities and facilities unmatched anywhere else. These resources have primarily been used to meet the national challenges of energy, environment, and defense for the U. S. Department of Energy.

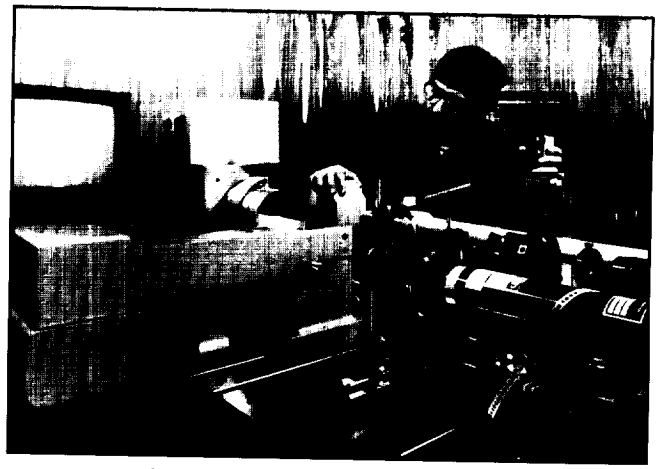
Specific advanced optical fabrication technologies have been developed at Oak Ridge as part of a Strategic Defense Initiative program to address manufacturing needs of space-based optical systems. Laboratory facilities developed under this program were focused on generic manufacturing science related issues. Approximately 5,000 sq. ft. of laboratory, clean room, and office space house the following manufacturing technologies:

- diamond single point turning
- ductile mode grinding
- ion beam milling
- optical metrology and characterization
- finite modeling for manufacturing technologies.

Broad applications are also available at Oak Ridge in the combined field of optics and electronics. Advanced photonics applications range from energy generation and detection to communications and information processing.

Technologies under development include:

- lasers and laser diagnostics
- fiber optics and fiber-optic sensors
- spectroscopy
- image processing
- environmental sensing and measurement
- holography
- electro-optics and optical materials.



ORNL Diamond Turning Facility

SCI Fiber Screening & Winding Lab

SCI Systems, Inc.

SCI is a "Fortune 500" electronics manufacturer with 1.85 billion dollars in annual revenues. Its plants serve a diversified and growing customer base in North America, Western Europe, and East Asia. The Company designs, manufactures, markets, distributes, and services electronic products for the computer, aerospace, defense, telecommunication, medical and banking industries, as well as the U.S. Government. SCI is the world's largest electronics contract manufacturer and operates the largest surface mount technology (SMT) production capability in the merchant market. The Company's success has been built on a foundation of high quality, responsiveness, and competitiveness.

SCI's corporate headquarters and Government Division facilities that support fiber optic tethers are located in Huntsville, Alabama. SCI has an experienced technical staff, modern production winding facility, and a proven performance record. SCI has wound fiber optic dispensers for ground launched, air launched, and undersea applications, including a variety of fiber and cable types in custom configurations.

Capabilities also include: optical fiber screening, pack mechanics modeling, payout dynamics modeling, high strength splicing, laboratory payout testing, optical couplers and connectors, fiber optic data bus products, and bidirectional data links.

Speedring, Inc.

Speedring performs ultra-precision machining and material processing on all conventional and most exotic materials, including beryllium, for aerospace, defense and communications. We routinely join forces with engineering companies to develop new applications, while meeting the increased demands of rapidly changing technologies in our ever expanding marketplace.

Business interests include machining of conventional and exotic materials, assemblies and subassemblies, material processing, coatings/platings, and single point diamond machining.

The company has a 100,000 sq. ft. manufacturing facility located in Cullman, Alabama.

FACULTY

Mustafa A.G. Abushagur
Associate Professor, ECE, UAH
Ph.D., California Institute of Technology, 1984
Optical Signal Processing

Manmohan D. Aggarwal
Professor of Physics, AAMU
Ph.D., Physics, Calcutta University, 1974
Growth of organic crystals by Czochralski method, growth of photorefractive materials by Czochralski and Bridgman, and top seeded solution growth methods

Anees Ahmad
Senior Research Scientist, CAO, & Associate Research Professor, OSE Program, UAH
Ph.D., University of Houston, 1979
Optomechanical engineering, virtual prototyping, expert systems, low cost fabrication

Partha P. Banerjee
Professor, ECE, UAH
Ph.D., University of Iowa, 1983
Nonlinear Wave Phenomena, Optical processing

H. John Caulfield
University Eminent Scholar and Professor of Physics, AAMU
Ph.D. in Physics, Iowa State University, 1962
Optical computing, holography, and neural network

Russell Chipman
Associate Professor, Physics, UAH
Ph.D., Optical Sciences Center, University of Arizona, 1987
Polarization and Lens Design

John O. Dimmock
Director, CAO and Professor, Physics, UAH
Ph.D., Physics,Yale University, 1962
Solid State Physics

Darell Engelhaupt
Sr. Research Scientist, CAO, UAH
B.S., Engineering/Physics, University of Missouri, 1973
Master's course work, University of Kansas, 1979
Combined disciplines related to precision instrumentation including optical instruments, electrochemistry non-reflective coatings, electroformed metals, ultra-precision machining, optical fabrication

Phillip A. Farrington
Assistant Professor, ISE, UAH
PhD., Oklahoma State University, 1991
Manufacturing systems, quality control, simulation and engineering economy

John A. Gilbert
Professor, ME, UAH
Ph.D., Illinois Institute of Technology
Experimental Mechanics and Applied Optics

Don A. Gregory
Associate Professor, Physics, UAH
Ph.D., University of Alabama in Huntsville, 1984
Fourier Optics

K. X. He
Assistant Professor of Physics, AAMU
Ph.D., Physics, Rensselaer Polytechnic Institute, 1987
Nonlinear optics, three and two photon processes on the surface and interface of thin films, and laser induced plasma spectroscopy

Lloyd W. Hillman
Assistant Professor, Physics, UAH
Ph.D., The Institute of Optics, University of Rochester, 1984
Lasers and Quantum Electronics

Stephen T. Kowel
Professor & Chairman., ECE, UAH
Ph.D., University of Pennsylvania, 1968
Opto-electronics Materials, Devices and Systems

Nickolai Kukhtarev
Research Professor of Physics, AAMU
Ph.D., Physics, Ukrainian Academy of Sciences, 1983
Photorefractive effect, dynamic holography, nonlinear optics of liquid crystals, real-time holographic interferometry, and radiation physics

Ravindra B. Lal
Professor of Physics, AAMU
Ph.D., Solid State Physics, Agra University, 1963
Solution crystal growth of IR material in low-g, growth of materials for second harmonic generation (SHG), growth of mixed organic crystal for SHG devices, and a study of superalloys

Leslie D. Interrante
P.E., Assistant Professor, ISE, UAH
PhD., University of Central Florida, 1991
Manufacturing, robotics, artificial intelligence, and computer simulation

C. T. Lee
Professor of Physics, AAMU
Ph.D., Physics, Rice University, 1965
Squeezed states; continuous quantum measurement; quantum optics

Robert G. Lindquist
Assistant Professor, ECE, UAH
Ph.D., The Pennsylvania State University, 1992
Electro-optics and Nonlinear Optics

Calvin W. Lowe
Professor & Chairman of Physics Department, AAMU
Sc.D., Solid State Physics, MIT, 1983
Growth of thin films for nonlinear optical devices by Physical Vapor Transport technique

Frank L. Madarasz
Senior Research Scientist, CAO, and Research Professor, OSE Program, UAH
Ph.D., University of Connecticut, 1978
Electro-optical Materials, Nonlinear Optical Properties in Quantum Confined Structures and Infrared Detectors

Sherri L. Messimer
Assistant Professor, ISE, UAH
PhD., Texas A&M University, 1989
Pattern recognition, automated visual inspection, engineering statistics, software engineering

Gregory P. Nordin
Assistant Professor, ECE, UAH
Ph.D., University of Southern California, 1992
Opto-electronics, Optical Neural Networks and Holographic Interconnects

Alexander D. Poularikas
Professor, ECE, UAH
Ph.D., University of Arkansas, 1966
Statistical Optics

B. R. Reddy
Assistant Professor, Physics, AAMU
Ph.D., Physics, Indian Institute of Technology, 1981
Frequency upconversion in optical materials and fibers, optical phase conjugation, nonlinear optics, and laser spectroscopy and interferometry

Albert T. Rosenberger
Associate Professor, Physics, UAH
Ph.D., University of Illinois, Urbana, 1979
Optical Physics, Nonlinear Dynamical Phenomena in Optical Systems

Anup Sharma
Assistant Professor, Physics, AAMU
Ph.D., Physics, Columbia University, 1982
Fiber optics, application of laser ablation including material processing and fabrication of novel structures, laser-aerosol interaction, and laser spectroscopy

C. C. Sung
Professor, Physics, UAH
Ph.D., University of California, Berkeley, 1965
Quantum Optics

James J. Swain
Assistant Professor, ISE, UAH
PhD., Purdue University, 1982
Applied statistics, computer simulation, numerical methods, and operations research

Donald Tippett
Associate Professor, ISE, UAH
B.S., U.S. Naval Academy, M. Eng. and Doctor of Engineering, Texas A&M University, 1981
Engineering management, organization structure and motivation, TQM, productivity and quality, and strategic management

Putcha Venkateswarlu
Professor, Physics, AAMU
Sc.D., Physics, Banaras University, 1947
Optical phase conjugation effects of color centers, nonlinear optics in organic systems, microsphere lasers, integrated optics using organic systems and polymers, nonlinear optics and laser spectroscopy

Chandra S. Vikram
Senior Research Scientist, CAO, and
Research Professor, OSE Program, UAH
Ph.D., Indian Institute of Technology, 1973
Holography, Interferometry, Speckle Metrology

Jack R. Walker
P.E., Associate Professor, ISE, UAH
Ph.D., Oklahoma State University, 1964
Engineering management, engineering economy and statistical quality control

J. C. Wang
Associate Professor, Physics, AAMU
Ph.D., Physics, University of Massachusetts, 1976
Crystal growth modeling, crystal composition segregation and interface stability, and double diffusion

Jerry D. Westbrook
P.E., Professor and Interim Chairman, ISE, and Director of Engineering Management Programs, UAH
PhD., Virginia Polytechnic Institute and State University, 1973.
Engineering management, organization structure and motivation, TQM, productivity and quality, and strategic management

Wyskida, Richard M.
P.E., Professor, ISE, UAH
PhD., Oklahoma State University, 1968.
Operations research, applied statistics, management control systems, project management, cost optimization, estimating techniques, cushioning systems

UAH

The University of Alabama in Huntsville

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E-mail (Internet): dimmockj@email.uah.edu

UAH
The University of Alabama in Huntsville

Colleges of
Engineering and Science

Colleges of Engineering & Science

A Practice Oriented Master's Degree Program in

Optics & Photonics Technology

Curriculum Requirements

21 hours of required core courses, including:
- * 6 credit hours in optics principles;
- * 9 credit hours in optical design & manufacturing technology;
- * 6 credit hours in engineering management.

6 hours in elective courses (two courses to be taken in one of the following areas):
- a. Optical systems and engineering
- b. Quantum optics
- c. Optical signals
- d. Optical communications
- e. Optical materials
- f. Manufacturing technology: Systems
- g. Manufacturing technology: Quality
- h. Manufacturing technology: Statistics
- i. Manufacturing technology: Reliability
- j. Engineering management, integrated production & processes
- k. Marketing, management and management science
- l. Physics

6 hours of on-site practicum and a thesis.

Facilities

The focal point of all optics research at UAH is the 118,000-square-foot Optics Building. There are more than 20 advanced optics laboratories in the building. These labs are administered by faculty from the physics, electrical and computer engineering, mechanical and aerospace engineering, and the chemical and environmental engineering departments, as well as researchers from UAH's Center for Applied Optics.

Some of the unique laboratories are:
Experimental Mechanics and Applied Optics.
Holography & Speckle Metrology;
Optical Coatings;
Optical Design and Modeling;
Optical Fabrication;
Optical Information Processing;
Optical Metrology;
Opto-electronics Research;
System Prototyping; and
Virtual Prototyping.

The following laboratories at Alabama A&M University are also available:
Crystal Growth;
Fiber Optics;
Glassy Carbon Manufacturing;
High Temperature Furnace;
Holography;
Laser Labs;
Materials Characterization;
Materials Irradiation Center;
Microgravity Space Experiments; and
Optical In-situ Crystal Growth Rate Measurement.

Practicum Examples

A number of on-site practicum opportunities are available for the students in the areas of precision optical fabrication; diffractive, binary and coherent optics; optical wave guides; metrology instruments for scatter and figure of aspheric optics; optical image processing; acousto-optic and microwave devices; optical instrumentation for ice detection; laser ranging; remote sensing; cryogenic radiometry; and fiber optic sensors. These practicum are offered at the facilities of the following program affiliates:
- * NASA/Marshall Space Flight Center
- * U.S. Army Missile Command
- * Oak Ridge National Laboratory
- * National Institute of Standards & Technology
- * Advanced Optical Systems
- * Dynetics, Inc.
- * Hughes Danbury Optical Systems, Inc.
- * Nichols Research Corporation
- * SCI Systems, Inc.
- * Speedring, Inc.

For more information, please contact:

Dr. John O. Dimmock, Program Director
Center for Applied Optics
The University of Alabama in Huntsville
Huntsville, Alabama 35899
Phone: (205) 890-6030, Ext. 400
FAX: (205) 890-6618
E-mail: dimmockj@email.uah.edu
Web site - http://www.uah.edu/cao/masters

A Space Grant College
An Affirmative Action/Equal Opportunity Institution

UH-97060

A Practice Oriented Master's Degree Program in

Optics & Photonics Technology

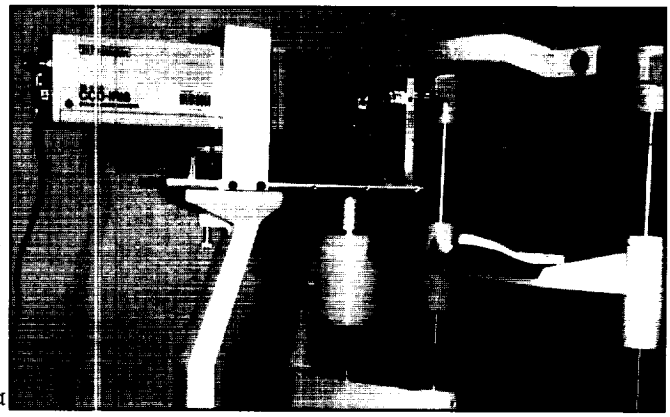
Colleges of Engineering & Science

UAH The University of Alabama in Huntsville

Introduction

A unique, industry-oriented interdisciplinary Master's degree program with a concentration in optics and photonics technology is being offered at The University of Alabama in Huntsville under the U.S. Manufacturing Education and Training Activity of the Technology Reinvestment Project.

A large number of industries, government and academic organizations have participated in designing, developing and implementing this program to produce highly-trained graduates who can solve practical problems. It includes an on-site practicum at a manufacturing location.



This corneal microscope prototype has been designed and fabricated by a POMO student as part of his practicum. It can perform high-resolution digital imaging of cells and structures through the entire thickness of the cornea.

The program is designed to enable full-time students, and the government and industrial defense work force to transition to commercial manufacturing, enhancing their competitiveness in the global marketplace, and to expand the U.S. job base and economy. Some distinguishing features of this program include:

- A mix of science, engineering and management courses;
- Applications-oriented courses with design and hands-on laboratory content; and
- An on-site practicum at an industry or government research laboratory.

The program emphasizes the fundamentals of optics, optical systems manufacturing and testing, and the principles of design and manufacturing to cost for commercial products. Participating organizations provide extensive personnel and laboratory facilities to ensure success.

The program is offered by the Electrical Engineering and Physics departments of The University of Alabama in Huntsville (UAH) under the auspices of the UAH Graduate School.

Admission Requirements and Financial Aid

* A bachelor's degree in science or engineering from an accredited institution; plus
* A minimum average of B (GPA of 3.0) on the undergraduate record; and
* A minimum score of 1,500 on the aptitude test (verbal, quantitative, and analytical) portion of the GRE.

These are Graduate School requirements. Some departments may require higher averages or additional qualifications. The applicant whose native language is not English is required to take the Test of English as a Foreign Language (TOEFL) and score at least 500.

Financial aid is available for all qualified students. Information regarding financial assistance is included with the application material sent to each prospective student.

Further information may be obtained by calling the Center for Applied Optics at (205) 890-6030.

UAH
The University of Alabama in Huntsville

Colleges of Engineering and Science

Systems and Advanced Manufacturing
14-17 October • Marriott Pittsburgh Greentree, Pittsburgh, PA USA. Abstract Due Date: 17 March

International Symposium on Voice, Video, and Data Communications
2-7 November • Grand Kempinski Hotel Dallas, Dallas, TX USA. Abstract Due Date: 7 April

Meetings of related interest

A listing of meetings which SPIE cosponsors or for which SPIE publishes proceedings.

International Conference of Experimental Mechanics: Advances and Applications
4-6 December • National University of Singapore, Singapore. SPIE will publish proceedings. Contact: ICEM '96 Secretariat, National Univ. of Singapore, Dept. of Mechanical and Production Engineering, 10 Kent Ridge Crescent, Singapore 119260. Phone: 65 772-2212. Fax: 65 779-1449. E-mail: mpeadm1@leonis.nus.sg

Delft University of Technology
Delft, The Netherlands

This meeting will address issues concerning optical education at academic institutes as well as optical training and retraining within the industry. Newly developed methods, materials, and demonstrations will be presented and discussed.

Sponsored by The International Commission on Optics (ICO), commemorating their 50th anniversary.

For meeting information contact:
Prof. Dr. H.J. Frankena;
Delft Univ. Of Technology,
Dept. Of Applied Physics; Lorentzweg 1,
2628 CJ Delft, The Netherlands.
Phone: (+31) 15 278 5309.
Fax: (+31) 15 278 8105.
E-mail: edu97@optica.tn.tudelft.nl.
URL: http://www.tn.tudelft.nl/optica/optica.html

Professional Education Res

Short courses offered by universities and SPIE Corporate Sustai

Arizona State University
Global system for mobile communications (GSM), 14-17 Jan. Contact: Marty Gibson, Senior Program Coordinator, Center for Professional Development, Arizona State Univ., Box 877506, Tempe, AZ 85287-7506. Phone: 602/965-1740. Fax: 602/965-8653.

Inframetrics
Thermography operator training course: 9-13 Dec. Contact: Margo Brown, Inframetrics, Inc., 16 Esquire Rd., N., Billerica, MA 01862-2598. Phone: 508/667-7880, ext. 314. Fax: 508/667-2702. E-mail: mfallon%infra@mcimail.com.

Labsphere
Reflectance technology seminar. Call for dates and locations. Contact: Technical Product Specialists, Labsphere, P.O. Box 70, Shaker St., N. Sutton, NH 03260. Phone: 603/927-4266. Fax: 603/927-4694.

Northwestern University
Prototyping and Tooling for Rapid Product Development, 7-8 Apr; Technology Reviews, 21 Apr; Design for Manufacture, 14-15 Apr; Quality by Design, 12-13 May. Contact: Allison Ando, Program Coordinator, Northwestern University, McCormick Continuing Professional Development, 2145 Sheridan Rd., Rm. 2823, Evanston, IL 60208. Phone: 708/491-3365. Fax: 708/467-3033.

UCLA Extension
Surveillance, tracking, low observables, and ECM/rac management: Algorithm design and real data applic tions, 6-10 Jan.; Optical coating technology, 13-17 Ja Quantum well infrared photodetectors (QWIPs), 3-5 Fe Project management principles and practice, 18-21 Fe Liquid crystal displays: A technology overview, 24-Feb.; Synthetic aperture radar: Understanding the ima ery, 3-7 March. Contact: Department of Engineeri Information Systems and Technical Management, UC Extension, 10995 LeConte Ave., Ste. 542, Los Angel CA 90024. Phone: 310/825-1047. Fax: 310/206-2815. mail: mhenness@unex.ucla.edu

University Consortium for Continuing Education
RF and microwave measurements and applicatio Monterey, CA, 11-14 Dec.; Error correcting codes communications systems: Palo Alto, CA, 16-19 D Contact: Joleen Packman, Associate Director, UC 16161 Ventura Blvd., M/S 752, Encino, CA 91436. Pho 818/995-6335. Fax: 818/995-2932. E-mail: ucc aol.com. WWW: http://www.ucce.edu/

University of California/Berkeley, University Extension
Techniques and patterns for distributed object comput with CORBA and C++, 4-6 Dec.; Systems engineerin complex software intensive systems, 10-13 Dec. C tact: Alice Boatwright, South Bay Program, UC Berke

ATTACHMENT 6

EXPENDITURES

ATTACHMENT 6

EXPENDITURES FOR MS/MSE DEGREE IN OPTICS AND PHOTONICS TECHNOLOGY
March 18, 1994 -- March 17, 1998
NAG8-1028

Expenditures:

Management, Faculty & Support Staff	$	130,128
Student Stipend, Practicum & Tuition	$	34,581
Fringe Benefits	$	26,771
Advertising	$	7,350
Travel	$	6,775
Xerox & Duplicating	$	1,341
Software	$	1,586
Other Supplies & Materials	$	408
Page Charges	$	90
TOTAL DIRECT CHARGES	$	209,030
Facilities and Administration	$	89,330
TOTAL EXPENDITURES	$	298,360

ATTACHMENT 7

COST SHARING

ATTACHMENT 7

COST SHARING CERTIFICATION FOR MS/MSE DEGREE IN OPTICS AND PHOTONICS TECHNOLOGY
March 18, 1994--March 17, 1998
NAG8-1028

University of Alabama in Huntsville: Dr. John Dimmock, Director, CAO Dr. Stephen Kowel, Chair, ECE Department Dr. Gordon Emslie, Chair, Physics Department Dr. Anees Ahmad, Associate Research Professor, CAO Dr. Don Gregory, Associate Professor, Physics Dr. Russell Chipman, Associate Professor, Physics Dr. Lloyd Hillman, Associate Professor, Physics Dr. Mustafa Abushagur, Professor, ECE Dr. Phillip Farrington, Associate Professor, ISE Dr. Joe Geary, Research Professor, CAO Dr. Bruce Peters, Adjunct Assocate Research Professor, CAO Mr. Darell Engelhaupt, Senior Research Scientist Dr. Vahid Riasatti, Assistant Professor, ECE Mr. Paul Burke, Student (Stipend and tuition) Mr. Jeff Meier, Student (Stipend and tuition) Mr. Napoli Oza, Student (Stipend and tuition) Mr. Andrew Nelson, Student (Stipend and tuition) Mr. David Sparks, Student (Stipend and tuition)	$	329,405
Dynetics, Inc. Attached	$	138,220
Hughes Danbury: Attached	$	6,480
Nichols Research, Inc. Attached	$	2,655
TOTAL COST SHARING:	$	476,760

John O. Dimmock, Ph.D.

Dynetics, Inc.

P O. Drawer B
Huntsville, Alabama 35814-5050
(205) 922-9230 • www.dynetics.com

16 July 1997

Dr. John Dimmock
University of Alabama in Huntsville
Center for Applied Optics
Huntsville, AL 35899

Dear Dr. Dimmock:

Dynetics, Inc. has been given approval to donate the attached listing of Government Furnished Equipment to the University of Alabama in Huntsville. Upon acceptance, this equipment will no longer be accountable to the Government or Dynetics and may be used as required by the University.

If you have any questions concerning this donation, please contact Dr. Bob Bernato at 922-9230, extension 315, or the undersigned at extension 436.

Sincerely,

DYNETICS, INC.

Mike West

Mike West
Property Administrator

mw:cg

Attachment

ACCEPTANCE: Joseph M. Geary DATE: 7/18/97

Dynetics input to Practice-Oriented Masters in Optics (POMO) Final Report

Dynetics has participated in several ways during this POMO program, as described below. In general, we have found that the program has been successful, although somewhat limited in the recruitment of large numbers of high-quality students for this program. We recommend that the program be continued based on its successful start and its potential for attracting greater numbers of quality optics students to the Huntsville region.

Activity 1: Formulation of Courses of Interest to Industry

Dynetics played an active role in reviewing outlines and suggesting new courses during the formulative stages of the POMO program.

Activity 2: Guest Lecturing

Dr. Bob Berinato of Dynetics also provided multiple guest lectures in the EE570 Optics and Photonics Systems Design course and the EE670 Optomechanical Design and Manufacturing course. These lectures highlighted our application of optical and mechanical principles to the design and development of acousto-optic signal processors for radar and signal intercept applications. We found these lectures to be a good opportunity to show students practical aspects of the design material they learned in class, and to gain broader exposure within the UAH graduate program.

Activity 3: Preparation of Publicity Material

Dynetics provided inputs throughout the program in support of the brochures and displays created by UAH for the POMO program. Dynetics also helped man the displays during local meetings.

Activity 4: Review of Student Projects

Dynetics attended a number of student-faculty-industry meetings to review the progress of the POMO program, and to hear the research activities of the participating students. We found these meetings to be a good way to learn about the progress of the program.

Activity 5: Offering of Summer Employment Opportunities

Dynetics offered students an opportunity to perform their on-site practicum work at our facilities. Unfortunately, no students worked at Dynetics during this phase of the program. One student did apply but there was not a technical match to their interests and qualifications. We also made an offer to one of the graduates of the POMO program, but he accepted employment elsewhere.

MS/MSE DEGREE IN OPTICS & PHOTONICS TECHNOLOGY

NAG8-1028

IN-KIND MATCH REPORT

PERIOD: YEAR 1: MARCH 18, 1994 TO MARCH 17, 1995.
YEAR 2: MARCH 18, 1995 TO MARCH 17, 1996.
YEAR 3 MARCH 18, 1996 TO MARCH 17, 1997.

PARTNER DYNETICS, INC.

SUBJECT: TECHNOLOGY REINVESTMENT PROGRAM (TRP) GRANT.
REPORTING OF DYNETICS, INC. COST DURING EACH PERIOD.

THIS IS TO PROVIDE A SUMMARY OF DYNETICS, INC. IN-KIND CONTRIBUTIONS AS OF THE SUBJECT PERIODS.

YEAR ONE (1):		
TOTAL HOURS	101.00	
TOTAL COST		7754.24
YEAR TWO (2):		
TOTAL HOURS	153.00	
TOTAL COST		12833.95
YEAR THREE (3)		
IN-KIND EQUIPMENT		117631.74
TOTAL IN-KIND CONTRIBUTION 3 YEARS		**138219.93**

SIGNATURE E P Kelley DATE: 3/15/98
Treasurer Controller Dynetics Inc

FROM FA (256) 964-4167 PHONE- (256) 964-4208

TO FAX: (205)895-6618 PHONE: 895-6030 (X474)
ATTENTION: MS. BAILEY

DESCRIPTION	QTY	COST PER@	TOTAL COST	GFE NO.
MIRROR MOUNT P/N 133000	1	$351.00	$351.00	29
MIRROR MOUNT P/N 133000	1	$351.00	$351.00	30
MIRROR MOUNT P/N 133000	1	$351.00	$351.00	31
MIRROR MOUNT P/N 133000	1	$351.00	$351.00	32
MIRROR MOUNT P/N 133010	1	$351.00	$351.00	39
MIRROR MOUNT P/N 133010	1	$351.00	$351.00	40
TRANSLATION STAGE P/N 338066	4	$180.00	$720.00	
EXTERNAL BRACKET 338223	4	$49.50	$198.00	
SMALL BRIDLES (SET OF 4) 338263	14	$2.70	$37.80	
SMALL BASE PLATE 3382038	7	$27.00	$189.00	
6MM M3 METRIC SCREW 080114	60	$0.29	$17.40	
8MM M3 METRIC SCREW 080115	60	$0.29	$17.40	
SILICON TOTAL REFLECTOR (FLAT) 105-70010	12	$54.00	$648.00	
SILICON TOTAL REFLECTOR (2M ROC) 105-70170	2	$70.00	$140.00	
POWER SUPPLY HIPOTRONICS R50B	1	$1,365.00	$1,365.00	41
DELAY GENERATOR MAINFRAME 40150-M	1	$482.00	$482.00	42
P/S DELAY GENERATOR (POWER SUPPLY) 40150-J	1	$482.00	$482.00	43
MICROSEC DELAY GENERATOR 40150-G	1	$482.00	$482.00	44
NANOSEC DELAY GENERATOR 40150-A	1	$345.00	$345.00	45
NANOSEC DELAY GENERATOR 40150-A	1	$345.00	$345.00	46
VOLTAGE DRIVER VD306A	1	$800.00	$800.00	47
LARGE CURRENT MONITOR 1423	1	$1,600.00	$1,600.00	48
CAPACITOR (0.22uf, 50 KV) 31160	1	$407.00	$407.00	49
CAPACITOR (0.22uf, 50 KV) 31160	1	$407.00	$407.00	50
CAPACITOR (0.22uf, 50 KV) 31160	1	$407.00	$407.00	51
CAPACITOR (0.22uf, 50 KV) 31160	1	$407.00	$407.00	52
CAPACITOR (0.22uf, 50 KV) 31160	1	$407.00	$407.00	53
CAPACITOR (0.22uf, 50 KV) 31160	1	$407.00	$407.00	54
CAPACITOR (0.22uf, 50 KV) 31160	1	$407.00	$407.00	55
CAPACITOR (0.22uf, 50 KV) 31160	1	$407.00	$407.00	56
CAPACITOR (0.22uf, 50 KV) 31160	1	$407.00	$407.00	57
CAPACITOR (0.22uf, 50 KV) 31160	1	$407.00	$407.00	58

DESCRIPTION	QTY	COST PER @	TOTAL COST	GFE NO.
CAPACITOR (0.22uf, 50 KV) 31160	1	$407.00	$407.00	59
CAPACITOR (0.22uf, 50 KV) 31160	1	$407.00	$407.00	60
CAPACITOR (ORANGE) 1nF 30463	4	$105.00	$420.00	
SPARK GAP 40264	4	$450.00	$1,800.00	
CAPACITOR (0.025uf, 50KV) 31852	1	$496.00	$496.00	61
OPTICAL MOUNT (LARGE AEROTECH) AOM110	1	$580.00	$580.00	62
OPTICAL MOUNT (LARGE AEROTECH) AOM130	1	$1,600.00	$1,600.00	63
DUAL TRACE VERTICAL AMPLIFIER 7A26	1	$500.00	$500.00	64
TIME BASE 7B80	1	$500.00	$500.00	65
DELAYING TIME BASE VERT. AMP. 7B85	1	$350.00	$350.00	66
OSCILLOSCOPE 7904	1	$1,000.00	$1,000.00	67
OSCILLOSCOPE 7904	1	$1,000.00	$1,000.00	68
COAXIAL CABLE (200') YELLOW RG213	200	$0.50	$100.00	69
SCREW TRANSLATOR 22-605	2	$197.50	$395.00	
MICROMETER HEAD 22-301	2	$47.00	$94.00	
SCREW SPINDLE TIP 22-0005	2	$5.70	$11.40	
BALL ATTACHMENT 22-0003	2	$5.70	$11.40	
PLANE PIPE, 12" DIA. SCHOTT GLASS RO300/1000/33	1	$1,617.00	$1,617.00	
ALUMINUM FLANGES FOR GLASS PIPE	1	$383.00	$383.00	
LEAD DIODES RTD50	2	$42.85	$85.70	
AL. TUBING (0.25" THICK, 12" DIA.) 6061-T6	1	$162.00	$162.00	
AL. TUBING (0.50" THICK, 10" DIA.) 6061-T6	3	$219.00	$657.00	
BRASS BAR 1/8" x 3" x 48"	1	$36.06	$36.06	
BRASS BAR 1/4" x 3/4"x 18"	1	$12.50	$12.50	
BRASS BAR 24" (INCORPORATED) 6061-T6	1	$30.60	$30.60	
ALUM. PLATE .25" 6061-T6 (CONSUMED)	1	$190.00	$190.00	
ALUM. PLATE .5" 6061-T6 (CONSUMED)	1	$341.25	$341.25	
ALUM. PLATE .75" 6061-T6 (CONSUMED)	1	$275.60	$275.60	
STEEL BAR 1/8" x 1/2" x 10"	1	$10.50	$10.50	
CLEAR ACRYLIC SHEET 1.000" (CONSUMED)	1	$225.44	$225.44	
CLEAR ACRYLIC SHEET .75" (CONSUMED)	1	$117.76	$117.76	
CLEAR ACRYLIC SHEET .500" (CONSUMED)	1	$111.36	$111.36	
CLEAR ACRYLIC ROD .75"	1	$8.82	$8.82	

DESCRIPTION	QTY	COST PER @	TOTAL COST	GFE NO.
EXTREN FIBERGALSS ANGLES 48443	1	40.40	$40.40	
DELAY GENERATOR CAGE 058-000000-001-001	1	31.00	$31.00	71
DELAY GENERATOR BOARD 065-073-8-77-001-000	1	39.00	$39.00	
CAPACITORS, ORANGE 1 nF 30463	3	15.00	$345.00	
100M, 15% RESISTORS 072-060411-108-001	7	11.00	$77.00	
220 OHM 75KV 20% RESISTORS 889	4	76.68	$306.72	
MOUNTING CLIPS FOR RESISTORS 35268	8	$2.75	$22.00	
5V REGULAOTR MC78M05CG	2	$1.64	$3.28	
MULTIVIBRATOR 3N74LS221N	2	$0.90	$1.80	
RESISTOR ASSORTMENT 37N1742	1	72.95	$72.95	
CAPACITOR (0.1 MICROFARAD) 18F2585	25	$0.58	$14.50	
TOGGLE SWITCH 61F871	2	$5.28	$10.56	
FM BULKHEAD BNC 39F3628	4	$3.97	$15.88	
DIP SOCKETS 135704	5	$1.71	$8.55	
ACRYLIC TUBE 14"x13" I.D. 1	1	$1 698.04	$1,698.04	
ACRYLIC TUBE 8"/7" I.D.	1	931.44	$931.44	
ACRYLIC SHEET .500x48"x96" (STORAGE)	1	221.67	$221.67	
ALUMINUM PLATE 1.000"x27x60 U-BRAGES,(6061-T6)	1	517.50	$517.50	
GRND SHAFT 1.000"144" #2	2	156.62	$313.24	
GRND SHAFT 1.000"144" #3	2	140.66	$281.32	
SHAFT SUPPORT BLKS 1.000" DIA. (8-STORAGE ON RAILS)	30	$16.65	$499.50	
SHAFT SUPPORT RAILS (RAILS IN STORAGE)	2	$67.05	$134.10	
OPEN BILLOW BLOCK SPB-16-OPN	8	$57.45	$459.60	
PILLOW BLOCK SPB-16	8	$47.10	$376.80	
ALUM. PLATE 1.00x10.25x22.75 6061-T6	2	$93.56	$187.12	
ALUMINUM PLATE 1.00x10.25x8.75 6061-T6	1	$64.40	$64.40	
BRASS BAR 1/8"x3"x60"	1	$73.22	$73.22	
CAP SCREW (100 PKG.)	1	$41.91	$41.91	
NICHROME WIRE	3	$16.72	$50.16	
ALUM. PLATE 1.00x15.75x15.75	2	$89.15	$178.30	
QUARTZ TUBING 4', 1MMx6MM	3	$15.20	$45.60	
QUARTZ TUBING 4', 1MMx6MM	3	$12.20	$36.60	

DESCRIPTION	QTY	COST PER @	TOTAL COST	GFE NO.
ACRYLIC SHEET 1.000"x12"x48"	2	$62.78	$125.56	
ACRYLIC SHEET 0.500"x12"x48"	1	$34.57	$34.57	
MALE CONNECTOR SS-6MO-1-4BT	2	$6.55	$13.10	
MALE CONNECTOR NY-6MO-1-4DT	5	$6.06	$30.26	
ULTRA TORR ADAPTER SS-4UT-A-8BT	3	$9.60	$28.80	
ULTRA TORR ADAPTER SS-16-UT-A-20BT	3	$35.75	$107.25	
ULTRA TORR MALE ADAPTER SS-4-UT-1-4BT	3	$12.76	$38.28	
BASE PLATE (LARGE) 33802040	8	$37.80	$302.40	
BRIDLES (SET OF 4) 338264	8	$11.70	$93.60	
POLYPROPYLENE TANK (18x12x18)	1	$107.86	$107.86	
BNC FEED THRU 39F3631	4	$16.22	$64.88	
DUST CAP 77B2417	4	$3.19	$12.76	
10 OHM, 2W CARBON RESISTORS 10F320	25	$0.56	$14.00	
FEMALE ADAPTER 77B2421	1	$17.97	$17.97	
1/8"x3"x72 BRASS BAR	2	$77.52	$155.04	
SS-3-VCO-4	2	$6.60	$13.20	
SS-3-VCO-3	2	$5.60	$11.20	
SS-8-VCO-1	2	$11.20	$22.40	
EDI FAST RECOVERY AXIAL DIODES	4	$42.85	$171.40	
1MOHM RESISTORS	7	$30.00	$210.00	
1.000"x12"x48" ACRYLIC SHEET	2	$62.78	$125.56	
0.500"x12"x48" ACRYLIC SHEET	1	$34.57	$34.57	
2-155 O-RING	10	$1.19	$11.90	
CURRENT MONITOR (MEDIUM) 110A	1	$600.00	$600.00	73
LASER ALIGNMENT SYSTEM 35104PB	1	$2,123.00	$2,123.00	74
QUARTER WAVE PLATE WPM-106559	1	$1,540.00	$1,540.00	76
THIN FILM POLARIZER TFP-Z-70R OR 80R	1	$1,060.00	$1,060.00	77
MTD. SHEET DICHROIC POLARIZER 03FPG0003 (HeNe)	2	$55.50	$111.00	82
GE BW EPOXIED ONTO MOUNT	1	$176.00	$176.00	84
12" ANNULAR PYREX MIRROR	2	$1,150.00	$2,300.00	85P
****DIELECTRIC COATING FOR MIRRORS	1	$675.00	$675.00	85P
****ADJUSTMENT COATING COSTS	1	$600.00	$600.00	86P
12" ANNULAR ZERODUR MIRROR	1	$7,530.00	$7,530.00	86P
SIZE 2-264 O-RING	4	$4.87	$19.48	

DESCRIPTION	QTY	COST PER @	TOTAL COST	GFE NO.
SIZE 2-279 O-RING	4	$8.16	$32.64	
PHOTODIODE AMPLIFIER 713-2-B	1	$475.00	$475.00	87
PLASTIC CAPACITORS HV PS Hv500-152M	1	$767.95	$767.95	88
SERIES S.O. CAPACITORS (30 KV) 31151(0.6uF)	4	$447.00	$1,788.00	89-92
DUAL ATTACH PLATE A-108-297	1	$50.00	$50.00	93 ff
DUAL LENS ATTACH PLATE A-108-298	1	$50.00	$50.00	
DUAL LENS UPRIGHT A-108-299	2	$18.75	$37.50	
LENS SUPPORT BASE PLATE A-108-300	1	$37.50	$37.50	
LARGE STAGE BASEPLATE A-108-301	1	$37.50	$37.50	
INSERTION PLATE (FLAT, 7 TRIGGER) A-108-304	1	$62.50	$62.50	
INSERTION PLATE (CHANNEL, 7 TRIGGER) A-108-305	1	$62.50	$62.50	
MIRROR BASE PLATE A-108-306	2	$65.00	$130.00	
INNER ELECTRODE 11461B	1	$1,300.00	$1,300.00	
OUTER ELECTRODE 11462B	1	$2,600.00	$2,600.00	
WOODEN CRATE	1	$100.00	$100.00	
PLATE "A" A-108-289	1	$37.50	$37.50	94P
PLATE "B" A-108-294	1	$37.50	$37.50	94P
MODIFIED BEARING MOUNT A-108-291	1	$37.50	$37.50	94P
INJECTION MIRROR SUPPORT BAR A-108-292	1	$25.00	$25.00	94P
ORIGINAL COPPER INJECTION MIRROR A-108-293	4	$12.50	$50.00	94P
MODIFICATION OF PLATE "B" A-108-294	1	$12.50	$12.50	95P
AEROTECH MIRROR MOUNT MOLD A-108-295	1	$75.00	$75.00	94P
MODIFICATION TO MOVING TABLE	1	$12.50	$12.50	94P
FLAT ELECTRODE A-108-225	1	$75.00	$75.00	
TEST FLANGE A-108-281	1	$65.00	$65.00	
TEST FLANGE A-108-282	1	$65.00	$65.00	
TEST FLANGE A-108-283	1	$65.00	$65.00	
TEST FLANGE A-108-284	1	$60.00	$60.00	
TEST FLANGE A-108-285	1	$55.00	$55.00	
TEST FLANGE A-108-286	1	$55.00	$55.00	
COMPRESSION PLATE A-108-288	1	$185.00	$185.00	
MODIFIED MOUNT STAGE A-108-302	1	$12.50	$12.50	

DESCRIPTION	QTY	COST PER@	TOTAL COST	GFE NO
COMPRESSION BAR A-108-303	1	$25.00	$25.00	
END RING A-108-275	1	$150.00	$150.00	
CHANNEL END RING A-108-308	1	$150.00	$150.00	
COMPRESSION RING A-108-276	1	$150.00	$150.00	
CHANNEL SUPPORT RING A-108-309	1	$150.00	$150.00	
COMPRESSION RING A-108-312	1	$150.00	$150.00	
CHANNEL COMPRESSION RING A-108-307	1	$150.00	$150.00	
ELECTRODE INSERTION PLATE A-108-313	1	$62.50	$62.50	
ELECTRODE INSERTION PLATE A-108-311	1	$62.50	$62.50	
ELECTRODE INSERTION PLATE A-108-310	1	$62.50	$62.50	
VILER SPRING PLUNGER HOLDER A-108-315	2	$20.00	$40.00	94P
MICROMETER STAND BASE PLATES A-108-316	1	$30.00	$30.00	
MICROMETER STAND A-108-317	1	$20.00	$20.00	
CHANNEL WINDOW PLATE A-108-277	1	500.00	$500.00	
2ND MOD AEROTEK MIRROR MOUNT	1	$25.00	$25.00	94P
THERMOCOUPLE PLUG A-108-314	1	$12.50	$12.50	94P
DUMMY TC PLUG A-108-319	1	$12.50	$12.50	
MODIFIED INJECTION MIRROR A-108-318	4	$12.50	$50.00	94P
VLIER SPRING PLUNGE HOLDER A-108-315	2	$20.00	$40.00	94P
MICROMETER STAND BASE PLATE A-108-316	1	$30.00	$30.00	94P
MICROMETER STAND A-108-317	1	$20.00	$20.00	94P
.375 DIA. SILICON REFLECTOR 105-70003	3	$45.00	$135.00	
2-142 O-RING	10	$1.10	$11.00	
2-106 O-RING	100	$0.42	$42.00	
10-32 x 5/8 STAINLESS SCREWS 92197A244	100	$0.09	$9.00	
10-32 x 3/4 STAINLESS SCREWS 92197A245	100	$0.10	$9.88	
8-32 x1/4 NYLO SET SCREWS 95862A190	100	$0.54	$53.80	
RELAY 65P2272	1	$4.89	$4.89	95P
10 OHM CARBON RESISTOR 5% 10F320	50	$0.56	$28.00	
100 OHM CARBON RESISTOR 5% 10F320	50	$0.56	$28.00	
200 OHM CARBON RESISTOR 5% 10F320	25	$0.56	$14.00	
60 CHANNEL INNER CONTOUR RING NO P/N	2	$187.50	$375.00	

DESCRIPTION	QTY	COST PER @	TOTAL COST	GFE NO.
.500 DIA. SILICON TOTAL REFLECTOR 105-70005	1	$80.00	$80.00	
1.000 DIA. SILICON TOTAL REFLECTOR 105-70185, 5M ROC	1	$85.00	$85.00	
1.000 DIA. SILICON TOTAL REFLECTOR 105-70060, 10MM ROC	1	$85.00	$85.00	
1.00" DIA. PARTIAL REFLECTOR 853433, 85% R	1	$292.00	$292.00	
1.00" DIA. PARTIAL REFLECTOR 253239, 90% R	1	$143.00	$143.00	
MODIFICATION OF DOWEL PINS	1	$237.50	$237.50	
TC ASSEMBLY ENCLOSURE	1		$1.00	95P
LASER SPECTRUM ANALYZER 16A	1	$2,420.00	$2,420.00	1
THERMAL IMAGE KIT 22-K	1	$329.00	$329.00	2
LASER BEAM PROBE KIT 23-S	1	$248.00	$248.00	3
DC AMPLIFIER 80-316	1	$727.00	$727.00	4
SHUTTER DRIVE EXPOSURE CONTROL T132	1	$395.00	$395.00	5
SHUTTER W/ T132 P/N V52532Z1	1	$345.00	$345.00	6
STAND 8-0060	1	$45.00	$45.00	7
TEKTRONIX VERTICAL AMPLIFIER 7A 13, DIFF. COMPARATOR	1	$1,250.00	$1,250.00	8
JOULMETER RATIOMETER JD2000	1	$3,792.00	$3,792.00	9
PYROELECTRIC JOULMETER J3-02	1	$1,051.20	$1,051.20	10
PYROELECTRIC JOULMETER J3-02	1	$1,051.20	$1,051.20	11
POST & STAND J3	1	$144.00	$144.00	12
POST & STAND J3	1	$144.00	$144.00	13
JOULMETER PROBE J25	1	$744.00	$744.00	14
POST & STAND J/25/J50	1	$144.00	$144.00	15
PYROELECTRIC INSTRUMENT P3-00	1	$1,147.20	$1,147.20	16
POST & STAND P3	1	$144.00	$144.00	17
OPTICAL CHOPPER CTX-534	1	$1,450.00	$1,450.00	18
BLANK BLADE CTD-500	1	$65.00	$65.00	
SLOT BLADE CTD-515	1	$95.00	$95.00	
DUTY CYCLE BLADE CTD-525	1	$125.00	$125.00	
MODE IR DETECTOR P006-2	1	$1,995.00	$1,995.00	19
TRIGGER GENERATOR 40295	1	$4,050.00	$4,050.00	20
SERIES 81 ENCLOSURE 81-W1-8	1	$8,100.00	$8,100.00	21
****POWER FILTER ULW	1	$460.00	$460.00	
****CONNECTOR PANEL P81-135-10	1	$280.00	$280.00	
****FAN & HOUSING	1	$200.00	$200.00	

DESCRIPTION	QTY	COST PER@	TOTAL COST	GFE NO.
MIRROR MOUNT 133000	1	$351.00	$351.00	22
MIRROR MOUNT 133000	1	$351.00	$351.00	23
MIRROR MOUNT 133000	1	$351.00	$351.00	24
MIRROR MOUNT 133000	1	$351.00	$351.00	26
MIRROR MOUNT 133000	1	$351.00	$351.00	26
MIRROR MOUNT 133000	1	$351.00	$351.00	27
MIRROR MOUNT 133000	1	$351.00	$351.00	28
TRANSLATION STAGE 338086	8	$180.00	$1,440.00	
EXTERNAL BRACKET 338223	7	$49.50	$346.50	
BASE PLATE 3382030	7	$27.00	$189.00	
BEAMSPLITTER, 90% R/AR, "P" 105-17116	1	$261.00	$261.00	
BEAMSPLITTER, 50% R/AR, "P" 105-17108	1	$290.00	$290.00	
GENERATOR(HV PULSER FOR EOM) 8025	1	$5,250.00	$5,250.00	34
LEAK DETECTION SYSTEM VARIAN 925-40 & ACCESSORIES	1	$6,500.00	$6,500.00	35
GUAGE CONTROLLER 330001	1	$595.00	$595.00	36
DEGAS OPTION 330002	1	$75.00	$75.00	
BENCH TOP 330008	1	$25.00	$25.00	
TUBULATED GUAGE 307042	1	$80.00	$80.00	
PULSE GENERATOR 101	1	$400.00	$400.00	37
LENS, 1" DIA., 5" FL, ZnSe 1205-100-0500	1	$333.00	$333.00	
LENS, BK7, 5" FL, 1" DIA. 01-LPK219	4	$18.80	$75.20	
PYREX PIPE, 6" DIA., 10' LONG 72-1490	1	$520.00	$520.00	
CAMERA POLAROID LAND TYPE	1	$593.00	$593.00	38
TRIGGER MODULATOR TM-11A	1	$788.00	$788.00	72
TEKTRONIX HV PROBE P6015	1	$550.00	$550.00	79
SMALL CURRENT MONITOR 4100	1	$450.00	$450.00	80
ELECTRO-OPTIC MODULATOR (HeNe) QC-8	1	$960.00	$960.00	81
DGC: DELAY GENRATOR CAGE	1			
CTC: COAXIAL TEST CELL	1			
PTC: PYREX TEST CELL	1			
	1384		117,631.74	

MS/MSE DEGREE IN OPTICS & PHOTONICS TECHNOLOGY

NAG8-1028

In-Kind Match Report

Period: 12/18/93 - 6/18/94

Partner: HUGHES DANBURY OPTICAL SYSTEMS, INC.

In-Kind Man Hours

Name: C. L. SCHAUB Hours: 4 x 168 = 672

Name: D. R. OLSON Hours: 12 x 242 = 2904

Name: _____ Hours: _____

Name: _____ Hours: _____

In-Kind Equipment $3,576

Equipment: N/A

Operations Match: N/A

Signature: _____ Date: 7/15/94

MS/MSE DEGREE IN OPTICS & PHOTONICS TECHNOLOGY

NAG8-1028

In-Kind Match Report

Period: 6/19/94--9/18/94

Partner: Hughes Danbury Optical Systems, Inc.

In-Kind Man Hours

Name: D. R. Olson Hours: 12 X $242 = $2,904

Name: _____ Hours: _____

Name: _____ Hours: _____

Name: _____ Hours: _____

In-Kind Equipment

Equipment: N/A

Operations Match: N/A

Signature: _____ Date: 10/14/94

Nichols Research Corporation
4040 S. Memorial Parkway
P.O. Box 400002
Huntsville, AL 35815-1502
(205)883-1140 FAX (205)882-3422

25 July 1995

UAH
The University of Alabama in Huntsville
Center for Applied Optics
Huntsville, Alabama 35899

Attention: Mr. John Dimmock

Reference: Cost Sharing on POMO Contract

Dear Mr. Dimmock:

Below represents the dollar value of Blair Barbour's time spent with respect to cost sharing on this effort.

HOURS	RATE/HOUR	TOTAL
32	$82.98	$2,655

If you have any questions please contact the undersigned at (205) 883-1170, extension 1545.

Sincerely,

Jennifer McCaghren

Jennifer McCaghren
Contract Administrator

ATTACHMENT 8

STEERING COMMITTEE

Attachment 8

POMO Steering Group

Mustafa Abushagur
UAH, ECE Dept.

Bob Berinato
Dynetics, Inc.

Jim Bilbro
NASA/MSFC

Jim Bonner
Shoals Community College

Harry Craft, Jr.
Technology Transfer Office

Steve Donley
Hughes - Danbury Optical Sys.

Gary Eberhart
Teledyne Brown Engineering

Gordon Emslie
UAH, Physics Dept.

Darell Engelhaupt
UAH, CAO

Keith Farr
AOS

Phillip Farrington
UAH, Industrial & Sys Eng

Joseph Geary
UAH, CAO

Don Gregory
UAH, Physics Dept.

Anthony Hale
Speedring

Richard Hartman
AOS

Lloyd Hillman
UAH, Physics Dept.

Miles Holloman
US Army Missile Comm. (MICOM)

Tommy Howard
Shoals Community College

Daryush Ila
Center for Irradiation of Material
Alabama A&M University

William Jones
USASSDC

Bill Key
ORNL

Stephen Kowel
UAH, ECE Dept.

Ravindra Lal
Alabama A&M

Sally Little
NASA/MSFC TRP

Jack McClanahan
Speedring

William C. McCorkle
US Army Missile Command

Jim McKee
Morgan Research Corp.

Art Miller
ORNL

Timothy Morgan
Morgan Research Corp.

Roy Nichols
Nichols Research, Inc.

Greg Nordin
UAH, ECE Dept.

David Porter
SCI

Ralph Reinhold
Boeing Missiles & Space Div.

H. Philip Stahl
Hughes - Danbury Optical Sys.

Warren Tomme
SCI

John West
NASA/MSFC