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ABSTRACT

This publication consists of colorful data sheets on the National Science Foundation's Engineering Research Centers (ERC) Program, a program designed to strengthen the competitiveness of U.S. industries by bringing new approaches and goals to academic engineering research and education. The main elements of the ERC mission are cross-disciplinary and systems-oriented research, education and outreach, and industrial collaboration and technology transfer. Data sheets on each of the 20 ERCs are grouped into the following technological areas of emphasis: biotechnology and bioengineering; design and manufacturing; infrastructure; materials processing for manufacturing; optoelectronics: microelectronics and information technology; and resource use and recovery. Each data sheet typically includes the Center's name, associated institution, area of major emphasis, a summary of the research being done, summary of educational activities, summary of efforts in industrial collaboration/technology transfer, description of facilities, director's name, address, e-mail address, phone and fax numbers. (CK)

Engineering Research Centers

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NATIONAL SCIENCE FOUNDATION

Engineering Research Centers: A Partnership for Competitiveness

Engineering Research Centers: A Partnership for Competitiveness

Promoting the discovery, integration, dissemination, and employment of new knowledge in service to society.

The Engineering Research Centers (ERC) Program of the National Science Foundation (NSF) stands as a landmark in federal support for university research in partnership with industry. Established by the NSF Directorate for Engineering in 1985 in accordance with a model envisioned by the National Academy of Engineering, the ERC Program introduced a number of bold new features designed to strengthen the competitiveness of U.S. industries by bringing new approaches and goals to academic engineering research and education, and by forging vital new links between universities and industry.

There are three main elements of this ERC mission:

- ***Cross-disciplinary and Systems-Oriented Research***— Bringing diverse engineering and scientific disciplines together to address fundamental research issues crucial to the next generation of technological advances in areas that will enhance the international competitiveness of U.S. industry. A unique feature of ERC research is its integrated "engineering systems" perspective.
- ***Education and Outreach***— Producing a new generation of engineers who are adept at the cross-disciplinary team approach to problem solving; who understand and share industrial perspectives on research, design, and manufacturing; and who are well prepared to contribute immediately and productively to industry. An important feature is active outreach to involve faculty and students from other schools — including precollege students and teachers — in ERC research and education programs.
- ***Industrial Collaboration and Technology Transfer***— Maintaining a strong commitment to collaboration and technology transfer between the ERCs and their industrial partners. The primary emphasis is on ensuring that the research pursued at ERCs is relevant to industry needs and that its results are explored in experimental proof-of-concept testbeds designed to advance the competitiveness of U.S. industry in the global technological marketplace. The program requires active participation and long-term commitments from industry and other member organizations.

Thus, from their inception the ERCs have reflected the new directions set forth in NSF's strategic plan, which include the development of intellectual capital, the integration of research and education, and the promotion of partnerships emphasizing shared investments, shared risks, and shared benefits. In many ways the program has redefined the concept of an academic research center, serving as a model for other centers programs subsequently launched by the NSF, by other federal agencies, and even by other governments.

The major technological areas upon which current ERCs focus are—

- Biotechnology/Bioengineering
- Design and Manufacturing
- Infrastructure
- Materials Processing for Manufacturing
- Optoelectronics/Microelectronics/Information Technology
- Resource Use and Recovery

Biotechnology/Bioengineering

Center for Neuromorphic Systems Engineering
California Institute of Technology
Pasadena, CA

Center for Emerging Cardiovascular Technologies
Duke University
Durham, NC

Biotechnology Process Engineering Center
Massachusetts Institute of Technology
Cambridge, MA

Center for Biofilm Engineering
Montana State University
Bozeman, MT

Design and Manufacturing

Engineering Design Research Center
Carnegie Mellon University
Pittsburgh, Pennsylvania

Institute for Systems Research
University of Maryland
College Park, MD

Center for Computational Field Simulation
Mississippi State University
Mississippi State, Mississippi

Center for Net Shape Manufacturing
Ohio State University
Columbus, Ohio

Center for Collaborative Manufacturing
Purdue University
West Lafayette, Indiana

Each ERC is established as a three-way partnership involving academe, industry and NSF (in some cases with the participation of state, local, and/or other Federal government agencies). Total annual funding for each Center ranges from $3.3 to $12.5 million, with NSF's contribution ranging from $1.4 to $2.9 million per year.

While the ERCs differ from one another, each must possess the following key features:

- A clear and coherent vision guiding the long-term, fundamental engineering and scientific research important for U.S. economic competitiveness.
- A strategically focused, systems-oriented, cross-disciplinary research program spanning knowledge creation to experimentation in testbeds, delivering knowledge and technological advances.
- A cross-disciplinary team effort fostering partnerships among faculty, students, and industry.
- Industrial collaboration facilitating a two-way flow of ideas between university and industry in planning, research, and education leading to the transfer of knowledge and technological advances to strengthen the long-term competitiveness of U.S. industry.
- An educational component that: involves both undergraduate and graduate students in the research culture of the ERC, preparing them for engineering practice; produces course and curriculum innovations based on the unique features of the ERC, which include life-long learning; and includes a commitment to increasing the diversity of the engineering workforce.
- Programs of outreach, such as summer research programs for undergraduates from other colleges and universities, joint research projects with other universities, programs to expose pre-college teachers and students to engineering, and contributions to the continuing education of practicing engineers.

Many of these features — the integration of research and education, the cross-disciplinary systems perspective, and involving undergraduates and industry — were explicitly designed to change the culture of academic engineering research and education. Such a change is now occurring on a national scale.

Infrastructure

Center for Advanced Technology for Large Structural Systems
Lehigh University
Bethlehem, PA

Materials Processing for Manufacturing

Engineering Research Center for Particle Science and Technology
University of Florida
Gainesville, FL

Center for Interfacial Engineering
University of Minnesota
Minneapolis, MN

Center for Advanced Electronic Materials Processing
North Carolina State University and other North Carolina institutions
Raleigh, NC

Center for Plasma-Aided Manufacturing
University of Wisconsin-Madison and University of Minnesota
Madison, WI and Minneapolis, MN

Optoelectronics/Microelectronics/Information Technology

Data Storage Systems Center
Carnegie Mellon University
Pittsburgh, PA

Optoelectronic Computing Systems Center
University of Colorado and Colorado State University
Boulder, CO and Ft. Collins, CO

Low-Cost Electronics Packaging Research Center
Georgia Institute of Technology
Atlanta, GA

Center for Compound Semiconductor Microelectronics
University of Illinois at Urbana-Champaign
Urbana, IL

Resource Use and Recovery

Advanced Combustion Engineering Research Center
Brigham Young University and the University of Utah
Provo, UT and Salt Lake City, UT

Offshore Technology Research Center
Texas A&M University and The University of Texas at Austin
College Station, TX and Austin, TX

At the end of their life-cycle as NSF-supported Engineering Research Centers, most ERCs will become self-sustaining. Currently there is one self-sustaining ERC:

Center for Telecommunications Research
Columbia University
New York, NY
(established in 1985 and self-sustaining from 1996)

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Center for Neuromorphic Systems Engineering

California Institute of Technology

Endowing machines of the next century with human senses

A National Science Foundation Engineering Research Center since 1994

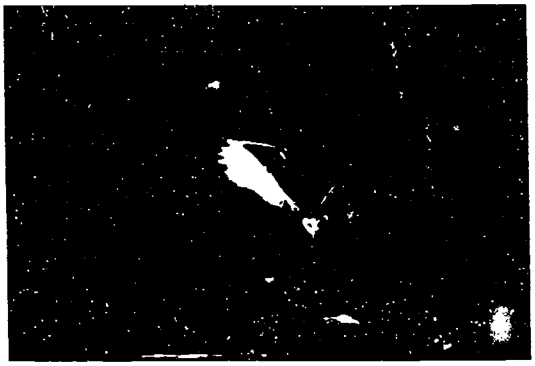
The mission of the Center for Neuromorphic Systems Engineering is to develop the technology infrastructure for endowing machines with the senses of vision, hearing, touch, and olfaction, and the ability to learn and adapt to their environment. The Center seeks to raise artificial neural network technology to a new level at which it can become an "enabling technology" for industry, with an impact comparable to that of the introduction of the microprocessor. A quantum leap in technology is needed for this research to manifest itself as innovative processes and products in U.S. industry. The Center aims to facilitate this leap by focusing on sensory processing in which the natural parallelism of artificial neural networks, and neuromorphic VLSI and optical circuits, can provide solutions to problems that are difficult for conventional computing to address. These problems include vision, audition, tactition, and chemical sensing (olfaction), in addition to locomotion, robotic control, and autonomous systems. Coupling high-bandwidth arrays of sensors and actuators with the processing power and learning abilities of distributed neural networks will facilitate vastly improved human-machine interaction and machine-environment interaction.

Research

The ERC pursues basic research in hardware and algorithms for sensory processing. The hardware effort is focused on the development of tools and techniques for analog and optical VLSI design.

The *algorithm* effort is focused on the development of learning and adaptive techniques for artificial neural networks. The Center aims to demonstrate the results of this research by developing industry testbeds in two applications areas that both require rich sensory environments: autonomous vehicles and human/machine interfaces. Typical example applications of autonomous vehicles are microspacecraft, car engine and braking control, vehicle navigation, sensory processing for robot manufacturing, and adaptive chemical plant control. Human/machine interface applications include face recognition, security systems, virtual reality interfaces, teleconferencing interfaces, and intelligent data manipulation and search.

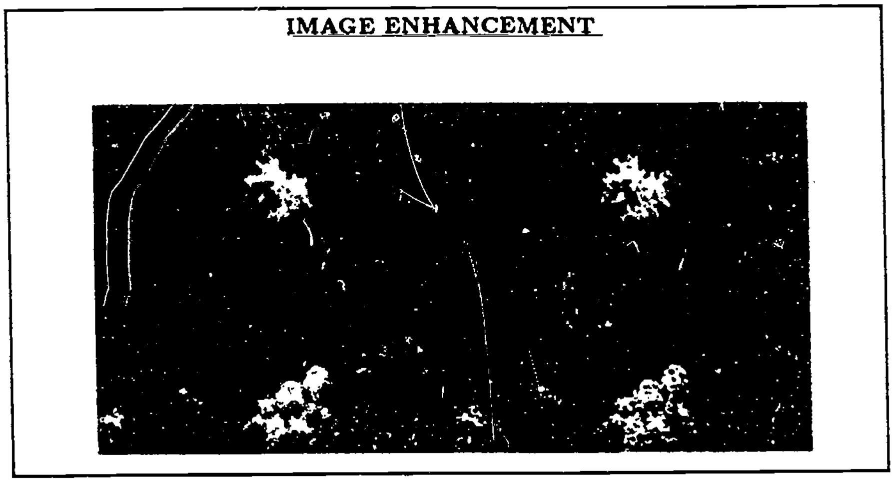
At the *hardware* level, a key research focus is the development of tools for constructing densely interconnected multi-chip vision and other sensory systems. Optical and event-driven interconnections will be researched to enable sensory chips such as silicon retinas for vision, silicon cochleas for audition, and micromachine tactile sensors, to communicate with neural network processing arrays. Pulse-based computation techniques that emulate biological neural firing, such as computation via action potentials, will be researched as a means for combining computation and



An infrared photograph showing a barn owl flying toward a mouse in total darkness. The rustling noises of the mouse are the cues for localization by the owl, which detects differences in the timing and intensity of sound between the ears. The neural circuits that compute interaural time difference have been identified and simulated in a VLSI chip.

communications in dense silicon sensory processing arrays. Learning and adaptation are key requirements for robust sensory processing arrays due to the natural parameter variability and noisiness of sensors. Silicon synapses, neurons, and techniques for non-volatile analog storage also are being explored as fundamental building blocks of silicon neural systems. Sensor fusion to achieve combinations of sensory modalities will also be researched. For example, the fusion of audition and vision allows sophisticated localization of moving objects. Techniques for combining new sensor technologies with VLSI silicon neural network processing also will be researched. These include chemical sensing and olfaction, and micromachine tactile, pressure, and sonar sensors. The combination of these technologies will allow the Center to build multi-chip systems such as an "electronic nose," capable of classifying odors, for applications such as environmental monitoring, drug and explosive detection, and chemical and plant processing and monitoring. Research in combining micromachine technology with neural network processing can allow the development of "intelligent sensory skins" for robot control, virtual reality, and autonomous vehicle guidance.

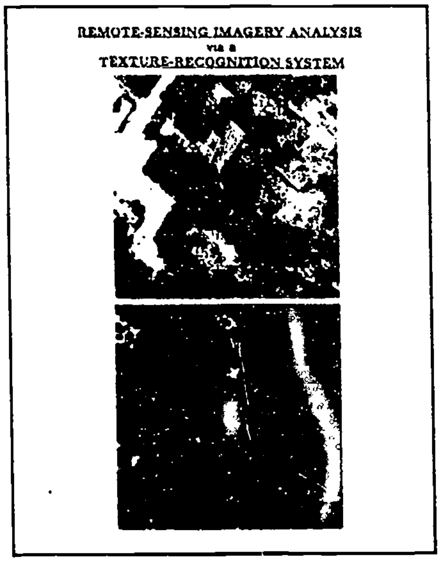
At the *systems* level the Center will focus on autonomous vehicle control and human-machine interfaces to demonstrate the capabilities of neuromorphic processing. An autonomous vehicle car platform equipped with silicon retinas for vision, together with tactile and sonar sensors, will be developed to investigate real-time learning and adaptation in a rich sensory environment. A model helicopter platform will allow investigation of learning techniques in which prior knowledge (of flight) needs to be fused with real-time adaptation, to achieve safe autonomous flight. Human/machine interfaces promise more effective human-machine-data communication in the face of the "information explosion." Sensory processing is again the key feature that is needed but the information processing required is quite different. In this case we need to understand the behavior of a human being rather than the entire environment surrounding the machine. Specifically, we aim to develop laboratory demonstrations that look at the head and upper part of the body of the user to extract information such as gaze direction (as a form of auto-mouse), face localization, identity recognition, verbal commands (lip reading), and hand gestures. Voice processing, handwritten character readers, fingerprint recognition, and intelligent touch pads are other human/machine interfaces the Center is targeting for experimental demonstrations.



Color image enhancement — on the left is a given blurred input, on the right is the enhanced result. The degradation model for the blurred image is unknown. The enhancement scheme we employ uses non-linear filtering to augment the frequency spectrum of a blurred input (creating new high-spatial frequencies). As a result of the enhancement, we create images with higher resolution than the sampling rate would allow. This property is highly valuable in application domains which require limited bandwidth to represent or transmit images, including the HDTV and videophone markets.

Education

The ERC is a part of the Computation and Neural Systems (CNS) doctoral program at Caltech. The program's chief goal is to examine the fundamental relationships between the structure of neuronal and neuron-like circuits and the computations performed either by living neural elements or by synthetic physical devices. It fosters exchange of ideas and collaborations among engineers, neuroscientists, and theoreticians. The Center also supports the Minority Summer Undergraduate Research Fellowship (MURF) program, which provides support for talented undergraduates to spend a summer working in a research laboratory. The MURF program is aimed at improving the representation of African Americans, Hispanics, Native Americans, and Pacific Islanders in the biological, engineering, and chemical sciences in the United States.



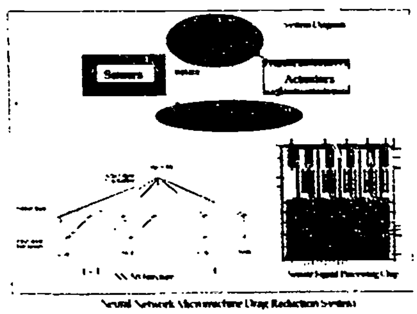
This example of remote-sensing imagery analysis demonstrates the use of a texture-recognition system in natural scene analysis, in this case via an airborne image. The texture-classes learned are bush (output label green), ground (output label red), and a structured area such as a field or the man-made structures (output label white). The system's learning mechanism provides for a generalization capability as well as for robustness to noise in a complex real-world image.

Industrial Collaboration/Technology Transfer

The Center promotes active partnerships with U.S. industry on a number of managerial, educational, and technical levels, all consistent with the mission of the Center. Industry participation occurs through three support groups of increasing involvement: the Caltech Industrial Associates Program, which provides initial access to general ERC information; the ERC Affiliates Program for companies with a general interest in neural networks, who will participate in ERC activities and have limited access to Center facilities and seminars in order to propose specific collaborative projects; and the ERC Members Program for companies seeking more substantive collaborations and Center involvement. These members provide management input to the Center to help define research thrusts, collaborate with faculty, and are provided space at the ERC for visiting engineers and scientists.

Facilities

The Center for Neuromorphic Systems Engineering is located at the California Institute of Technology. The Center occupies approximately 40,000 sq. ft. of space in the Gordon and Betty Moore Laboratory of Engineering. This new $21 million, state-of-the-art engineering facility is the focal point for Center activities. In addition to faculty research areas and teaching and student laboratories, there are two laboratories — a VLSI design lab and a vision processing lab — specifically intended for industrial collaborative projects.



Neural network micromachine drag reduction system.

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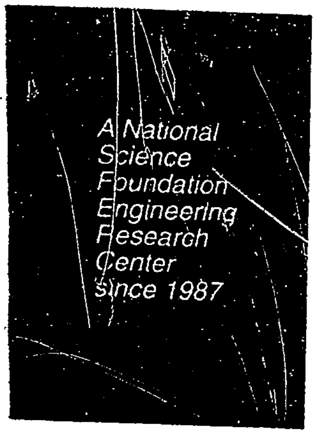
NSF 96-23b

Center for Emerging Cardiovascular Technologies

Duke University

Interdisciplinary research to improve health care and technology



The vision of the Center for Emerging Cardiovascular Technologies is the development of advanced instrumentation systems and techniques that will enable improved diagnosis, therapy, and monitoring of coronary artery disease and its sequelae in the myocardium. The application of these technologies will lead to a more complete understanding of the interrelationship among the metabolic, electrical, and mechanical events of the heart.

Research

Coronary artery disease and its related effects are a major cause of death and debilitation in the United States. The Center is well positioned to make significant contributions to the detection and treatment of disorders resulting from this disease. We believe that improved instrumentation coupled with interdisciplinary, focused research will advance the understanding of electrical, mechanical, and chemical changes associated with coronary heart disease, leading to better, more cost-effective care. Research in electrophysiological diagnosis and antiarrhythmic therapy will be focused toward improved mapping and treatment of aberrant electrical effects. Real-time 3D ultrasound and magnetic resonance microscopy will be improved to allow noninvasive visualization and assessment of coronary arteries and cardiac functions. Biosensors will be used to study chemical changes resulting from ischemia. Specific research goals to achieve those aims include the development of systems to:

- Provide advanced instrumentation and sensors for cardiovascular disease
- Image coronary arteries noninvasively
- Measure coronary artery blood flow noninvasively
- Quantify beat-to-beat myocardial function noninvasively
- Determine regional myocardial motion and contractility
- Determine plaque morphology and evolution
- Simulate realistic conduction models of the myocardium
- Develop smart endocardial mapping
- Measure the heart's metabolic and ionic state
- Treat the affected myocardium

The Center is a major partnership between universities, industry, and government. Duke's academic partners are the University of North Carolina at Chapel Hill, North Carolina State University, Case Western Reserve University, and the University of Alabama at Birmingham.

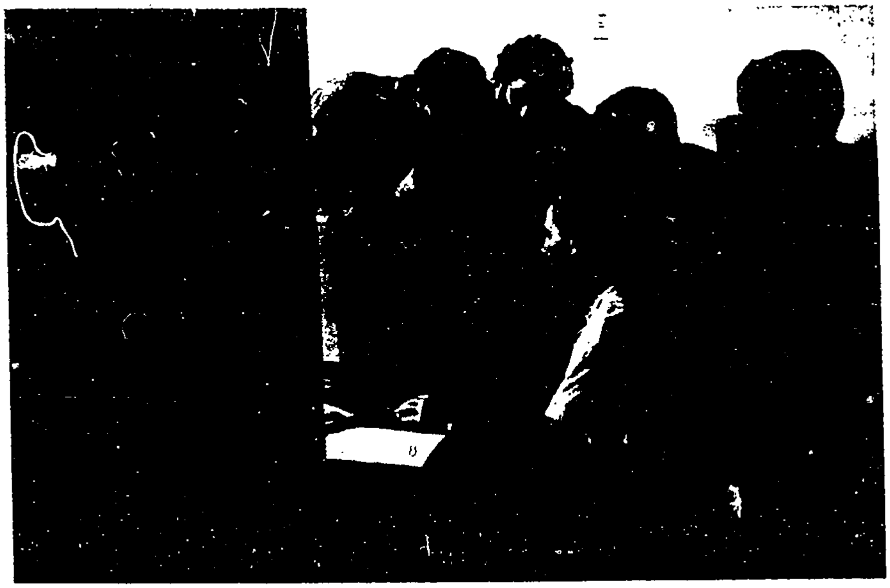
Research Thrusts

In its quest to achieve these goals and fulfill its vision, the Center is organized into four research thrusts. These four thrusts and their corresponding deliverables are:

- *Electrophysiological Diagnosis and Antiarrhythmic Therapy*— smart endocardial mapper, controllable ablator, arrhythmia prediction and prevention
- *Noninvasive Imaging of Anatomy and Function*— noninvasive myocardial function, noninvasive volumetric flow and anatomic imager, *in vivo* coronary microscopy
- *Chemical Sensors in Coronary Artery Disease*— accurate, inexpensive chemical sensors; smart, wireless implantable sensor system; modeling and control of arrhythmia based on ionic and metabolic state; biocompatible sensors for chronic applications
- *Advanced Technologies*— 100x100 5 MHz transthoracic ultrasound array, automated quantitation of volumetric geometries, 3D visualization, integrated electrode systems

To demonstrate the impact that this research can have on health care, consider this example. Part of the research focuses on implantable devices that prevent or halt ventricular fibrillation, the major cause of sudden cardiac death, from which 400,000 Americans suffer each year. If only 10% of these potential victims could receive implants, many lives could be saved; and the U.S. market will yield $500 million per year.

3-dimensional modeling and visualization of medical information is one of the most promising fields of research conducted at the Center. Here, a computer-generated rendering of the epicardial surface of a heart helps NSF/ERC researchers to understand and quantify the electrical stimulation and conduction mechanisms responsible for normal and aberrant cardiac function.



Undergraduate and Predoctoral NSF/ERC Fellows are working with NSF/ERC Faculty in the Visualization and Image Analysis Laboratory to develop advanced visualization and modeling tools for biomedical applications.

Education

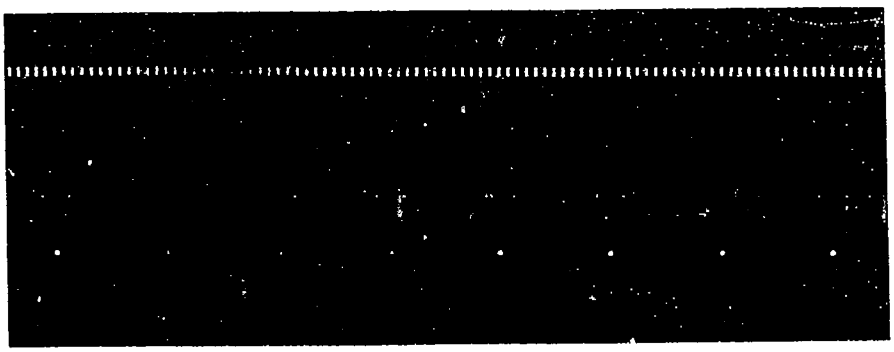
The heart of the Center's education and research work force is its students. Central to the Center's interdisciplinary philosophy is the interdependent and mutually beneficial relationship among research, education, and industrial interaction. This Center believes that the engineering student is the essential element in this collaboration. An important component of the Center's educational program is its industry-supported Educational Partners Program. This program provides major educational opportunities for NSF/ERC Predoctoral and Undergraduate Fellows and, as part of their engineering training, enables them to interact with industrial investigators.

The Emerging Cardiovascular Technologies Seminar Series is an integral resource in the Center's educational program. Seminars telecast weekly to universities across North Carolina provide opportunities for faculty, students, and guests from industry to discuss ongoing research topics.

The Research Experiences for Undergraduates (REU) Program is an outreach program aimed at students traditionally underrepresented in engineering research laboratories. The Center has made a special commitment to working with persons with disabilities, especially the deaf and hearing impaired. Other outreach programs are directed towards high school and middle school students.

Industrial Collaboration/Technology Transfer

The Center accomplishes industrial collaboration and technology transfer through the Educational Partners Program. It is through the Partners program that industries have access to students for internships, attend workshops on specific areas of Center research, serve on the Industrial Advisory Board, and receive current Center publications.



Microfabricated, Kapton-based electrochemical sensors for cardiac applications. The sensor "Christmas trees" to be inserted in the myocardium are shown as batch-fabricated, prior to separation.

The ultimate users of Center-developed technologies are not the medical device companies that commercialize these products but practicing physicians who utilize new biomedical devices to improve patient treatment. To ensure that the Center is developing technologies that doctors need and that will actually benefit patients, the Center has established a Clinical Partners Program. Under this program, the Center obtains feedback on technologies currently in development through concept validation research conducted in clinical settings jointly with researchers at Duke University Medical Center and, prospectively, other medical centers in the region. Clinical Partners, like Educational Partners, serve on the Center's advisory board.

Facilities

The Center has outstanding laboratory facilities and equipment across the Duke campus as well as at its affiliated institutions. The Center's research facilities include thin and thick film microelectronics fabrication laboratories, advanced visualization and analysis systems, extensive capabilities for ultrasound transducer research and fabrication, unequaled magnetic resonance tools for real-time *in vivo* microscopy, and extensive electrophysiological capabilities for the study, mapping, and therapeutic treatment of cardiac arrhythmias.

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Dir., External Affairs: Mr. Richard A. Lucic

Dir., Outreach: Ms. Martha Shumate Absher

Admin. Dir.: Ms. Marianne Hassan Risley

NSF 96-23c

Biotechnology Process Engineering Center (BPEC)

Massachusetts Institute of Technology

Collaborative research and education are building the foundations of a major new industry

A National Science Foundation Engineering Research Center since 1985

The BPEC at MIT is a pioneering program in education and research for the biotechnology industry. The BPEC takes an innovative, cross-disciplinary approach to biotechnology, integrating life sciences and bioprocess engineering with the goal of producing advanced manufacturing technologies.

Graduate student monitoring bioreactor operation.

Research

Research is focused in two thrust areas:

- *Therapeutic Protein Production: Quantity and Quality*

Research in this thrust area is directed at two goals. The first goal is to develop an integrated, ultra high-productivity/titer cell culture system with the aim of producing 10 grams per liter of monoclonal antibody from a two-week fed-batch hybridoma cell culture. The second goal is to develop the means to control product quality based on an improved understanding of glycosylation and other post-translational intracellular steps leading to glycoprotein biosynthesis in mammalian cell cultures.

- *Therapeutic Protein Aggregation, Stability, Formulation, and Delivery*

Research in the second thrust area deals with the engineering and scientific principles involved in therapeutic protein production with respect to protein aggregation, protein stability, protein formulations, and protein delivery. The research in this area focuses on deleterious processes that occur in therapeutic protein formulations, and on the design of rational stabilization strategies and alternative modes of administration. The primary emphasis is on lyophilized (freeze-dried) proteins as it relates to the use of protein within polymeric drug delivery devices.

Education

Undergraduate. Enrollment in the Chemical Engineering, Chemistry, and Biology Departments provides an ideal base for undergraduate studies in biotechnology. The interdisciplinary needs of the students are fulfilled through up-to-date biotechnology courses offered by the BPEC faculty, and a flexible elective course policy allows students to cross-register between departments. Throughout the year and during the summer, a diverse group of undergraduates gains research experience at the BPEC through MIT's Undergraduate Research Opportunities Program (UROP). UROP students work on BPEC research projects for pay or academic credit. Students from colleges and universities other than MIT also benefit from the BPEC's unique research environment through participation in the Research Experience for Undergraduates (REU) program.

Graduate. Graduate students associated with the BPEC play a major role in developing the Center's research projects. Most of these students are MS or PhD candidates in Chemical Engineering; their biotechnology education focuses on core and elective courses in Chemical Engineering complemented by electives in Biology and Chemistry. Other BPEC graduate students are completing doctoral degrees in Biology or Chemistry. Frequently, biochemical engineering students elect to complete a minor in Management. Due to the nature of the research thrusts in this Center, an integrated approach requiring cross-disciplinary interactions is a necessary aspect of the graduate students' research. Thus, the team approach where each student contributes in a synergistic manner toward the overall effort is essential for the success of the educational program.

Available at the BPEC is an Interdepartmental Biotechnology Training Grant Program funded by the NIH (NIGMS). Faculty trainers who participate in this program consist of not only BPEC faculty, but also additional faculty from the departments of Electrical Engineering, Mathematics, Biology, Chemistry, and Chemical Engineering. To provide the students with a broader perspective of biotechnology, each candidate must complete cross-disciplinary requirements specific to this program.

Industrial. Each summer, BPEC faculty present short, intensive courses to the industrial community. These one-week courses provide training on such topics as Fermentation Technology; Biotechnology: Principles and Processes; Modeling, Simulation, and Optimization; and Downstream Processing.

Pre-College Outreach. The BPEC involves gifted high school students in its research, allowing the students to gain laboratory exposure and experience in biotechnology. Lectures on biotechnology and tours of the Center's research facilities are given to other pre-college students and teachers.

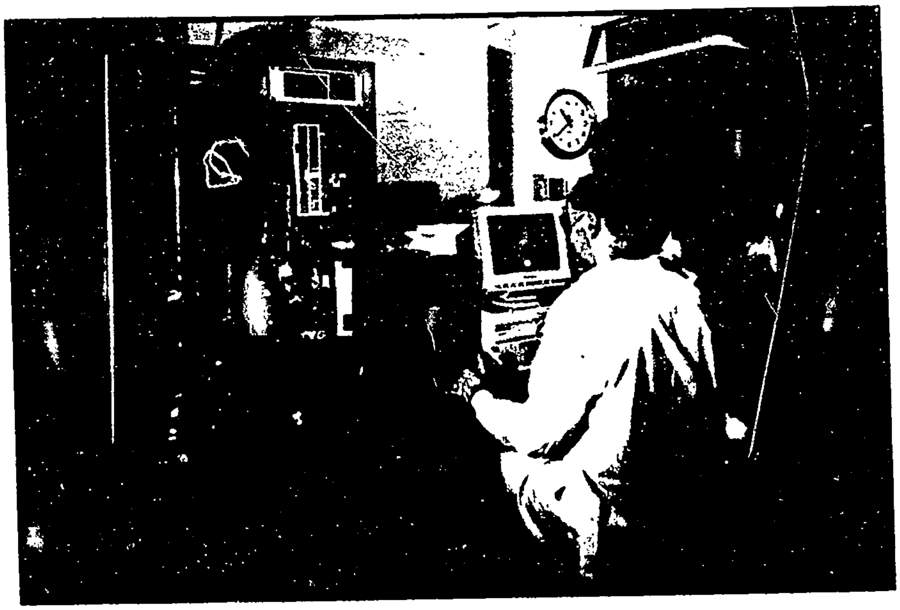
Industrial Collaboration/Technology Transfer

The Industrial Consortium Program is a vital, interactive program for communication between the Center and industry. Workshops are held solely for these industrial members to provide a forum for information and technology exchanges. Direct industrial collaborations with the Center's students, research staff, and faculty have also been quite active. The collaborative efforts involve the Center personnel working directly with companies either at the Center or at the industrial sites.

Transfer of technology and information is also routinely accomplished through several other avenues, including an annual symposium; publications, presentations, seminars, and theses from the Center; and Consortium Workshops.

Facilities

Research programs are conducted in a variety of environments. All of the research dealing with the first thrust area described above is housed in the BPEC's centralized facility. In addition, facilities associated with the co-principal investigators are available in support of the Center's other research programs. Due to the multi-departmental participation in this Center, our researchers have access to a number of instrumentation facilities that are operated and maintained by different MIT departments.



Monitoring protein glycosylation patterns by MALDI-TOF Mass Spectrometry.

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Asst. Director, Administration and Operations: Ms. Audrey Jones Childs

NSF 96-23d

Center for Biofilm Engineering

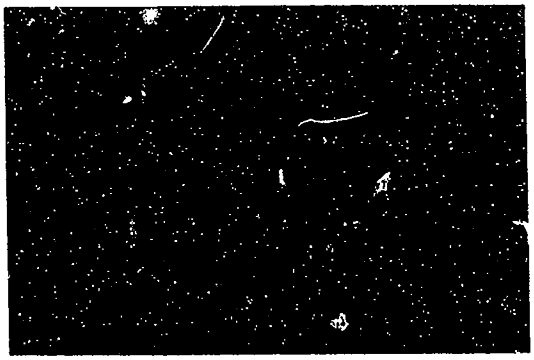
Montana State University—Bozeman

Pursuing research on biofilm processes in vital industrial, environmental, and medical arenas

A National Science Foundation Engineering Research Center since 1990

The widespread impact of biofilm activity is the focus of increasing national attention. For example:

- Biocorrosion and biofouling related to biofilms cost U.S. industries *billions* of dollars annually.
- Microbial tendencies to adhere to any available surface affect the efficacy of environmental bioremediation efforts.
- The production of hydrogen sulfide by biofilm bacteria endangers oilfield workers and makes enormous oil reserves expensive or impossible to recover.
- Biocide-resistant biofilms harbor bacteria which may pose a health threat to U.S. drinking water systems.
- Antibiotic-resistant biofilms contaminate implanted medical devices and endanger lives.



Anne Camper, Research Associate in Microbiology/Civil Engineering, and Paul Stoodley, Research Specialist, in the Center's Scanning Confocal Microscope laboratory.

Research

The mission of the Center for Biofilm Engineering is to address industrial, environmental, and medical aspects of biofilm processes. The Center's goal is to develop the instrumentation, processes, and knowledge that industry needs to stay ahead in an increasingly competitive world. The Center's pioneering work on interfacial microbial processes and its extensive network of experts and collaborators make it potentially the world leader in biofilm research.

The Center conducts basic and applied research to resolve industrial problems and to strengthen U.S. competitiveness. Center researchers:

- Perform cross-disciplinary, microscale research to advance the science and technology of interfacial microbial processes.
- Pursue cross-disciplinary, proof-of-concept research to provide validated knowledge and technology ready for testbeds on-site or in industry.
- Develop instrumentation and technology for process control of industrial systems and environmental processes.
- Work closely with industrial partners and with universities and research organizations around the world.

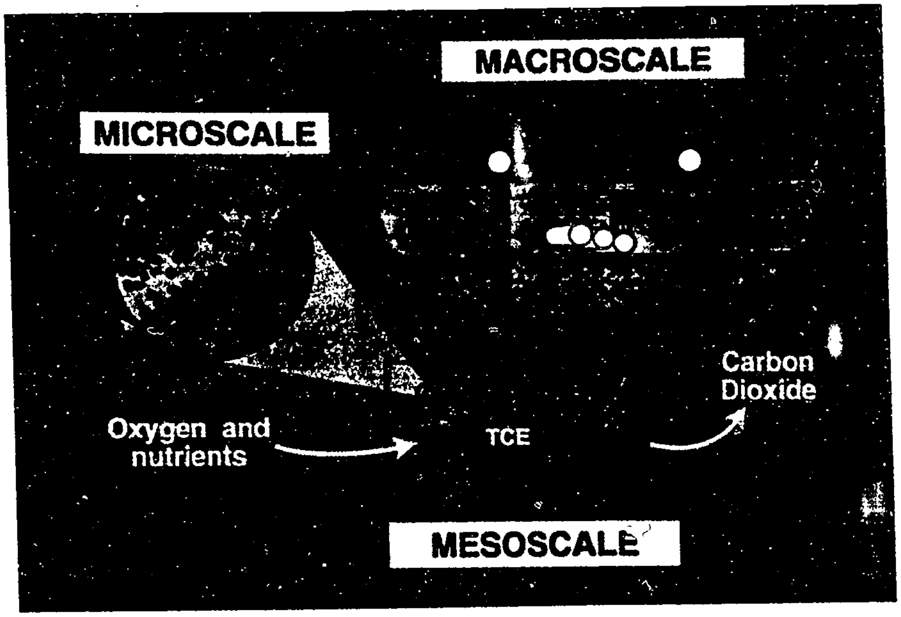
Education

Students help to develop innovative solutions for industry by working in cross-disciplinary research teams. Center graduate students take advantage of internship opportunities with the Industrial Associates. They develop communication skills by making presentations at seminars and at Industrial Associate and national meetings. Faculty from nine academic departments cooperate in Center educational programs. A summer program, Research Experience for Undergraduates (REU), enables exceptional students from across the United States to conduct research in the Center laboratories. The Undergraduate Research Program (URP) gives MSU students an opportunity to work with MSU researchers on applied research projects. The Center's Undergraduate Outreach Minority Research Program is a collaborative effort with California State University-Long Beach and San Jose State University.

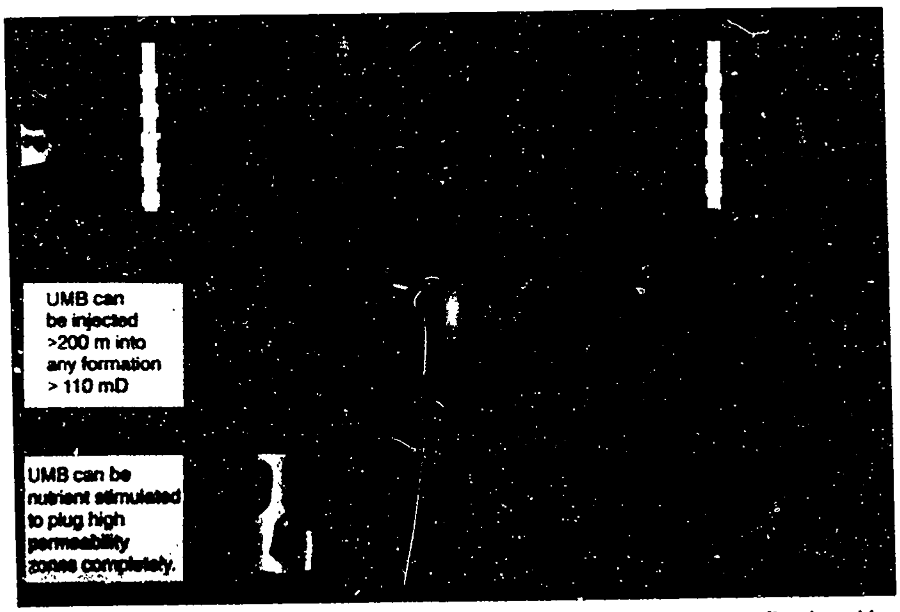
Industrial Collaboration/Technology Transfer

Industrial participation is an essential part of the Center's research planning. The Industrial Associates program represents a wide diversity of industries affected by biofilms: petroleum production, drinking water, specialty chemicals, and health. Industrial Associate representatives attend meetings twice a year to review Center projects, to help set research priorities, and to identify technologies that could be advanced through collaboration with the Center. Representatives from industry visit the Center regularly to learn Center-developed methods and techniques.

Quality research faculty and staff with diverse backgrounds energize the Center's collaborative research efforts with industry. Increased sponsorship from one or more companies allows the pursuit of more targeted research in the form of Research Initiatives. Current Initiatives focus on the role of biofilms in microbial contamination of drinking water distribution systems, biobarriers, and bioremediation of water and soil contaminated by petroleum hydrocarbons and other organics. Initiatives in health research are under development.



The Center's micro/meso/macroscale research approach is shown in this illustration of a contaminated groundwater aquifer. The macroscale system is a plug-flow reactor. At the mesoscale, the influence of geometry and fluid dynamics impacts biofilm cell accumulation and activity in the aquifer. Interestingly, at the microscale, activity is similar regardless of whether the system is a cooling tower, a paper machine, a wastewater treatment plant, an oil spill, or the human body.

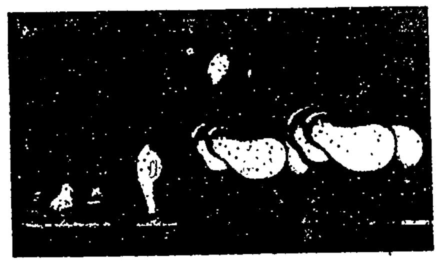


Ultramicrobacteria are very small, starved bacteria which can be more easily placed in oil wells to plug permeable zones or used for bioremediation of contaminated sites. With the addition of nutrients, they are resuscitated and form biofilm *in situ*. Center researchers are currently working on developing improved methods of bacterial delivery.

Facilities

The MSU College of Engineering has provided 10,000 square feet of contiguous laboratory and office space for use by the Center. This space encourages cross-disciplinary interaction. A new Engineering and Physical Sciences building will provide 20,500 square feet of additional contiguous space for the Center, with access to a new telecommunications network.

A Confocal Scanning Laser Microscope housed at the Center, combined with computer imaging, has changed our concepts of biofilm structure. Time-of-Flight SIMS and Electron Spectroscopy for Chemical Analysis (ESCA) instrumentation has vastly increased the capability of the Center to analyze surface structures and to relate these structures to biofilm accretion. Other instruments currently available include a Scanning Electron Microscope (SEM) with Energy-Dispersive X-ray microanalysis (EDX) system, Scanning Auger Microscopy (SAM), and Secondary Ion Mass Spectroscopy (SIMS).



At the microscale, researchers are discovering that "heterogeneities" of biofilm (e.g., physiological, electrical, chemical, structural, ecological variations) have practical consequences, such as biocorrosion and biofouling. Control and manipulation of these heterogeneities are goals of the Center. This figure illustrates a current hypothesis regarding biofilm structural heterogeneity.

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NSF 96-23e

Engineering Design Research Center (EDRC)

Carnegie Mellon University

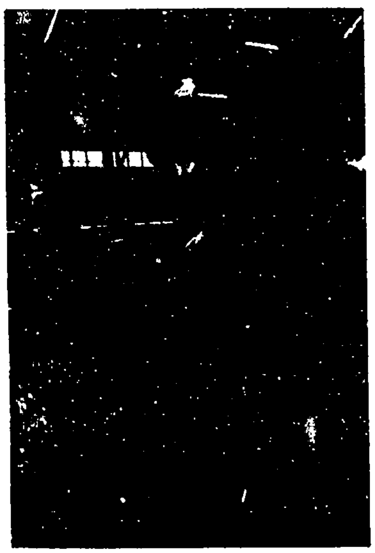
Companies that continually upgrade their design practices are the ones that lead their industries

A National Science Foundation Engineering Research Center since 1986

EDRC develops advanced design methodologies to drastically reduce the design-to-product cycle. and to build flexible. domain-independent design environments to integrate quantitative and qualitative methods for design optimization.

EDRC is a multidisciplinary community of faculty. students, and staff who develop and integrate computer-based methodologies for more rapid, effective design in industry. Research applications are in areas as diverse as high-rise buildings and computer board component layout. The goal is to develop a design workstation that incorporates the method-based tools developed at the Center. EDRC joins academic research with industrial needs as it pursues research and education in engineering design.

EDRC's research blends disciplinary expertise to create and integrate quantitative and AI-based design methodologies. Through an industrial affiliation program, EDRC pursues technology exchange with member companies through people. In parallel with its research program, EDRC trains both undergraduate and graduate engineers to develop and implement new design technologies.



A mechanic uses the Vu Man 3, a wearable computer with a heads-up display, to test aircraft avionics. All necessary information to perform the task is viewed on the display. Large volumes of information can be stored and accessed at any time while inspecting or repairing the plane.

Research

EDRC's research program is organized into two laboratories:

Design for Manufacturing Laboratory

Faculty from electrical and computer engineering, mechanical engineering, and computer science are developing methodologies to inform designers of the downstream consequences of decisions they make while formulating a design. The three areas of research are: simultaneous electrical/mechanical design capability as applied to wearable computers; drastic reduction of the design-to-product cycle: and combining non-manifold geometric representations and expert systems to communicate to the designer reasoning inherent in the manufacturing process. Other research foci include rapid prototyping and manufacturing cost models.

Currently, multiple mechanics must perform maintenance tasks due to cumbersome manuals and restricted workspace.

Synthesis Laboratory

Combining expertise from computer science, architecture, and chemical, civil, and mechanical engineering, this lab is developing and integrating qualitative and quantitative methods for optimizing design in the areas of electromechanical design, layout design, separation system synthesis, and preliminary design of engineering systems.

The EDRC community spans nine campus entities, including the six engineering departments of the Carnegie Institute of Technology, the departments of architecture and design in the College of Fine Arts, the Graduate School of Industrial Administration, and the School of Computer Science.

EDRC operates from the premise that design practice can —

- Improve dramatically at an early stage by applying formal methodology that enables designers to anticipate life-cycle concerns
- Generate and select design alternatives automatically
- Develop design systems that are easy to learn, use, and modify.

Education

Graduate and advanced undergraduate students are involved in the cross-disciplinary research of the EDRC and may attend courses stemming from EDRC research. These courses include "Advanced Programming Concepts in CAE," "Engineering Design: The Creation of Products and Processes," "Advanced Process Analysis and Synthesis," and two special topics courses focusing on "Wearable Computers" and "Green Design." In addition, EDRC also participates in the university's cross-disciplinary course "Design, Manufacture, and Marketing of New Products," which involves faculty and undergraduate students from design, industrial administration, and EDRC, which serves as the representative of the engineering school.

Short courses targeted to a particular industry expose industrial professionals to new technologies emerging from EDRC research. These courses are offered for industrial affiliates both at the EDRC and at industrial sites.

EDRC's Design Lecture Series promotes developments in industrial and academic design research. The series has featured speakers from General Electric, the Ford Motor Company, Black and Decker, and academic centers such as the University of Lancaster (UK), the University of Sydney (Australia), UCLA, and Berkeley.

Industrial Collaboration

An industrial affiliation program provides two ways in which companies intent on improving design methods may join the Center. A company may affiliate with EDRC by supporting ongoing research (*partnership*) or by sponsoring a joint research project (*sponsorship*). EDRC also offers consortium memberships in selected fields of research.

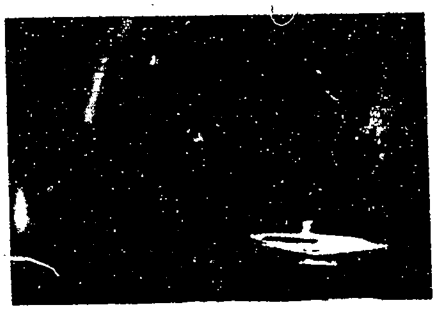
EDRC partners support ongoing research as general affiliates of the Center. *Project partners* follow the progress of an ongoing project, while *lab partners* observe the work of an entire lab. In addition to receiving all technical reports and theses from projects of interest, project and lab partners visit EDRC frequently and host seminars at their own sites to apprise themselves of the current status of the research.

Sponsors define joint research projects with EDRC in conjunction with EDRC's strategic plan for research, which includes protection of proprietary data. A project sponsor typically commits a technical resident to the project. While working at EDRC, the technical resident can prepare a framework for efficient transfer of new technology to the sponsor.

Companies that participate in EDRC's industrial affiliation program appoint an upper-level representative to EDRC's Industrial Planning Committee, a board that meets twice each year to review progress and advise EDRC on matters of strategic planning, research direction, and industrial interest.

The shape deposition process enables the manufacture of complex designs in less time-to-market.

Shape deposition testbed.



Material deposition.

Finished artifact.

EDRC Headquarters

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NSF 96-23f

Institute for Systems Research (ISR)

University of Maryland

A National Science Foundation Engineering Research Center since 1985

Developing the fundamental knowledge and tools for the integration of heterogeneous systems

The ability to rapidly design and produce durable, affordable, and versatile high-performance systems is a strategic objective of U.S. industry. The ISR is pursuing this objective by developing fundamental knowledge and tools for the seamless integration of advanced technologies into heterogeneous systems. ISR initiatives employ the combined efforts of academia and industry to accelerate the synthesis of existing and new technologies into better systems and products.

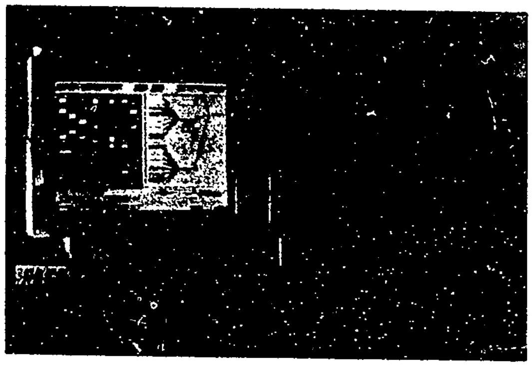
ISR conducts satellite networking experiments using a T1-VSAT terminal and NASA's ACTS satellite. The terminal installed by NASA at the ISR is comprised of the indoor unit, shown here, and an outdoor satellite dish.

The ISR was established as an ERC in 1985. The State of Maryland granted permanent institute status to the ISR in 1992. In addition to its 14 constituent and affiliated laboratories, the ISR has been the spring-board for several industry-university research consortia at Maryland. These include: the Center for Satellite and Hybrid Communication Networks, a NASA Center for the Commercial Development of Space; the CALCE Electronic Packaging Research Center, an NSF State/Industry/University Cooperative Research Center; and the Neural Networks Club, an initiative that facilitates industry-university cooperation in the fast-emerging area of neural network technology.

Research

The ISR's research program provides engineers with a conceptual framework for the integration of complex engineering systems. The ISR research program seeks to —

- Explore dynamic systems that evolve over time
- Integrate control, communication, and computation with physical and process knowledge
- Synthesize existing and new technologies into better systems and products
- Establish new systems paradigms
- Provide leadership and innovation in research, education, and industrial collaboration.



Tree-browsing is a feature of the next generation network management system in development at the ISR. The tree-browser visualization tool helps users select the best match for their information needs from among thousands of nodes being browsed.

The thrusts and associated topics of ISR research are—

- *Intelligent Control*
  - Modeling and Simulation
  - Control Methodology
  - Sensors and Inference
- *Systems Integration*
  - Models, Modules and Complexity
  - System Architecture
  - Performance and Trade-off Analysis
- *Intelligent Signal Processing and Communications*
  - Signal Representation and Processing
  - Unified Signal Processing and Networking
  - Modeling and Performance Evaluation

ISR researchers employ robots, such as the one shown here, to test intelligent control systems and related modeling, control, optimization, and signal processing techniques. The ISR's Walking Robot project incorporates applied research and instructional components and provides an interdisciplinary experience for students in mechanical engineering, electrical engineering, and computer science.

Education

The ISR's unique and renowned educational program has —

- Developed or modified more than 130 undergraduate and graduate courses, including both regularly taught classes and special topics classes closely tied to ISR research
- Established a prestigious graduate fellows program that has involved more than 125 students
- Developed a new Master's degree program in Systems Engineering that addresses topics that its industry partners deem critical for the next generation of engineers
- Developed a new program featuring research opportunities for undergraduate engineering students
- Created a modern computing and laboratory environment for engineering design by establishing or enhancing 8 constituent laboratories and 6 affiliated laboratories
- Provided a rich cross-disciplinary environment that offers at least 60 seminars, 6 colloquia, 6 student/faculty colloquia, and 5 workshops per academic year that involve industry, government, research institute, and academic speakers from around the world.
- Developed for the Clark School of Engineering the new Gemstone Program, which brings together teams of undergraduate students—from engineering, business and management, the social sciences, and the humanities—who will spend four years analyzing and investigating societal problems associated with technological change.

Faculty

ISR activities draw on the participation of —

- 11 departments at the University of Maryland, including Aerospace Engineering, Chemical Engineering, Civil Engineering, Business & Management, Computer Science, Electrical Engineering, Materials and Nuclear Engineering, Mathematics, Mechanical Engineering, Physics, and Zoology
- Nearly 50 faculty members, including a member of the National Academy of Engineering, 12 NSF Presidential Young Investigators, an NSF Young Investigator, 10 IEEE Fellows, and fellows of the ASME, APS, AIChE, and the AAAS.

Industrial Collaboration/Technology Transfer

To enhance interaction among the academic, industrial, and government research communities, a broad program for industrial collaboration and technology transfer has been established. It features —

- Joint research activities
- Industrial visitors program
- Faculty and student visitors to industry
- Joint use of laboratories
- Industrial fellowship program
- Tailored short courses and workshops
- Technical report series
- Student placement service
- Seminar and colloquia series.

Facilities

The University of Maryland has dedicated 30,000 square feet to ISR facilities. The ISR's affiliate, Harvard University, has allocated 4,000 square feet for facilities. The ISR's constituent and affiliated laboratories include—

- Advanced Design and Manufacturing
- Autonomous Mobile Robotics
- Chemical Process Systems
- Communication and Signal Processing
- Computer Aided Control Systems Engineering
- Computer Integrated Manufacturing
- Harvard Robotics
- Human-Computer Interaction
- Intelligent Servosystems
- Neural Systems
- Systems Engineering Integration
- Space Systems
- VLSI Systems
- Digital Signal Processing.

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NSF 96-23g

ENGINEERING RESEARCH CENTER
COMPUTATIONAL FIELD SIMULATION

Center for Computational Field Simulation: Complex Geometry/Complex Physics

Mississippi State University

A National Science Foundation Engineering Research Center since 1990

The new computational paradigm: High-performance computing is adding a third mode of scientific investigation to engineering analysis and design

Large-scale field problems are among the computational grand challenges of the nation's High Performance Computing and Communications Program; the ability to solve them has been cited by the Departments of Defense and Energy as a critical technology of the 1990's. The computational simulation of large-scale field problems on real-world configurations requires advances in computing performance and capacity that can only be met by a concerted hardware and software design effort driven by the demands of engineering applications. Only a close collaboration among computational engineers, computer engineers, computer scientists, mathematicians, and applications engineers can achieve the advances that are necessary. Although individual research projects from many sources contribute to this effort, only a systems approach can bring all the relevant technology together to provide the computational capability needed by industry to make a real impact on engineering design and applications.

The NSF Engineering Research Center for Computational Field Simulation at Mississippi State University is mounting a concerted research program to provide U.S. industry with the capability for computational simulation of large-scale, geometrically complex physical field problems for engineering design and application. The primary effort is directed toward the development of this capability at the high level that will ultimately be needed, while continually making state-of-the-art technology available for current application in industry.

Research

The Center's strategic goal is to research and develop the technology necessary to enable significant reduction of the overall time required to do effective and accurate computational field simulations on complex geometries with complex physics, and to transfer these technologies to U.S. industry and agencies.

Prop-fan powered cruise missile.

The Center's strategic approach is to develop an integrated computational field simulation system environment that provides rapid application set-up, rapid simulation, and rapid solution analysis; and that features convenience of use, accurate graphical results, and portable, scalable, and reusable software modules for industrial applications.

The Center's mission places this ERC directly in concert with the nation's High Performance Computing and Communications Program (HPCC), since the research and educational programs of the Center are focused directly on high performance scientific computing. The Center's research thrusts (Grid Generation, Scientific Visualization, System Software, and Computer Architecture) and its two graduate programs (Computational Engineering and Computer Engineering) together address all of the program components of the HPCC program.

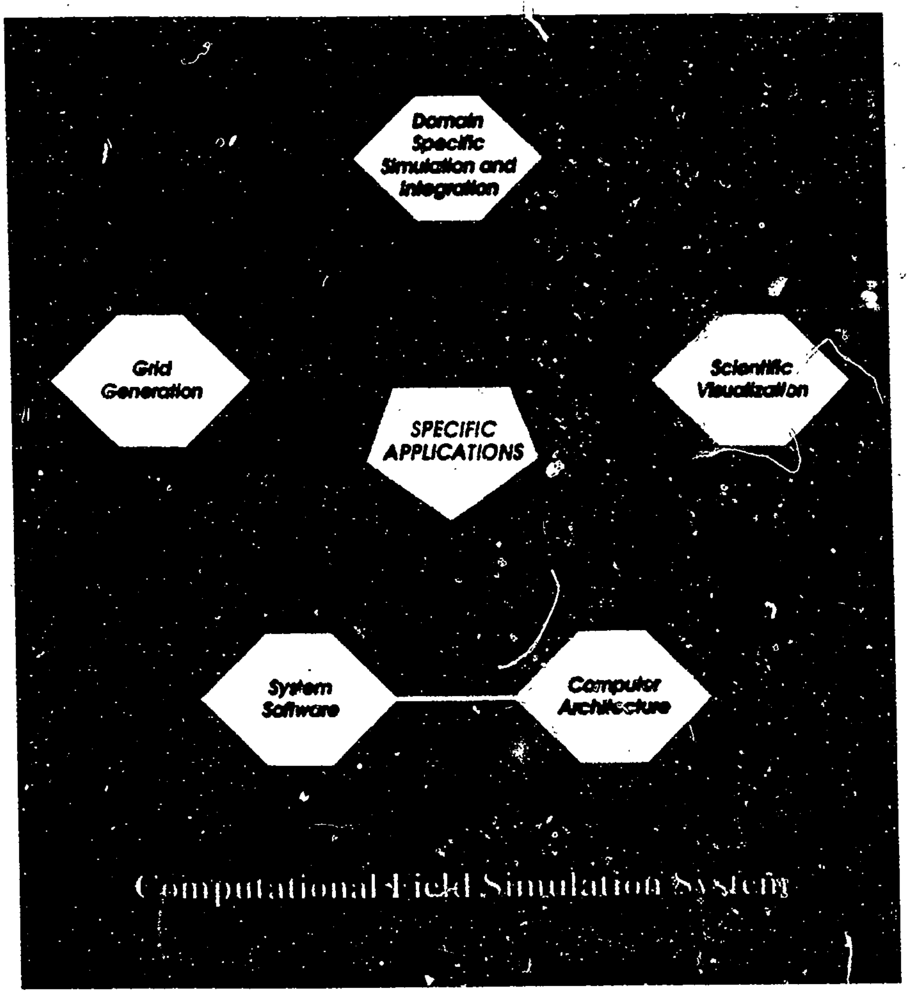
To continually serve industry at the state of the art, specific application projects funded by industry and Federal laboratories are conducted by the two laboratories of the Center: the Computational Fluid Dynamics Lab and the Microsystems Prototyping Lab.

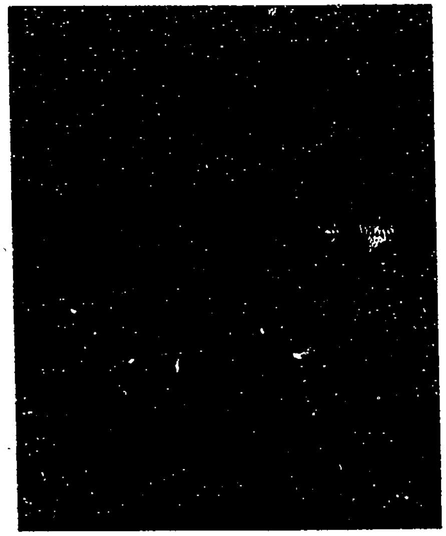
Education

Emergence of high performance computing as the third mode of scientific investigation has created a need for new curricula in computational science and engineering to meet the Nation's need for scientists and engineers who have the broad understanding necessary to develop and apply these new investigative tools to scientific analysis and engineering design. To this end, cross-disciplinary graduate programs in Computer Engineering and in Computational Engineering have been instituted. Particular emphasis is given to the following:

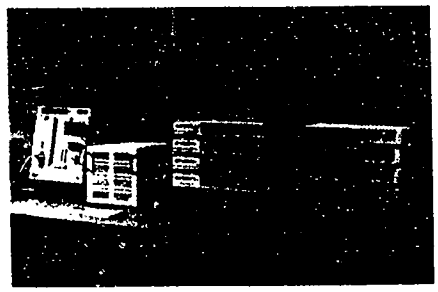
- Cross-disciplinary education of graduate and undergraduate students to produce scientists and engineers with broad viewpoints and backgrounds who can integrate the interaction of computational and computer engineering design
- Continuing professional education to maintain the state of the art in the component areas of computational and computer engineering and to build a bridge between these areas.

The Center also assists in advancing the research potential of nearby institutions by focusing on education of underrepresented groups and women; and Center staff work with area high schools and junior colleges to provide incentives to enhance the career opportunities available in engineering and scientific computing.





F18 fighter.



ERC-developed 32-processor multicomputer, SuperMSPARC, provides minimally intrusive performance monitoring for CFS code optimization.

Industrial Collaboration/Technology Transfer

The Center interacts directly with industry in the short term by bringing-state-of-the-art expertise to bear on current industrial problems in Computational Field Simulation (CFS). In this role the Center develops, maintains, and supports large-scale CFS codes for use by industry. The Center also provides a focal point of effort in computational field simulation to combine support from Federal laboratories, to the ultimate benefit of industry, through the attainment of needed high performance systems. The Center, therefore, numbers several Federal laboratories among its affiliates.

Facilities

The Center building is completely networked with thin net, approximately 12 miles throughout the building, has (FDDI) Dual Ring Backbone and Single Ring Subnet, and is connected to the outside world via SURAnet, NSFnet, and Internet (T1). The facilty incorporates a video classroom, affording the use of video equipment in class and allowing production of video-taped classes for live satellite transmission to remote sites. Computer equipment includes five Sun servers, 139 Sun Sparcstation class workstations, a four-processor and an eight-processor Silicon Graphics Onyx Reality Engine 2 server, a four-processor Silicon Graphics Challenge XL server, a four-processor (TFP) Silicon Graphics Challenge server, a six-processor Silicon Graphics 4D/460 server, a 32 Node Intel IPC 860, 3 IBM RS/6000 workstations, 23 Silicon Graphics Indigo2 workstations, 54 various other Silicon Graphics workstations, a 32-processor SUPER-MSPARC8 (designed and constructed at the ERC), a large format Display Master Color PostScript Printer, 5 color PostScript printers, and an assortment of black-and-white PostScript printers. The Center is a heavy user of supercomputers at installations around the country over T1 networks.

Center Headquarters

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NSF 96-23h

Center for Net Shape Manufacturing (ERC/NSM)

The Ohio State University

Net shape technology seeks the best way to shape a given material into useful parts

A National Science Foundation Engineering Research Center since 1986

The ERC/NSM was established in May 1986 to conduct engineering research and education in manufacturing processes. The Center is an intellectual partnership between NSF, The Ohio State University (OSU), and more than 80 manufacturing companies.

The focus of the ERC/NSM is manufacturing of discrete parts to net or near-net dimensions via die casting, polymer processing, and sheet and billet forming. To support these activities the ERC/NSM also conducts R&D in die/mold design and manufacturing.

Our *mission* is to:

- Conduct scientifically challenging and industrially relevant R&D in Net Shape Manufacturing processes, tooling, and machinery
- Educate and train students in Manufacturing Engineering so that they can obtain highly satisfying jobs in an increasingly competitive global market place
- Assist large, medium, and small size companies in developing and implementing new processes as well as in continuous process and quality improvement.

To achieve this mission, our *strategy* consists of:

- Cross-disciplinary research as required by a project
- Simultaneous consideration of product and process design
- Close industry and university cooperation
- Cooperation and benchmarking with other national and international centers of excellence in manufacturing.

The ERC/NSM—

- conducts R&D in manufacturing
- prepares students for the global marketplace
- assists manufacturing companies

Research

The Center's research is directed at reducing development time for new processes by eliminating trial and error. Through computer-aided techniques: (a) material flow is predicted as a part is shaped in a die so that defects are eliminated and product quality increased; (b) dimensional accuracy is improved; and (c) part complexity is increased to make NSM more cost effective.

Organizationally, the ERC is divided into five thrust areas: billet forming, sheet forming, polymer processing, die casting, and die/mold manufacturing. Faculty and students from five departments of the College of Engineering participate in the ERC's research.

Education

Our innovative education programs support our research activities and include:

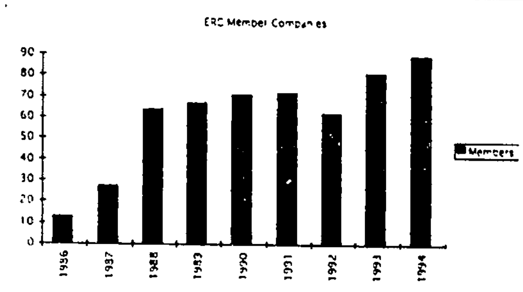
- The Graduate Fellowship Program for U.S. Residents ($17k/year plus tuition and fees)
- The college wide Manufacturing and Systems Engineering Program (MS level)
- The Undergraduate Programs, which have several variations — i.e., summer internship, academic year internship, scholarship/internship, first-year women scholarship/internship, honors program, and the Research Experiences for Undergraduates (REU) program.
- The combined BSc/MSc program
- The Undergraduate Summer Internship Program, started in 1987. The majority of the summer interns are employed at the ERC for up to 20 hours a week during the academic year. We also participate enthusiastically in the NSF-sponsored REU program.

The ERC/NSM has been instrumental in attracting to OSU highly qualified graduate students as well as young faculty. Nearly a third of the Center's graduate students are ERC Fellows.

Industrial Collaboration/Technology Transfer

An Industry Advisory Board, and its Executive Committee, provide advice and review our activities. One third of the Center's annual $3 million budget is obtained from membership fees of 80+ companies and from contract research; the rest is provided by NSF, the Ohio State University, and the Ohio Board of Regents. Nearly 40 of our members are small businesses, with fewer than 500 employees.

All of our graduates have jobs, and a very large percentage, including those with PhD degrees, are employed in industry. Our industrial membership has increased steadily, even during the recession years.



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The ERC/NSM maintains and continuously expands contacts with various North American universities (Wisconsin, Colorado School of Mines, Florida, British Columbia), as well as with professional associations (IAMS, CAMP, FIA, ASM, SME). On an international level, excellent ties have been established with renowned European and Japanese universities and research centers at Stuttgart, Aachen, Hannover, Darmstadt, Denmark, Tokyo, and Kyoto.

Facilities

Our facilities include more than $4 million worth of new manufacturing processing equipment, die/mold manufacturing machinery, and computer hardware/software, assembled into three new laboratories for instruction and research. These laboratories form a complex that has no equal in the U.S. engineering education system.

The Center has extensive facilities for experimental research as well as computer software and hardware for CAD/CAM/CAE used in product and die design and in process modeling. The ERC/NSM supports the establishment of other manufacturing-related centers at OSU. Two examples are: LEGOS (Life Cycle Engineering Group at Ohio State) and the Center for Die Casting, established jointly with the North American Die Casting Association.

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NSF 96-23l

Center for Collaborative Manufacturing

Purdue University

Cross-disciplinary research to facilitate collaboration in manufacturing

A National Science Foundation Engineering Research Center since 1985

The Center for Collaborative Manufacturing, established in 1994, builds upon the previous Engineering Research Center for Intelligent Manufacturing Systems, which originated at Purdue in 1985. Starting from a successful base of accomplishments in cross-disciplinary research, education, industrial involvement, and outreach, the new Center is undertaking a larger mission as befits a mature ERC. The technical scope includes all technical activities in the manufacture of mechanical and electrical discrete products from early design to completion.

The motivating vision for the Center derives from fundamental changes in the business environment that profoundly affect the ways that manufacturing activities will be performed in the future. Globalization, downsizing, outsourcing, partnering, a faster pace of innovation, and new arrangements present challenges to manufacturing companies that formerly tried to control as much as possible of their own work. Even very large companies that are dominant in their markets have been forced to seek collaborative arrangements for research, for design, for production, and for distribution. At the same time, new opportunities stemming from progress in information and communication technologies are being revealed. Manufacturing companies that can engage effectively in collaborative arrangements will have better market opportunities, a wider range of design and processing options, fewer and looser constraints restricting their capability, lower investment costs, better utilization of resources, and faster responsiveness to changes.

The Center will create and disseminate an organized body of knowledge that will enable Collaborative Manufacturing to become an effective mode of operation for the future. For our purposes, the defining attributes of Collaborative Manufacturing include the following:

- integrated product and process development, including customers and suppliers
- flexible manufacturing distributed over networks of cooperating facilities
- teamwork among geographically and organizationally distributed units
- high-technology support for the collaboration, including high-speed information networks and integration methodology
- multi-disciplinary and multiple objectives (speed, cost, quality, environmental consciousness, etc.).

Preparing tapes of alumina ceramics on a laboratory tape casting unit. This is one of the outstanding undergraduate students who participated in our Research Experiences for Undergraduates (REU) Program.

Research

The Center conducts research through collaborative projects that operate at two levels. Each project pursues focused technical objectives that are determined by the project team participants. For example, one project may focus on advancing process capability for precision grinding, another may focus on software to assist rapid product realization, while yet another may focus on innovations in semiconductor fabrication. The projects vary in structure, duration, and size, as well as in the focus problem definition. Each involves multiple participants at multiple sites and covers multiple disciplines. Each focused project, viewed in isolation, can be seen as a joint venture among the participating organizations to achieve advances in the area of its unique focus. Viewed from a broader perspective, the total collection of projects represents a set of experiments in Collaborative Manufacturing. The diversity of projects provides cases in which the factors affecting success will vary.

Projects are formed among interested companies who agree upon a technical agenda with shared benefits. All projects are cross-disciplinary, and all projects involve the active participation of at least one member company. Some projects also involve the participation of national laboratories, industrial consortia, trade associations, or other universities.

Current projects fall into three thrust areas:

- Precision Mechanical Products
- Custom Engineered Components
- Processing of Advanced Materials.

Part inspection is performed on parts manufactured on the Cincinnati Milacron CNC Lathe.

One special cross-cutting project focuses on the challenges of technical collaboration *per se*. Using the focused projects as realistic cases, it is designed to extract the lessons from these experiments, develop tools and methods to facilitate collaboration, and define the metrics for assessing the costs and benefits of collaboration. The project exploits advances in high-bandwidth computing and communication networks, computer methods for collaboration support, and improved understanding of the human aspect of collaboration. As results are generated by the cross-cutting project, they will be incorporated into the project management and communication systems used by the teams involved with the focused projects.

Education

The Center also fosters continuing innovations in education and outreach. The prior Engineering Research Center pioneered innovations in such areas as undergraduate participation in research projects, short- and medium-term graduate internships in industry, and experience in cross-disciplinary team projects. The new Center carries these further. A new kind of financial support for highly qualified beginning graduate students provides supervised educational experiences in industry. A program to involve high school and middle school teachers in Center activities is aimed at increasing the awareness of opportunities in manufacturing among pre-college students. We have increased the university's flexibility to undertake short-term projects of only a few weeks' or months' duration. These might focus on, for example, benchmarking studies, the installation of a new technology, or assessments of alternative approaches to a manufacturing problem. We have developed innovative approaches to the management of such projects to ensure their compatibility with an academic environment.

Over the last decade, our ERC has supported over 1000 students who have received the benefits of a special educational experience involving cross-disciplinary teamwork with manufacturing companies. These graduates have been sought after by recruiters and have proven their abilities on the job. The new Center for Collaborative Manufacturing enlarges the scope and extends the outreach of this research and educational revolution.

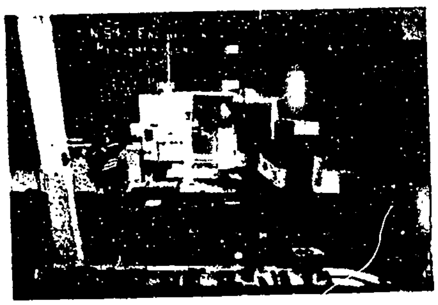
Industrial Collaboration/Technology Transfer

Companies are able to participate in the activities of the Center in two ways. They may join one or more of the focused projects as *project participants* engaged in the planning and execution of that project. They may also join as a *member* of the Center, participating in the cross-cutting project, helping to guide the education and outreach programs, and obtaining the benefits of an overall perspective of the Center. The information and methods to enhance collaborative work are shared among the members for their own evaluation and use, while directly serving the focused projects. Access, early participation, and learning about the benefits and pitfalls of Collaborative Manufacturing enables member companies to conduct their own exercises in this increasingly important and complex area.

Facilities

As one of the largest technical universities in the world, Purdue has many resources. The Schools of Engineering, the Krannert School of Management, the School of Science, and the School of Technology collectively account for over 800 faculty and nearly 17,000 students per year. Almost every kind of technical expertise is represented and the university offers unique capabilities or notable strengths in many areas.

The Center's offices and laboratories occupy 16,000 square feet in two adjacent buildings centrally located among the University's complex of engineering buildings. The laboratories contain a wide variety of high-performance computing workstations and full-scale manufacturing process equipment. Many Center projects make use of additional laboratories maintained by the various Schools of Engineering. The Center has a special room for cross-disciplinary interaction that is also used for meetings with its industrial collaborators.



Working with the manufacturing equipment, robots, and material handling equipment, students gain knowledge and experience of overall manufacturing process control and operations in the CIMLAB.

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NSF 96-23j

Infrastructure

AT/LSS

Advanced Technology for Large Structural Systems (ATLSS)

Lehigh University

Advancing construction technology and productivity: Design, fabrication, erection, inspection, protection

A National Science Foundation Engineering Research Center since 1986

The ATLSS Engineering Research Center aims to advance the fundamental engineering knowledge base for new technologies in structures for the U.S. construction industry. Such advances will help to increase productivity in the industry and improve the infrastructure underlying the U.S. economy.

Research

ATLSS brings together expertise in civil, industrial, and mechanical engineering, computer science, chemistry, materials science and engineering, business, and education.

The scope of ATLSS research includes: (1) new and better design concepts integrated with fabrication and erection; (2) powerful new computer-based tools for design, fabrication, and life-cycle engineering; (3) higher strength, higher value-added materials; (4) automation integrated into fabrication and construction; and (5) new sensing, coating, and protective systems.

There are three main thrust areas of ATLSS research:

- *Advances in design concepts* aims to improve traditional rules, methods, and materials used in designing structures and connecting structural members. This research studies improved structural use of traditional concrete and steel connections and of connections that involve mixed construction materials, and the use and joining of new composite and other higher-value-added materials.

- *Innovation in fabrication and construction* aims to modernize practices that are inefficient and time- or labor-intensive. Research focuses on how automation can be introduced where feasible, how site and shop operations can be improved and how computer software can be used to ease the designer/fabricator interface.

- *In-service performance and assessment* seeks ways to increase structural reliability and longevity. This research is seeking to learn how monitoring systems, with in-situ sensors, can be introduced easily in a design and how monitoring of corrosion and fatigue can be an integral part of assessing a structure's operation and performance.

Each thrust draws on relevant disciplines, such as structural design, large-scale experimentation, materials engineering, manufacturing processes, computer technology, in-service performance, and business and economics, and is integrated with the other thrusts through these disciplines. Through these thrusts ATLSS seeks to pave the way for successfully integrating key functions of the construction industry.

Key Strengths

Vital to each thrust area is development and use of knowledge-based systems, and the experimental validation of new concepts at ATLSS' huge Multidirectional Experimental Laboratory.

Education

The ATLSS Center provides an outstanding environment for its students to study and perform innovative cross-disciplinary research on problems of importance to the construction industry.

Engineering education in large structural systems is emphasized at the undergraduate and graduate levels. Multidisciplinary (team-taught) graduate courses are part of the curricula for all graduate students associated with ATLSS.

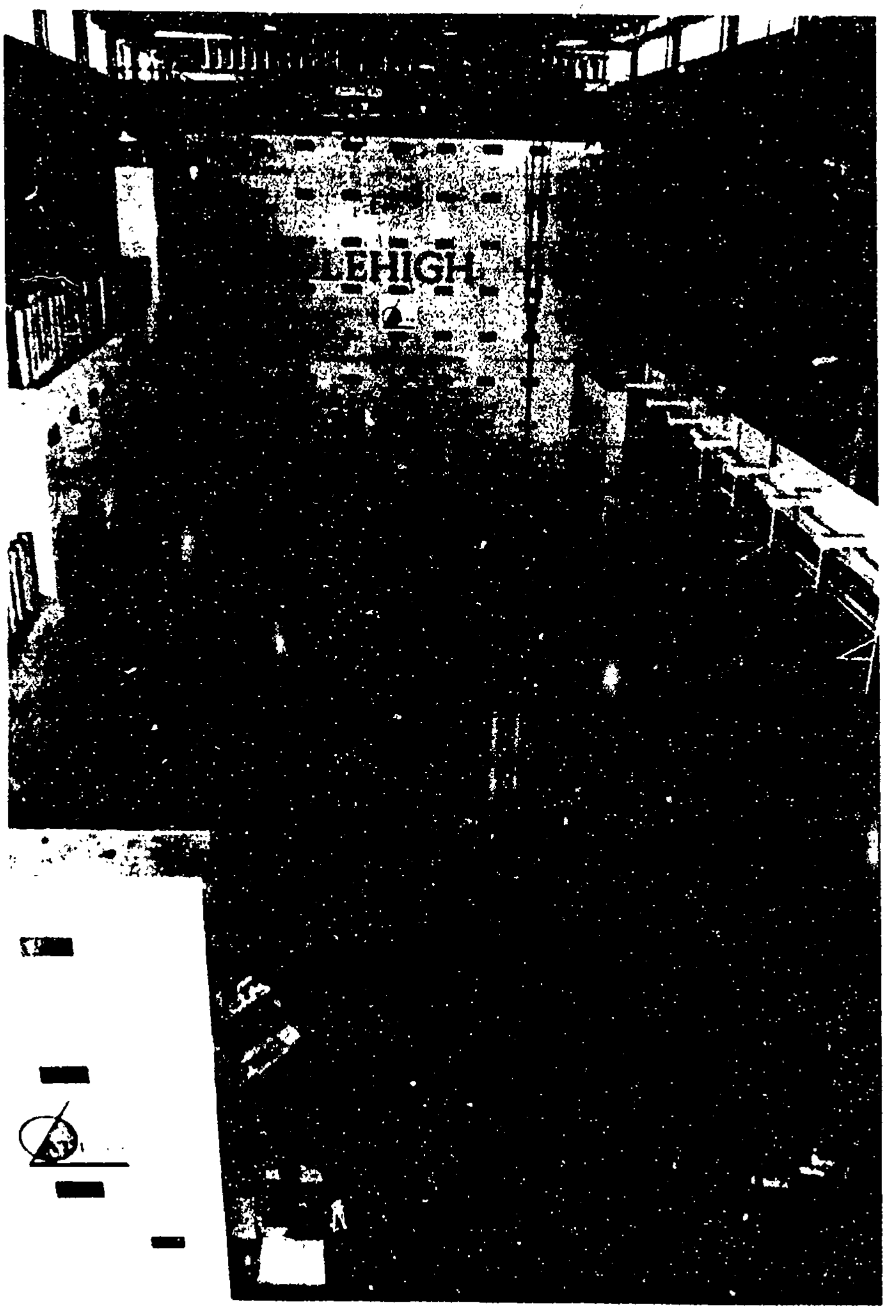
For summer and academic-year research programs, ATLSS has drawn a significant number of undergraduate men and women, including many underrepresented minorities, from regional and national schools, some of which do not offer engineering. Under NSF's program of "Outreach to Women, Minorities, and Persons with Disabilities," ATLSS faculty have engaged in collaborative research with faculty from two predominantly minority institutions, providing undergraduate and graduate minority students at both institutions with unique research opportunities. Faculty members from several major colleges and universities have participated in research and spent sabbatical leaves at ATLSS. ATLSS has also attracted international scholars from Switzerland, Czechoslovakia, Ecuador, Egypt, Israel, Korea, Japan, Taiwan, and China for extended stays at the Center.

Industrial Collaboration/Technology Transfer

Industry has four major roles within ATLSS:

- Assisting in overall financial support
- Helping to develop and set priorities for the research agenda through an Industry Advisory Council
- Helping in the technical evaluation of research projects
- Helping move technological developments to practice.

The ATLSS Industry Advisory Council meets twice a year to discuss new directions in the construction industry and their effect on research plans, to review progress of current research projects, and to consider, with the Center Directorate, priorities for new and continuing projects and strategies.



View of the ATLSS Multidirectional Experimental Laboratory

ATLSS personnel actively interact with industry personnel. Industry Partners share their research and practice-oriented experiences with the students and faculty. This exchange aids in strengthening the understanding between industrial and university researchers. Partners also gain significant advantage for assessing and recruiting students participating in the ATLSS program.

Industry Partners receive advance knowledge of ATLSS intellectual property, research results, detailed research reports, and prepublication copies of research papers. Many research results are presented in workshops, seminars, and short courses that Partners may attend without charge.

Facilities

ATLSS headquarters is in a major building on Lehigh's Mountaintop Campus. The building houses ATLSS' world-class Multidirectional Experimental Laboratory — the largest of its kind in the United States — as well as ATLSS' extensive materials evaluation and computing laboratories. Other major ATLSS research facilities are in the Fritz Laboratory and other buildings on Lehigh's adjacent main campus.

The Multidirectional Experimental Laboratory supports experimental research on large-scale structures with a footprint as large as 42' x 100' and a height of up to 50' that require multidirectional loadings to establish their structural behavior. This facility enables researchers to experimentally evaluate computer models of structures on a scale not otherwise possible, and under two- and three-dimensional static, dynamic, and fatigue loading regimes that relate directly to service. The facility has high-capacity actuators and is computer integrated and driven, allowing it to serve as a highly sophisticated experimental environment for study not only of structures, but also of sensing systems, design concepts, connection behavior, and expert systems. These capabilities of the facility make it an ideal site for use in cooperative research by other national centers and by industry consortia.

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NSF 96-23k

Particle Science & Technology

Engineering Research Center for Particle Science and Technology

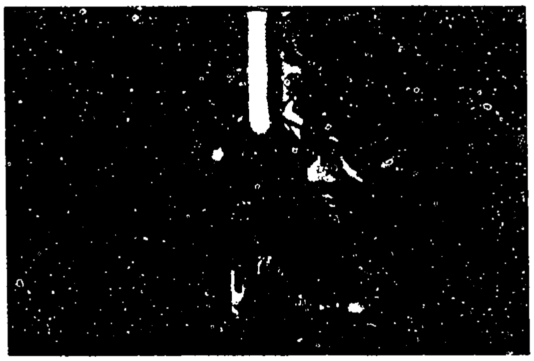
University of Florida

Applying particulate systems expertise to develop cost-effective and environmentally sound industrial products and processes

A National Science Foundation Engineering Research Center since 1994

Particle technology deals with the production, characterization, modification, handling, and utilization of organic and inorganic powders, in both dry and wet conditions. Particulate systems as a core technology impact a number of industries, including advanced materials, energy, chemicals, environmental, minerals, agriculture, pharmaceuticals, and food processing. Industrial processes involving particles tend to be complex; and due to an inadequate understanding of multiphase processing schemes, these processes rarely reach more than 60% of their design capacity.

The goals of this Center are to understand, monitor, and modify particle behavior to allow efficient utilization of particulate systems in existing and emerging industries. Achievement of these goals will enhance the competitiveness of U.S. industry by providing the means for efficient and cost-effective processing and handling of particulate systems, and also by educating students and professionals in the engineering practice of particle science and technology (PS&T).



Undergraduate student performing a calibration of a fiber optic probe that measures particle velocity.

Research

The Engineering Research Center for Particle Science and Technology is advancing the knowledge base in key areas of research such as on-line analysis, reliable processing and monitoring, and predictive models, which are all critical to the next generation of particulate (multiphase) technology.

To develop cost-competitive processing methodologies, the Center focuses its research efforts on six thrusts: (1) concentrated particulate dispersion, consolidation, and redispersion, (2) transport and handling, (3) analytical systems, (4) simulation, modeling, and visualization, (5) engineered particulates, and (6) advanced separation processes. Participation of researchers from other institutions is actively sought to further strengthen the research capabilities within the Center.

Education

The educational aim of the Center is to promote cross-disciplinary learning, creation, and sharing of information in a team environment. Graduate and undergraduate student involvement in on-site research activities and co-op programs at manufacturing facilities of the member companies is encouraged because it provides the students with a systems view of engineering. The Center is arranging internships for students and faculty at various National Laboratories. Other educational programs at the Center include Research Experiences for Undergraduates (REU), which provides opportunities for qualified students from other institutions, and Minority Research Fellowships, which offers research experiences to selected students from groups traditionally underrepresented in engineering.

Center faculty are developing a series of courses to offer Particle Science and Technology as a minor in departments such as Materials Science and Engineering and Chemical Engineering. Special courses and seminars will be offered to the faculty and students so that they may acquire a better appreciation of current industrial practice and related economics.

To reach out to community college and high school students, the Center will organize and sponsor summer programs for students and science teachers in order to provide science and engineering educational opportunities beyond those available at their respective schools or colleges.

The Center is committed to the development of effective teaching materials in particle science and technology. It provides incentives to faculty and industry experts to develop computer-assisted learning materials, multimedia presentations, and textbooks in PS&T.

Industrial Collaboration/Technology Transfer

The Center recognizes that its success depends on active participation and support by industry for its research programs, and on rapid transfer of technology to the industrial partners. The Center will conduct industrially relevant research and educate the next generation of professionals who are crucial to the success of industry. The member companies, for their part, will work closely with the Center to help it achieve its goals and objectives.

A two-tiered membership fee structure provides for varying levels of industry/university exchange and active participation by industry in managing, planning, and monitoring the research and educational programs of the Center. Companies participating in the Industrial Partners Program sustain a high level of interaction with the Center. Representatives of small, medium, and large Industrial Partner companies may, during visits to the Center, work on mutually agreed-upon research projects, mentor students research, learn specialized techniques, and/or present special seminars. It is expected that Industrial Partner representatives will develop strong interactions with the Center faculty.

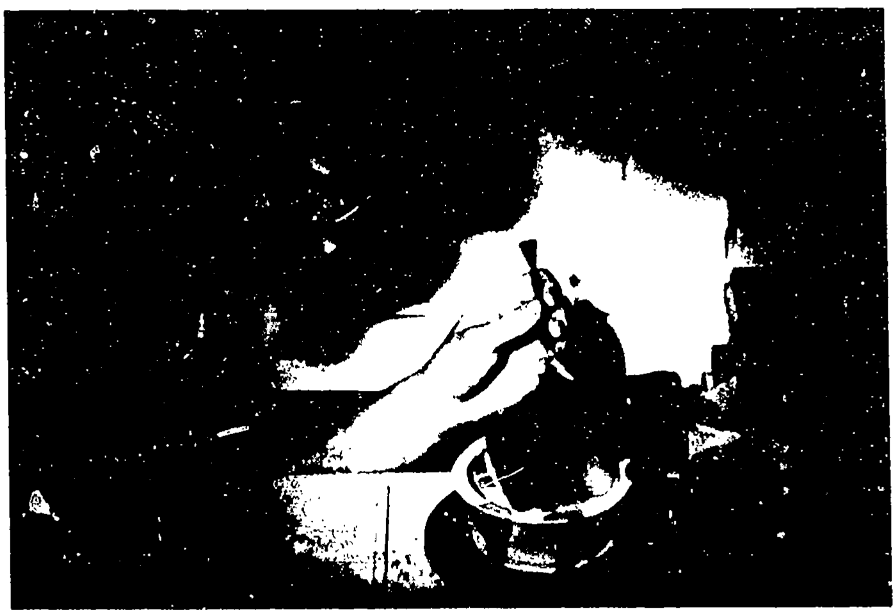
An Industrial Advisory Board consisting of all Industrial Partners establishes priorities in the educational and research programs and evaluates progress toward the Center's goals and objectives. Technical Advisory Committees comprised of Industrial Partners set research priorities within the individual research thrusts and ensure synergy among the various projects in each thrust area.

Atomic force microscopy.

Facilities

An important feature of the Center is the establishment of a Characterization, Research Instrumentation and Testbed (CRIT) Facility, which provides characterization, analytical, and pilot-scale testing services to Center faculty and member companies. This flexible testbed facility in the Center will further promote industry/university exchange.

A Particle Technology Information Network (ParTIN) is being created to promote speedy exchange of information and to provide industrial partners with access to the knowledge base. This network also will help to direct industrial members to the appropriate faculty member(s) for assistance with specific problems.



A graduate student preparing a powder sample for analysis.

Center Headquarters

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NSF 96-231

CIE

Center for Interfacial Engineering (CIE)

University of Minnesota

Optimizing interfacial properties that underlie key industrial processes

A National Science Foundation Engineering Research Center since 1988

The long-term health of many U.S. industries, and their ability to compete in a global marketplace, depends on optimizing interfacial processing technologies to yield reproducible and reliable products.

Engineering new composite structures which depend on interfacial properties is a prerequisite for designing the high-performance materials needed in many high-tech applications. Interfaces are critical at every stage of microelectronic fabrication. They play a vital role in coating photographic, optical, and magnetic films and in resolving the complex colloidal problems associated with development of alternative energy sources and control of environmental pollutants.

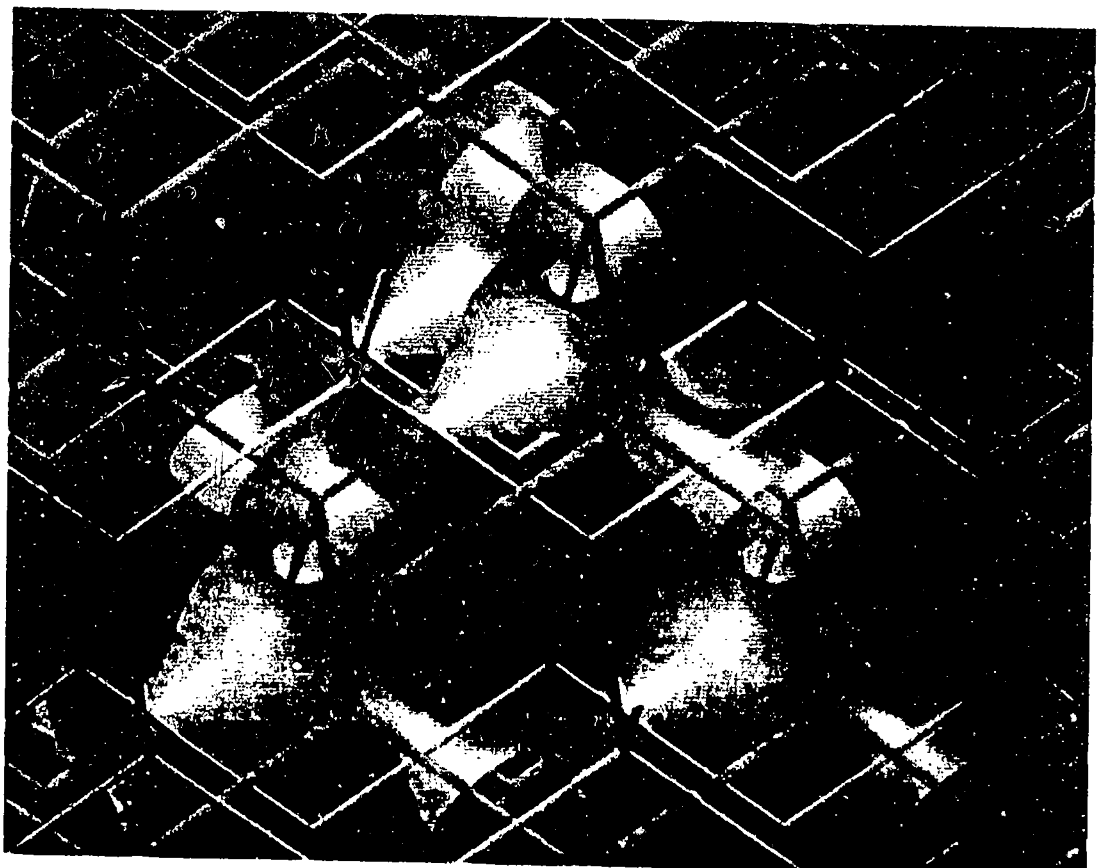
The Center is committed to the interdisciplinary research needed to understand and control molecular structure and behavior at such interfaces. Based on a collaboration among academia, industry, and government, the Center's program emphasizes transfer of basic research into industrial applications as well as education of researchers and scientists skilled in the disciplines of interfacial engineering.

Research

Interfacial processing technologies share a common knowledge base: the molecular interactions that occur at the boundary between two materials. CIE's interdisciplinary research teams focus on three areas within this new field: nucleation and growth, adhesion and wetting, and fracture mechanics.

Research projects are conducted within four programs:

- *Coating process fundamentals.* Spin coating, spray coating, and flow coating techniques used to fabricate multilayer films, tapes, and disks.



A supercomputer-generated surface is being studied as a model of a structure believed to occur in certain types of liquid crystals, microemulsions, phase-segregated polymer blends, porous catalysts, and other materials of scientific interest.

- *Polymer microstructures.* Interfacial formation in polymer materials, such as polymer surfaces with controlled adhesion in composites and block copolymers with controlled microstructures.
- *Surfactancy and self-assembly processes.* Spontaneous formation of thin sheets or interwoven bicontinuous systems used in the next-generation electronic devices, sensors, and high-performance membranes.
- *Bio-interfacial engineering.* Application of expertise in polymeric, amphiphilic, metallic, and ceramic interfaces to problems involving medical implantations, drug delivery systems, and development of new biocompatible materials.

Philips CM30 scanning and transmission electron microscope in use in a CIE laboratory.

Education

CIE's education program involves close collaboration between industry and the university. Industrial scientists-in-residence pursue joint research projects with faculty and students, teach classes, and serve as curricular consultants and as coadvisors for thesis programs. Exchange programs bring faculty from other colleges to the university and send graduate students to collaborate on industrial research. Undergraduates working as members of research teams are supported by Research Experiences for Undergraduates (REU) fellowships and by industrial sponsors through internships and fellowships.

Because interfacial engineering constitutes a new field of study, CIE is designing a curriculum and producing a series of textbooks that will define its scope. Interdisciplinary and media-assisted materials support the active learning encouraged in the Center's program. Representatives from industry and visiting faculty as well as students participate in a series of cross-disciplinary workshops, seminars, and short courses.

Industrial Collaboration/Technology Transfer

More than 50 industrial companies are affiliate or sponsoring members of CIE and serve on the Technical Advisory Committees which review and advise the four research programs. Sponsoring members are also represented on the Planning and Policy Board.

Through the Residency Program directed by the Center's Office of Technology Transfer, sponsors may send Industrial Fellows to CIE for 3-12 months to perform collaborative research with faculty and students. Fellows may hold appointments as adjunct faculty in the appropriate departments.

Short courses and workshops planned with industrial presenters supplement regular personal contacts between faculty, Center staff, and member companies. A triannual newsletter and bulletins (both paper and electronic) which offer early information on transferable technology, as well as access to preprints and other research publications, help maintain a continuous exchange of information.

Facilities

Since its inception, CIE has invested $5 million to equip a state-of-the-art research facility. A $1.5 million underground facility that provides a vibration-free environment for sensitive equipment has recently been added to the Center's laboratory space at the University of Minnesota.

Among the instruments currently in use are scanning tunneling, atomic force, and transmission electron microscopes, a Langmuir-Blodgett film balance, chemical vapor deposition systems with analytical capabilities, an x-ray diffraction unit equipped with a rotating anode generator, a spectroscopic ellipsometer, stress and fluid rheometers, video and computer-enhanced microscopes, and ion beam analysis capabilities.

The University of Minnesota is the only academic partner in the Cold Neutron Research Facility in Washington, D.C. CIE's participation in the consortium ensures researchers of unique access to neutron scattering and reflection equipment.

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NSF 96-23m

Center for Advanced Electronic Materials Processing (AEMP)

North Carolina State University and other North Carolina Institutions

A National Science Foundation Engineering Research Center since 1988

Developing techniques to boost America's ability to compete in semi-conductor manufacturing

AEMP seeks to develop technologies for high-quality, reliable wafer processing (cleaning, deposition, etching); to develop techniques for monitoring each process and characterizing the materials; and to use such information to automate and control the individual processes and to integrate the technologies into single-wafer processing module clusters.

Research

AEMP research focuses on the development of processing technology at atomic and molecular levels to produce the next generation of electronic devices. These devices will have submicron feature sizes, requiring precise control of the deposition, doping, and patterning processes. The AEMP program emphasizes low-thermal-budget processing using plasma, rapid thermal, and optical processes, and it will integrate sensors with automation and control equipment to obtain precise process control.

Because future devices will be extremely small (submicron), control of particulate contaminants will be mandatory for good yields in manufacturing. Therefore, the AEMP program involves the design, fabrication, and assembly of module clusters of high-vacuum, interconnected processing chambers for low-thermal-budget, in-situ, single-wafer processing.

Success in this research can give the U.S. semiconductor industry an advantage that is crucial to the Nation's ability to compete in such major industrial sectors as computers, telecommunications, robotics, aerospace, and defense.

AEMP Research Thrust Areas

- Dielectrics and Polysilicon
- Selective Epitaxy and Metals

AEMP Research Support Areas

- Wafer cleaning for in-situ processing
- In-situ diagnostics
- Materials/device characterization

AEMP Process Integration and Device Demonstration

- Development of process module clusters and system integration
- Fabrication of demonstration devices

Interdisciplinary Research

AEMP research is a collaborative effort among chemists, physicists, materials scientists, and electrical, mechanical, industrial, and computer engineers. It is supported by graduate and undergraduate students in various disciplines and by advisers from industry.

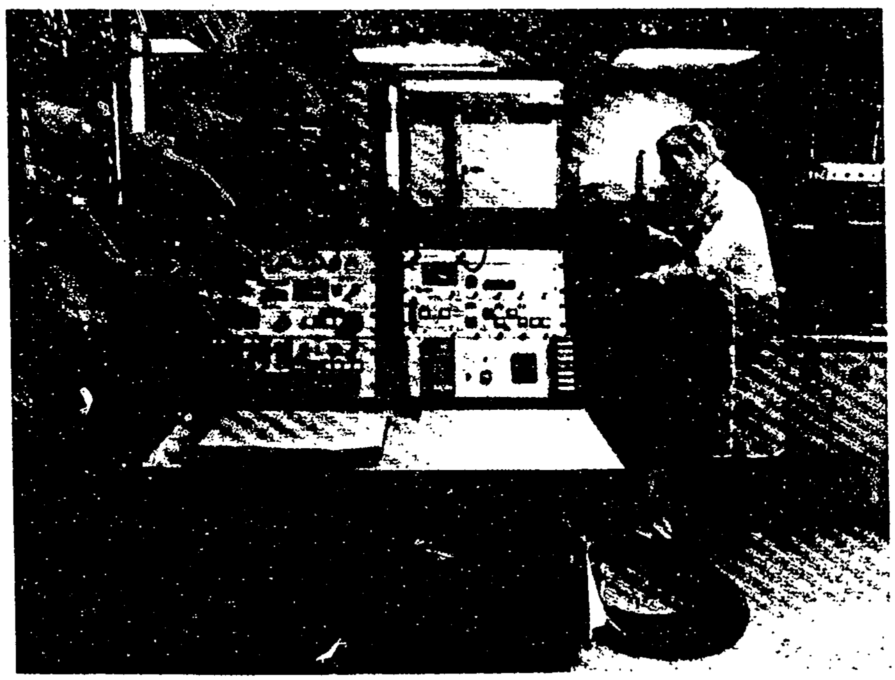
Support from Affiliated Institutions

The AEMP research program is a joint effort with researchers from the University of North Carolina, Chapel Hill and Charlotte campuses; Duke University; the North Carolina Agricultural and Technical State University; and the Microelectronics Center of North Carolina (MCNC). Many of the participating faculty and researchers have come from industry, where their cumulative experience represents over 300 years of electronic materials and devices research.

A major research effort of AEMP involves Rapid Thermal Processing (RTP) for the deposition of insulating and semiconductor thin films.

Education

All facets of AEMP's educational program aim to create a strong academic program in electronic materials processing for undergraduate and graduate students. Emphasis has been on developing requisite courses, including ones to provide students with relevant laboratory experience. Involvement in AEMP gives students direct contact with industry and a rich interdisciplinary research experience, including the use of sophisticated processing equipment and modern microelectronics facilities. The Center's Research Experiences for Undergraduates (REU) program provides summer research internship opportunities for students from a wide range of other institutions. The REU program is combined with a special outreach program with North Carolina A&T State University and has been successful in attracting minority students from across the United States into graduate studies in electronic materials processing at NC A&T State University and NCSU.



Ion implantation is a precise, highly controllable technique for the introduction of dopant atoms into semiconductors during the microelectronic chip fabrication process.

Industrial Collaboration/Technology Transfer
Industry-based support for AEMP has three components:

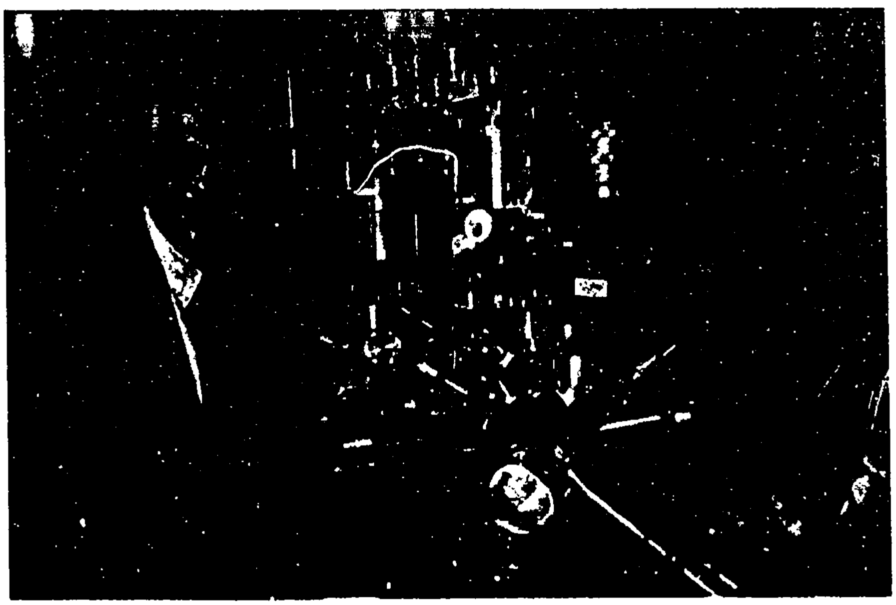
The *Semiconductor Research Corporation (SRC)* supports several electronic materials processing research programs on the various campuses.

A *SEMATECH Center of Excellence* on Advanced Single Wafer Processing has been established at NCSU and is an important component in the overall AEMP program. This support provides a strong format for interacting with industry at several technical levels and for involving industry in specific aspects of the ERC research program.

Each member company of the AEMP *Industrial Affiliates Program* has a representative on the Industrial Advisory Board (IAB). The IAB works closely with the Director and faculty in defining and setting goals for the AEMP research and educational programs. Each member company also assigns one or more technical mentors to provide technical interaction and industrial perspective to the research projects.

The state-supported MCNC also provides a base for industrial interactions, fabrication, characterization, and support services, as well as an industrially oriented setting for the manufacture of semiconductors.

Facilities
The administrative offices and system integration laboratory of AEMP are housed in a research building on the NCSU Centennial Campus. Research projects are presently distributed across the various participating AEMP institutions. A $35 million Engineering Graduate Research Center is under construction for the graduate research programs of the NCSU College of Engineering. About one-third of the total 130,000 square feet will be allotted to the AEMP research program on electronic materials.



Remote Plasma-Enhanced Chemical Vapor Deposition is used for the deposition of thin insulating and semiconductor films.

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NSF 96-23n

Center for Plasma-Aided Manufacturing

University of Wisconsin-Madison and University of Minnesota

The use of electrically charged particles in the manufacturing process has direct applications in many high-technology and traditional industries

A National Science Foundation Engineering Research Center since 1988

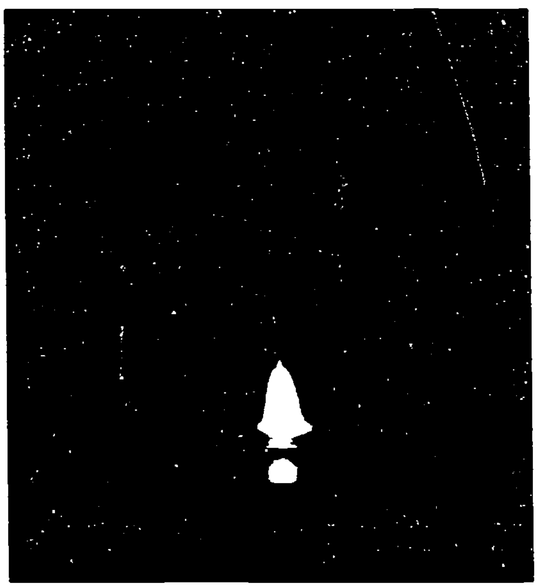
The versatility of plasmas for manufacturing has been known for some time. Yet the ability to exploit them in the manufacturing environment has remained limited because of the lack of process control for specific applications.

The high-technology products market impacted by plasma-aided manufacturing is estimated to exceed $150 billion per year. For semiconductor devices alone, one-third of all processing steps are done with plasmas. Innovation in plasma technology is also expected to substantially change the markets in hazardous waste control, metal refining, medical industries, instrumentation manufacturing, ceramics companies, chemical companies, packaging companies, and the automobile, tool manufacturing, and electronics and microelectronics industries. Rapid advancement in this emerging technology will help the United States to recapture its industrial market share in microelectronics, high-temperature ceramics, machine tools, and other industries.

Research

The technical goals of this Center are to —

- Explore new plasma processes which produce advanced materials and products of importance to manufacturing
- Generate fundamental control strategies which can be utilized for manufacturing.



Free-burning arc reactor.

Center research addresses two types of plasma processing that are relevant to manufacturing industries:

- Nonequilibrium or glow discharge plasma processing is used in sputtering, etching, polymerization, and surface modification.
- Thermal plasma processing is used for plasma spraying, wire-arc spraying, and thermal plasma-assisted chemical vapor deposition (CVD).

Thrust Areas

Center research projects are organized under four thrust areas and are phenomenologically interrelated:

- Plasma etching for microelectronics
- Plasma deposition and polymerization
- Thermal plasma coating technology
- Plasma modification of materials.

Research involving thermal plasma is carried out jointly with the University of Minnesota.

Cross-disciplinary Resources

Research at the Center brings together cross-disciplinary teams of engineers, scientists, and other experts in plasmas, chemistry, materials, statistics, microelectronics, manufacturing, physics, and a variety of engineering disciplines. It also involves other centers at the University of Wisconsin-Madison such as the Center for Quality and Productivity Improvement, the Manufacturing Systems Engineering Program, the Center for Applied Microelectronics, and the Sematech Center of Excellence in X-ray Lithography.

Education

In each research thrust area, undergraduate and graduate students are involved in the Center's interdisciplinary approach to research. Students are exposed to current research activities in industry through summer internships and a weekly plasma-aided manufacturing seminar that features speakers from industry, universities, and national laboratories. A videotaped, graduate-level course in plasma processing and technology is being made available to the Center's industrial partners for educational purposes.

The Center presents seminars, short courses, and videotapes for University of Wisconsin and University of Minnesota students and for all persons interested in the rapidly advancing plasma technology. Center faculty members participate in the University's Research Apprentice Program, through which minority and other high school students participate in the Center for eight weeks during the summer to learn about and take part in research on plasma-aided manufacturing.

The diagram summarizes the Center's approach to its task of producing new and improved manufacturing processes.

Through a grant from the Advanced Research Projects Agency, the Center's educational activities extend beyond the boundary of plasma-aided manufacturing to impact manufacturing engineering education curricula.

The education programs include —

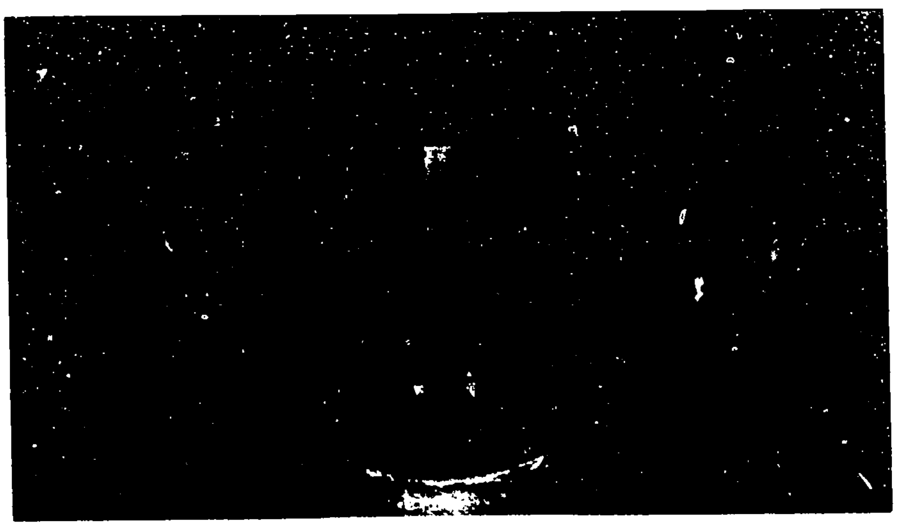
- New graduate and undergraduate courses in plasma-aided manufacturing
- An ERC/Society of Women Engineers (SWE) undergraduate internship program
- An ERC/Wisconsin Black Engineering Students' Society (WBESS) undergraduate internship program
- A summer program for pre-college students and their middle or high school instructors to spend two to four weeks conducting hands-on research projects
- A program with the Madison Area Technical College to involve their technical faculty and students in Center activities
- A program for faculty and students from minority universities to spend the summer conducting research at the Center.

Industrial Collaboration/Technology Transfer

The Wisconsin Plasma Processing and Technology Research Consortium (WISPP), with over 30 participating companies, is the vehicle through which industry interacts with the Center. Participating companies accept "co-op" and summer intern students, provide research opportunities for staff and graduate students at their sites, and undertake joint Center/industry projects. Industrial researchers also spend sabbaticals in campus laboratories and classrooms.

Facilities

Central facilities include offices and a large laboratory that contains a number of different plasma-etching and deposition reactors. Utility services include a high-capacity hazardous gas and vacuum pump exhaust system, gas cabinets, fume hoods, a central recirculating process cooling loop, and a dry nitrogen distribution system. The Diagnostics, Statistics, Real-time Control, and Center Technical Support Groups as well as the ERC's computing center for Theory and Modeling occupy spaces that adjoin the laboratory. Research on plasma modification of materials takes place in a laboratory that is specifically designed for the special requirements of the processing system. Thermal plasma spray and coating experiments are performed in well-equipped laboratories at the University of Minnesota.



Multi-dipole RF plasma etcher.

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NSF 96-23o

Data Storage Systems Center (DSSC)

Data Storage Systems Center

Carnegie Mellon University

A National Science Foundation Engineering Research Center since 1990

Advancing the state-of-the-art in magnetic and magneto-optic recording systems

Goals of the Center are to —

- Pursue innovative cross-disciplinary research that will advance the state-of-the-art in its field
- Educate systems-oriented, well-rounded engineers ready and able to help the U.S. data storage industry gain a competitive edge in U.S. and world markets
- Encourage other universities to intensify education and research and more students to pursue careers in the data storage field
- Effectively transfer technology developed at the Center to industry
- Help solve specific technical problems posed by members of the data storage industry
- Draw upon industrial expertise whenever possible in planning and carrying out research
- Increase public awareness of how crucial this industry is to the well-being of all Americans.

The Center pursues these goals through —

- Interactive research on data storage systems
- Educational programs within the university
- Special outreach programs to other institutions
- Collaboration with industrial firms.

A recently developed technique using a high-speed magneto-optical camera system allows: (1) measurement of the dynamic evolution of the spatial distribution of temperature resulting from the application of semiconductor laser pulses on magneto-optic recording media and (2) evaluation of the dynamic processes of domain writing and erasure in magneto-optic recording media.

Research

Through aggressive systems research, the Center aims to demonstrate the feasibility of 10 GBit/in^2 recording density for both magnetic and optical recording systems to motivate the research and provide a basis for selection of projects.

The Center's four main research thrust areas focus on—

Magnetic recording technology to discover materials, processes, and designs that will make possible combinations of record and read heads, storage media, and their interface that will reliably support high storage densities and data rates

Optical recording technology to advance technologies that will enable optical storage to take a substantial place in the market

Electronic subsystems to advance the two major electronic subsystems of magnetic and optical disk and tape drives — the signal modulation and detection system and the track following system

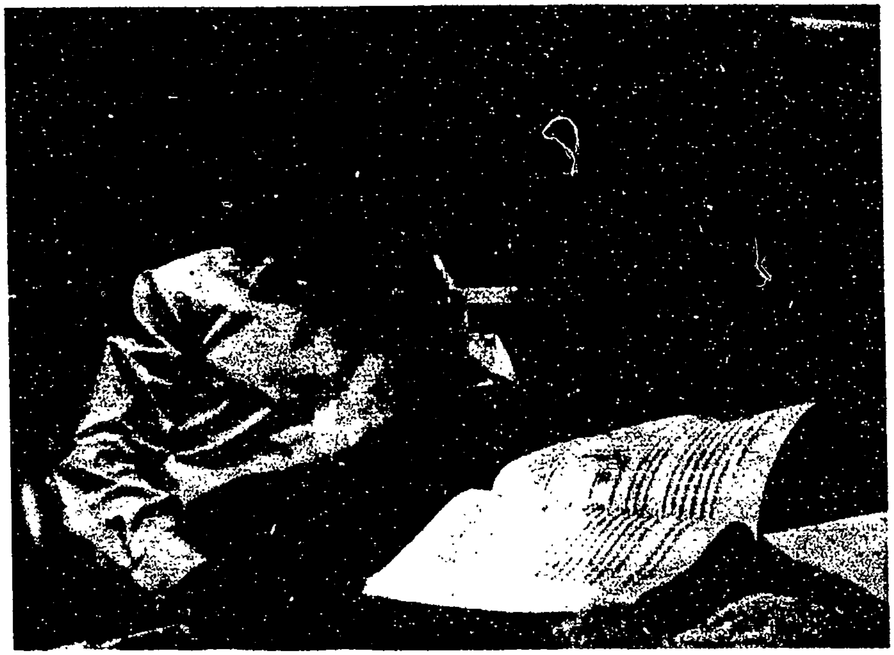
Storage and computer systems integration to explore efficient integration of storage systems into high-performance computing environments.

Evaluation of magnetic media using a Cambrian Super Spin Stand. The Spin Stand is a highly automated research and engineering tool aimed at the development of read/write heads, media, and interface electronics. This is the primary testbed for the magnetic recording technology and electronic subsystems thrusts.

Education

Faculty members from six Carnegie Mellon academic departments and visiting faculty and industry leaders —

- Involve students in hands-on interdisciplinary research. In 1995-96, for example, 102 graduate and 64 undergraduate students took part in Center research programs
- Prepare significant numbers of broad-based engineers able to advance the competitiveness of the U.S. data storage industry
- Reach out to a wide range of industrial, commercial, and educational groups to raise their awareness of the state-of-the-art in data storage technology
- Offer a wide range of courses, seminars, and workshops directly related to data storage systems



A faculty member analyzes the file systems as part of the storage and computer system integration thrust. Computer work stations are also used for micromagnetic media modeling, finite element modeling of recording heads, model-based signal detection schemes, and signal processing design.

technology, as well as courses in which data storage is but one of many possible applications

- Establish research and education outreach programs with other universities, including a special program with the University of Alabama at Tuscaloosa
- Provide support for undergraduates from other institutions to carry out research at the Center
- Contribute to general interest publications and lectures
- Sponsor a seminar series open to the public.

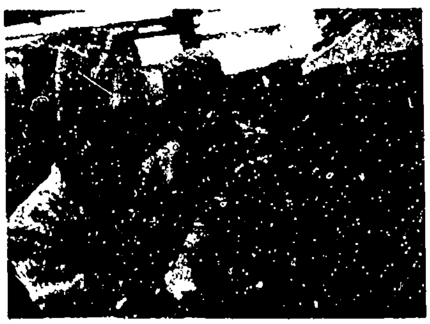
Industrial Collaboration/Technology Transfer

Effective industrial interaction is the key to the success of the Center's research and education programs. The Center —

- Establishes cooperative interactive research programs with industrial sponsors
- Involves industry extensively in the planning process through the Industrial Advisory Committee
- Provides students and faculty the opportunity to better understand industrial needs through interaction with industry.

In addition to working with individual industrial sponsors, the Center is also a member of the National Storage Industry Consortium (NSIC), a group of U.S. industrial companies, universities, and government agencies involved in the field of data and image storage. NSIC's mission is to develop cooperative university/industrial research thrusts in data storage technology. The Center is currently a key participant in major NSIC research efforts on ultrahigh density recording systems, optical recording systems, and holographic data storage systems.

The Center has over 35 industrial participants. Of these, the great majority are sponsors that provide cash or in-kind support to the DSSC; most have joint research projects with the Center or are applying or extending technology developed at the Center. A number of industrial visitors have been in residence at the Center.



Thin-film materials for magnetic and optical recording media and heads are atomically deposited using a high-vacuum sputtering system.

Facilities

The Center plans to invest about $1,000,000 per year in capital equipment. About a third of the support for these purchases will come from the National Science Foundation and the rest from industry and the University.

The Center has a 4,000 sq. ft. class-100 clean room and extensive laboratory and office space. Space for expansion is being provided through a new building that is planned for the Center. Construction for the $17.6 million research building will be completed by Fall 1996.

DSSC Headquarters

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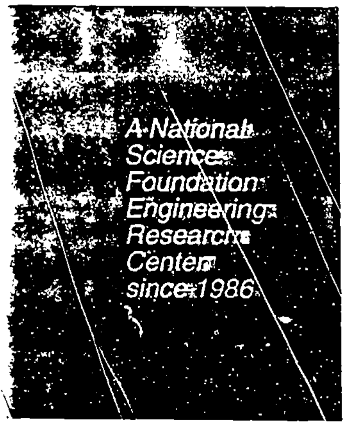
NSF 96-23p

Optoelectronic Computing Systems Center (OCS)

University of Colorado at Boulder and Colorado State University, Ft. Collins

Optoelectronics in computing is changing the way information is stored, processed, displayed, and acquired



The NSF/ERC for Optoelectronic Computing Systems (OCS) provides a cross-disciplinary research program for educating students in optoelectronic materials, devices, and architectures, thus creating a new work force for the information age of the 21st century. OCS exploits the advantages of optoelectronics in computer interconnects, processing, and storage and display computer peripherals.

To pursue this program, the Center brings together teams of researchers skilled in computer architectures, optics and electro-optics, image and signal processing, spatial light modulators, packaging, photorefractive materials, liquid crystals, polymer waveguides, fiber lasers, and vertical cavity surface-emitting lasers.

The OCS application focus drives the materials, device, and systems research. Working with our industrial colleagues, advances in optoelectronic systems are rapidly transitioned to and from industry as new products, processes, and models.

Research

To carry out its mission, the Center has organized its research into two application-driven, vertically integrated research thrusts: 1) *Optical Interconnects in Digital Systems* and 2) *Optical Signal and Image Processing*. The first thrust is focused on demonstrating power- and density-efficient reconfigurable computer interconnects, using three-dimensional computer architectures. The second thrust concentrates on spatio-temporal processing of high space-bandwidth product signals using optical morphology and neural networks.

Each thrust is organized into the following individual projects:

Optical Interconnects in Digital Systems:

- Vertical-Cavity Surface-Emitting Laser (VCSEL) Arrays
- Silicon Photodetector Arrays
- Holographic Interconnect Element Arrays
- 3-D Computer Architectures
- Packaging of VCSEL Arrays

Liquid crystal on silicon micro-display with the potential for presenting full-color HDTV images for applications to head-mounted displays and optical pattern recognition.

Optical Signal and Image Processing:

- Optical Image Processing of Medical Data
- Liquid Crystal on Silicon Microdisplays
- Optically Addressed Displays
- Photorefractive Liquid Crystal Chemistry and Physics
- Sound Processing with Photorefractives
- Microdisplay Packaging
- Radar Signal Processing
- Low Voltage Liquid Crystals

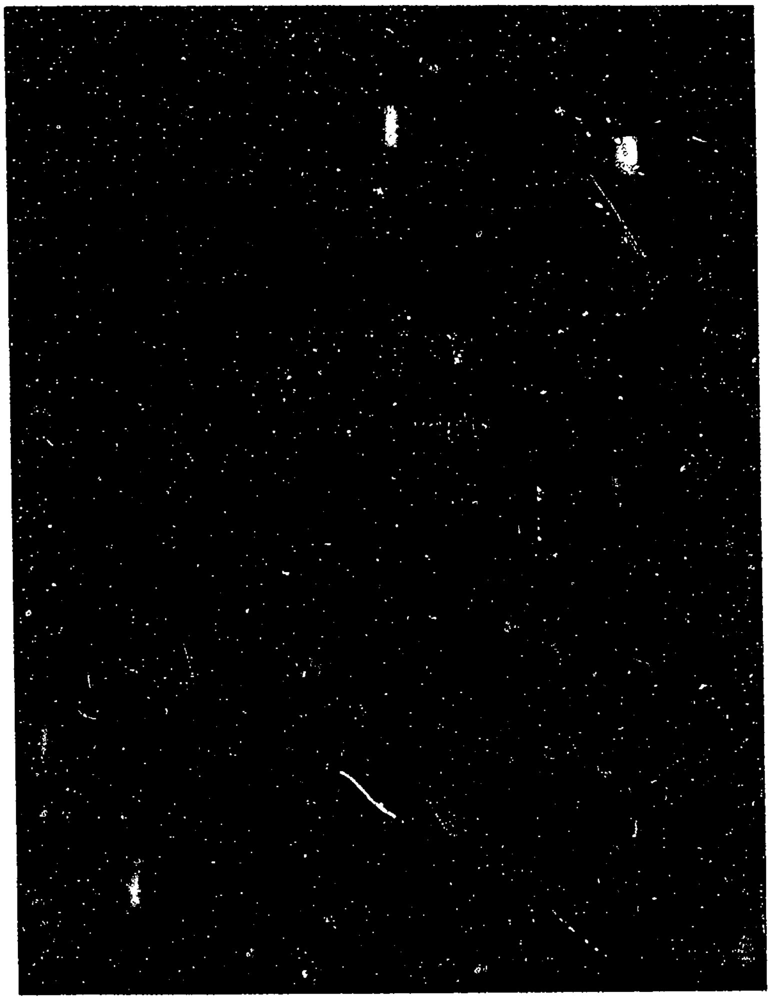
Education

The underpinning of this ERC is a strong curriculum in optoelectronic materials, devices, packaging, computer architectures, neural networks, and information processing in six departments (computer science, electrical and computer engineering, mechanical engineering, chemistry, physics, and electrical engineering) at the University of Colorado and Colorado State University. More than twenty faculty members and over one hundred undergraduate and graduate students actively participate in this ERC and are committed to outreach and diversity. In addition to coursework and independent study classes, students and faculty organize cross-disciplinary seminars in liquid crystals, photorefractive materials, neural networks, image processing, diffractive optics, spatial light modulators, and three-dimensional computing systems.

Industrial Collaboration/Technology Transfer

OCS encourages working partnerships with industry through industrial membership in the Center — over fifty companies help this ERC plan its education and research programs. The State of Colorado and the Center jointly developed the Colorado Business Program to actively build the local base of optical industry. Faculty team with industrial colleagues on ATP, TRP, and Department of Defense joint research and development projects. In addition, a Cooperative Research and Development Agreement (CRADA) has been established with the National Institute for Standards and Technology.

Over sixty optoelectronic-related patents have been filed or issued by Center faculty and students, a number of which have been licensed by industry, and several startup companies have been formed as a result of the NSF/ERC for Optoelectronic Computing Systems.



This optoelectronic array, viewed through the 13mm diameter window of its ceramic package, serves as the building block for the Center's systems based on optical interconnection between silicon chips. The small square is an 8x8 vertical-cavity surface-emitting laser (VCSEL) array, and the large rectangle is the silicon chip. Intra-package electrical interconnect traces also are visible.

Facilities

At the University of Colorado at Boulder, the Center occupies a 16,000 square foot facility including research labs, a teaching lab, and student offices. At Colorado State University, 7,000 square feet houses laboratories devoted to materials growth, characterization, and device fabrication.

OCS Headquarters

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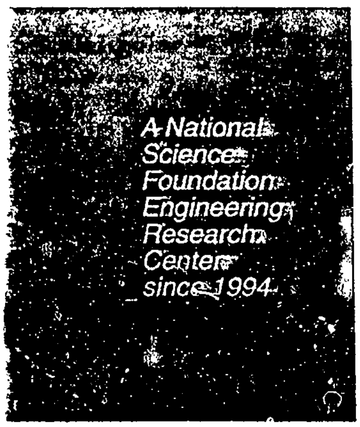
NSF 96-23q

Low-Cost Electronics Packaging Research Center

Georgia Institute of Technology

Development of low-cost, highly integrated electronic packages is a key to future leadership in the worldwide portable electronics market



Low-cost packaging of electronics will be a key technology as we enter the 21st century, with an ever-increasing application of microelectronics to both consumer and industrial products. The Low-Cost Electronics Packaging Research Center (PRC) provides leadership in research, development and pilot manufacturing for electronic packaging. The Center's activities span the spectrum from invention to the building of prototype hardware. Its aim is to provide leadership to the nation in electronic packaging and help establish the United States as the world leader in packaging technology and manufacturing.

Dramatic changes are underway in the computer, telecommunications, automotive, and consumer electronics industries. In addition to increased performance at lower cost, computing is increasingly being performed in hand-held computers. In the telecommunications industry, the user also is employing high-performance, multifunctional, portable units. Multimedia consumer products offering voice, image, video, text, hand-writing, and speech recognition are expected to become commonplace within the next decade. Major increases in the amount of electronics used in automobiles and the functions needed to support the planned new intelligent vehicle highway systems are also occurring. The common requirements in all of these electronics are: (1) ultra low-cost, (2) thin, light, and portable, (3) very high performance, and (4) diverse functions involving a variety of semiconductor chips.

Electronics, particularly low-cost electronics — the focus of the PRC — is a vital strategic technology for U.S. industrial competitiveness, since it is the basis of for all electronic products in the computer, automotive, telecommunications, consumer electronics and aerospace industries. Today, electronics technologies, once considered the sole province of the United States, have in many cases come to be dominated by nations of the Pacific Rim. This is particularly true of consumer electronics. The absence of a strong U.S. electronics packaging industry is a major contributor to this situation. A recent NSF-sponsored Japanese Technology Evaluation Center (JTEC) study confirmed that the United States trails badly in packaging Results of that study are summarized in Table 1.

PRC RESEARCH VISION

CURRENT STRATEGY
- Miniature components
- Pack lot of components
- Automatic assembly
- "Inspected" quality

PRC STRATEGY
- Very low-cost, thin, light
- Integrated, high perfor.
- Very few components
- Extremely compact
- "Built-in" quality

	Current Packaging	Integrated Packaging	Improvement Factor
Size (nominal)	10	1	10x
Packaging Efficiency	8%	80%	10x
Performance	50-100 VHz	200-IGHz	5-10x
Cost (of VCV)	10	1	10x
Reliability	1	10	10x

Figure 1

TABLE 1
PACKAGING TECHNOLOGY ASSESSMENT: U.S. vs JAPAN (JTEC STUDY)

CATEGORY	LEADER TECHNOLOGY	LEADER VOLUME APPLICATIONS
Single Chip		
Plastic	Japan	Japan
Ceramic	U.S.	Japan
Multichip		
Thin Film	U.S.	U.S.
Ceramic	U.S.	Japan
PWB	Japan	Japan
COB, COG	Japan	Japan
Chip Assembly		
Flip Chip	U.S	U.S.
TAB	Japan	Japan
Wire Bond	U.S.	Japan
Board Assembly	Japan	Japan
Passive Components	Japan	Japan
PWB	Japan	Japan
Flex	Japan	Japan
Connectors	Japan	Japan
Package Design	U.S.	U.S.

The objectives of the PRC are:
- to carry out research, development, and prototype manufacturing in low-cost, high-performance, and portable electronic packages consistent with industry needs;
- to transfer this knowledge to industry; and
- to educate students and industry personnel to be globally competitive packaging engineers and technology leaders.

Research

The goal of the PRC is to improve cost performance, and size all by a factor of about 10 to meet the future requirements of the $300B electronics market that is directly dependent on low-cost and highly integrated packaging. Figure 1 graphically describes the PRC's vision, extrapolating from today's conventional single chip on printed wiring boards. The PRC's packages achieve:
- high performance due to copper wiring in low dielectric-constant polymer medium
- high-bandwidth due to optoelectronic functions
- compactness due to elimination of discrete passives along with the use of area array chips

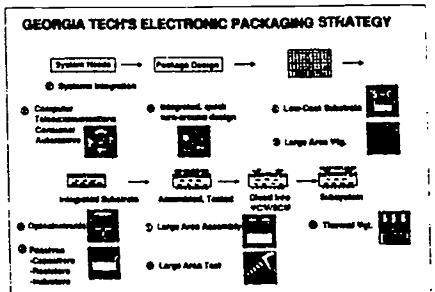


Figure 2

- low cost due to large-area substrate fabrication, assembly, and test
- high reliability due to minimization of packaging levels to one.

The PRC will have one of the most comprehensive system-level research activities in the country aimed at developing both a skilled workforce and technologies needed by industry.

The PRC addresses all of the above requirements by means of major cross-disciplinary innovations that integrate research, development, and prototype manufacturing. It will exploit advances in (1) low-cost multichip design, (2) materials, and (3) large-area manufacturing processes, including integration with (4) optoelectronics and (5) passives, (6) assembly, (7) test, and (8) thermal management. In addition, there is an overarching effort in (9) systems integration. The PRC strategy in these nine research areas is illustrated in Figure 2. Figure 3 illustrates the Center's integrated-multichip vision compared to current printed wiring laminate and more expensive, but high-performance, ceramic and thin-film multichip technologies. The overall research goal is to achieve high thin-film multichip module performance at printed wiring laminate cost. Another goal is to educate and train students in this leading-edge research area. Education and research, therefore, go hand-in-hand at the Center.

Education

Educational components of the PRC include an extensive list of course offerings in all of the major engineering disciplines as well as courses that address the cross-disciplinary integration toward engineering systems. A new curriculum structure supports a range of educational initiatives, including a new MS certificate program in electronics packaging. As a result, the number of courses is expected to increase by a factor of four to about 40, and student participation at the BS, MS, and PhD levels to increase by a factor of 10 to about 150 in five years. Continuing Education courses will be offered annually in most of the nine research areas. Figure 4 summarizes the educational objectives of the PRC.

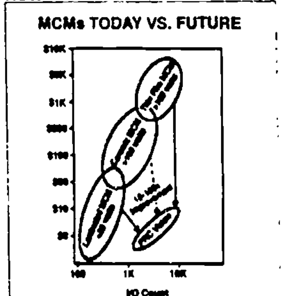


Figure 3

Industrial Collaboration/Technology Transfer

The ultimate beneficiary of the PRC is the U.S. electronics industry. Industry recognizes the benefits of the Center for two primary reasons: (1) its vision and strategy are consistent with industry's expressed needs, and (2) the Center provides a more than ten-times cost leverage to any particular company because of cost-sharing among industry, university, and federal agencies. In view of drastic research and development reductions and escalating research and development costs in the industry, the PRC becomes one of the best vehicles for pursuing technological advances in this area. In addition, the Center provides expertly trained students in cross-disciplinary, low-cost electronic technologies and systems. Because of these benefits, a large number of companies have agreed to commit funds, to assign people on campus to carry on joint research and educational programs, and to participate on technical and advisory boards.

Industry collaboration falls into two categories: membership in the Center for strategic research at a cost of about $25-50,000 per year; and contract research, specific to the company, leveraging the strategic membership fees. In addition, the Center expects to work with a number of industrial and non-NSF institutions such as Sematech and the Advanced Research Projects Agency to carry out prototype manufacturing and systems development both for military and commercial applications.

Facilities

The Center features three cross-disciplinary rapid-prototyping facilities designed to integrate various technology elements derived from advances made in discipline-oriented labs throughout Georgia Tech and other research organizations around the country. Integration facilities are in the Manufacturing Research Center (MARC), the Microelectronics Research Center (MiRC), and the new Georgia Center for Advanced Telecommunications Technology (GCATT) Center. The low-cost MARC prototype facility is a new $20 million facility equipped with large-area processing tools and funded by industry and the State of Georgia. Optoelectronics and passive integration facilities are in the MiRC. Prototype facilities for design, assembly, test, and system integration, totalling about 12,000 square feet, will be in the GCATT Center.

Center Organization

The management structure consists of: (1) the center Director, who is an internationally recognized packaging expert, a multichip pioneer at IBM, and former director of IBM's worldwide Advanced Packaging Laboratory; (2) an Industrial Advisory Board representing the industries the PRC serves, which will guide, review, and assess the overall technical strategy of the PRC; and (3) a University Administrative Committee consisting of the directors of all of the Georgia Tech engineering departments and Deans and Vice Presidents, as well as the directors of MARC, MiRC, and the PRC. A research Committee oversees the direction of research in the nine areas; and a Technology Transfer Committee ensures the efficient communication of research results and technology to industry. In addition, there will be an operations staff who will be responsible for industrial partnership and technology transfer, budget, prototype facility maintenance, curriculum, course development, and continuing education.

The PRC team consists of a strong, cross-disciplinary and experienced faculty, along with a diverse student representation from the College of Engineering, the College of Computing, and the physics and chemistry departments. In addition, the Center includes a number of distinguished engineers from the Georgia Tech Research Institute (GTRI). The faculty team (numbering 35 initially) represent seven engineering and science departments and the GTRI.

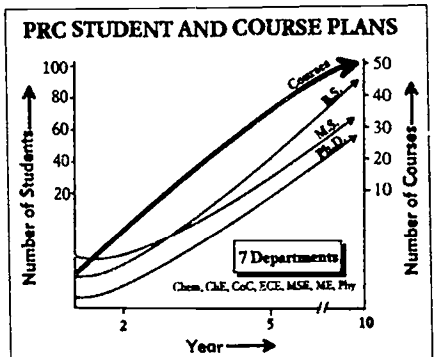


Figure 4

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NSF 96-23r

Center for Compound Semiconductor Microelectronics (CCSM)

University of Illinois at Urbana-Champaign

Research in optoelectronic materials, devices, and systems

A National Science Foundation Engineering Research Center since 1986

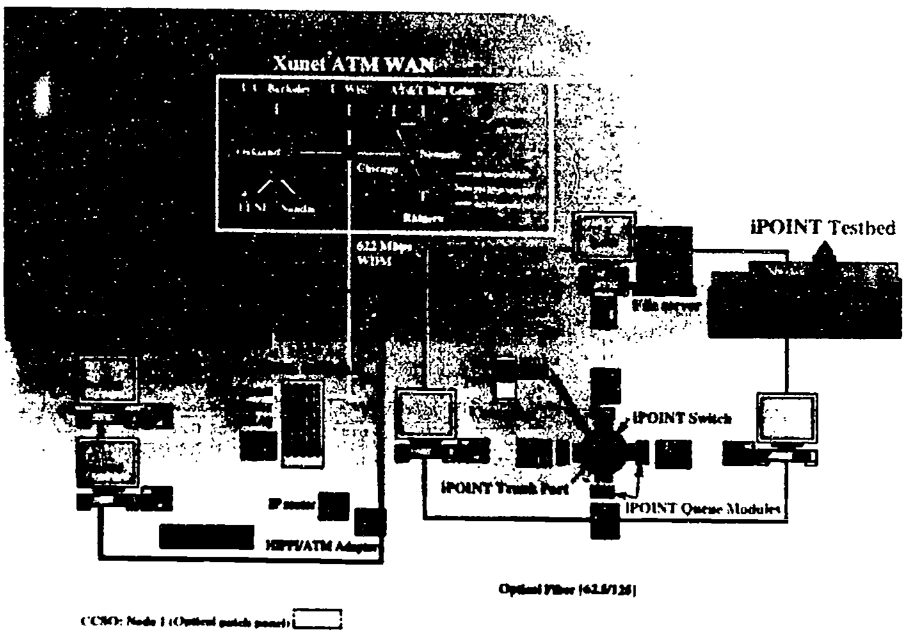
The CCSM's vision and research are focused on establishing optoelectronic or photonic technologies and communication systems as pervasive enablers of U.S. industrial competitiveness. Cost-effective lightwave communication systems that provide unlimited, affordable bandwidth will drive the creation, storage, accessing, processing, and transmission of information on a scale ranging from chip-to-chip to global. Photonic technology will facilitate "information superhighway" services for business, education, health care, government, and defense; it will fundamentally change the way society works and uses information.

Realizing the CCSM vision of unlimited affordable bandwidth requires advances in knowledge and technology to address both performance enhancement *and* cost reduction. A powerful combination of multidisciplinary research in materials growth and processing, in the design, simulation, fabrication, and testing of devices and circuits, and in systems architecture and design is carried out at the CCSM in a highly interactive mode. The CCSM's research objectives are twofold—to integrate high-performance electronic and photonic devices in monolithic optoelectronic integrated circuits (OEICs), and to insert and test the OEICs in on-campus and industry-based systems testbeds.

Research

CCSM research programs are organized into three vertically integrated thrusts:

- The *Lightwave Systems and Testbeds (LST)* thrust provides the overall systems vision, perspective, and guidance for CCSM programs. LST work defines the systems-level objectives of the integration, subsystems, devices, and materials programs, and points the way to realizing the ultimate goal of photonic communication systems. Research areas include systems architecture, ultrabroad-bandwidth transmission, and optoelectronic computer-aided design. CCSM's Illinois Pulsar-based Optical Interconnect (iPOINT) testbed, for multimedia service and network computing applications, creates opportunities to test Center integration technology and OEICs in a systems environment designed by industry.
- The *Optoelectronic Devices and Components (ODC)* thrust provides the foundation of materials, processing, fabrication, and integration technologies for sources, modulators, routing structures, and receivers



The CCSM's Illinois Pulsar-based Optical Interconnect (iPOINT) project explores how optical interconnects can increase the information-carrying capabilities—namely bandwidth—and speed of computer networks. iPOINT optically connects three Sun Sparcstation workstations at the University of Illinois via an asynchronous transfer mode (ATM) switch, making it feasible to transmit voice and video data among the machines. In turn, these workstations are optically linked through the switch to AT&T's nationwide experimental university network (XUNET). When fully scaled up, iPOINT will be capable of transmitting up to 128 billion bits of information per second (Gb/s). In comparison, the current generation of ATM switches can send data at roughly one third this rate.

A CCSM faculty member and graduate research assistant review design rules for a four-channel optoelectronic integrated circuit (OEIC) receiver in the Center's OEIC Design facility. This receiver will be implemented in the Center's iPOINT optical interconnect testbed.

(detectors/amplifiers); subsystems for serial and parallel optical links; and transmitters and receivers for space division multiplexing (SDM), wavelength division multiplexing (WDM), and terabit coherence division multiplexing (CDM).

- The *Subsystem Integration and Testing* thrust plays a central role in coordinating and bridging between the research programs of the LST and ODC thrusts. Its research focuses on the barrier issues which impede the transition across the interface between devices/components and systems. These issues include: materials, processes, and design for packaging of optoelectronic devices, OEICs, and components; the consequences of integration such as thermal management, cross-talk, and reliability; design for manufacturability; and technologies for hybridization, bonding, and optical alignment.

Education

The CCSM makes significant contributions to enhance the research and education culture on the University of Illinois engineering campus. For example, Center faculty develop and modify graduate- and undergraduate-level optoelectronics courses to better integrate classroom instruction with laboratory research. The Center's iPOINT optical interconnect testbed helps institutionalize an interdisciplinary systems approach to research by providing a unique focus for interactions among research groups. The Center promotes graduate students' professional development by having them:

- manage the Optoelectronics Seminar Series and Undergraduate Summer Intern Program projects
- serve on the CCSM Student Advisory Council
- participate in national and international technical conferences.

Undergraduates from our campus and more than a dozen universities nationwide complete valuable research projects through the Center's annual summer internship program. Finally, the Center sponsors a series of innovative pre-college science outreach programs that provide students and teachers nationwide with access to the campus' resources.

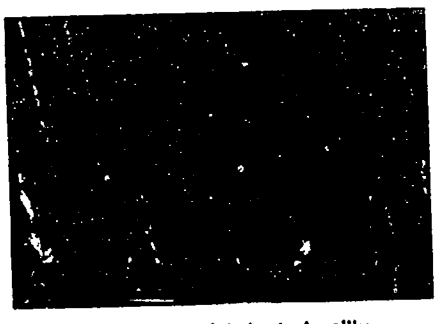
Industrial Collaboration/Technology Transfer

The CCSM has established flexible programs for interaction with industry. These programs include personnel exchanges, sponsorships and affiliate memberships, industrial mentorships, and business partnerships and strategic alliances. This participation provides a timely transfer of knowledge and technology to industry. The Center places more than half of its doctoral graduates in jobs with U.S. industry; in addition, current CCSM graduate and undergraduate students participate in industrial research internships throughout the year. The Center welcomes industrial scientists and engineers as researchers-in-residence in its labs. Center faculty and students collaborate with their industrial colleagues, and regularly publish their collaborative research results in peer-reviewed journals.

The CCSM also maintains an active Technical Advisory Committee, which has been a key industrial resource for the Center. CCSM management relies on the TAC for guidance and endorsement in formulating its research plans.

Facilities

The CCSM is housed and facilitated in the Microelectronics Laboratory on the campus of the University of Illinois at Urbana-Champaign, one of the nation's premier institutions for engineering education and research. The $13.5 million Microelectronics Laboratory, which was funded by the State of Illinois, has 8,000 square feet of class 100 and 1000 clean room space, is vibrationally tuned to less than 10 microinches, and is the first university facility to conform to the stringent H6 fire and safety codes applicable to semiconductor laboratories. The building houses some of the most technologically advanced facilities available for artificially structured optoelectronic materials' growth, submicron device patterning and fabrication, high-speed optical and electrical measurements, and ultra-high-purity semiconductor characterization. Finally, CCSM researchers have access to a unique array of interdisciplinary laboratories and research centers on campus. These facilities include the Beckman Institute for Advanced Science and Technology, the NSF Science and Technology Center for Superconductivity, and the NSF National Center for Supercomputing Applications.



CCSM researchers fabricated gallium arsenide (GaAs) quantum wires (pictured) by high-resolution electron-beam lithography and selective-area epitaxy. Semiconductor lasers fabricated with quantum wires are expected to outperform quantum-well lasers.

CCSM researchers used electron-beam lithography to fabricate this OEIC receiver based on modulation-doped field-effect transistors (MODFETs) and metal-semiconductor-metal (MSM) detectors. The 1.55 μm wavelength receiver will be used for long-haul communication applications.

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NSF 96-23

Advanced Combustion Engineering Research Center (ACERC)

Brigham Young University and the University of Utah

Cleaner and more efficient combustion of domestic fossil fuels: A key to more affordable energy

A National Science Foundation Engineering Research Center since 1986

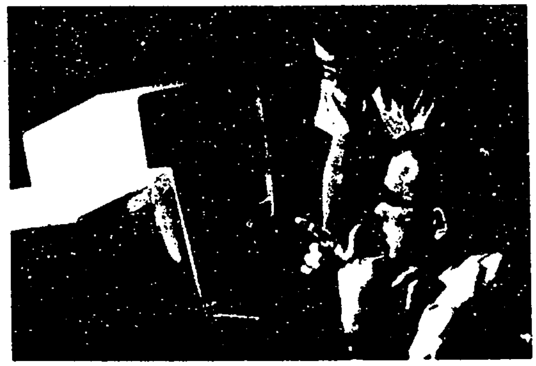
America's economic future is tied largely to the ability of U.S. industry to stay in the forefront of world competition. To do so requires an affordable supply of high-quality energy.

Burning low-cost domestic fuels, such as coal, shale-oil, and heavy petroleum liquids, increases pollution and complicates the task of reducing acid rain, smog, particulates, and the "greenhouse effect" from carbon dioxide emissions. Current combustion technologies need substantial improvement to maximize the extraction of fuel values from low-cost, low-quality fuels.

To address these problems, engineers and scientists from Brigham Young University and the University of Utah have joined with industry, state and federal government, and other universities to create in ACERC a research program aimed at improving the nation's fossil combustion systems.

ACERC objectives are to —

- Expand the fundamental knowledge of combustion in order to improve related technology and practices
- Educate students at all levels about ways to increase the all-round efficiency of combustion, particularly in chambers fired by readily available, low-cost fuels
- Transfer developed combustion technology to industry to help solve crucial combustion problems.



ACERC graduate students evaluate graphics displayed on engineering workstation in the Combustion Computations Laboratory (CCL).

ACERC participants (including faculty, professionals, and students) conduct about 35 coordinated research projects.

Most ACERC research is done at Brigham Young University and the University of Utah. Investigators from other universities including the University of North Dakota, Cornell, the University of Kentucky, and the University of Leeds have participated in ACERC research projects.

Research

ACERC research priorities are to --

- Understand mechanisms of fossil-fuel combustion and of pollutant and soot formation
- Understand relationships between fuel properties and conversion
- Develop robust, reliable computer models to control and record the performance of particular combustion chambers
- Apply nonintrusive diagnostics for complex combustion systems.

ACERC research projects are focused in six thrust areas:

- Fuel structure and reaction mechanisms
- Fuel minerals, fouling, and slagging
- Pollutant formation/control and solid waste incineration
- Turbulent, reacting flows
- Comprehensive model development
- Model evaluation data and process strategies.

Each thrust area has an active working group of ACERC researchers and national or international authorities, primarily from industry, who help identify research needs. At any one time, more than 130

Education

Students of Brigham Young University and of the University of Utah are engaged in ACERC research at both campuses. In all, more than 60 students on the various campuses are involved in ACERC research projects. These students are exposed to the whole range of combustion systems and of industrial users. Within their normal curricula, graduates may earn a minor in combustion engineering, and undergraduates may take optional courses in combustion and energy.

Seminars and special classes. ACERC conducts joint combustion seminars featuring prominent guest speakers at both universities. Students at either institution often attend these and other selected classes through a microwave link that provides two-way, teacher-student communication.

Scholarships and fellowships. ACERC offers stipends of up to $15,000 per year plus tuition for both undergraduate and graduate students. ACERC also offers NSF-sponsored research assistantships for undergraduates from area universities and colleges under the Research Experiences for Undergraduates (REU) program.

ACERC's Coherent Anti-Stokes Raman Spectrometer (CARS), used to study coal- and gas-flame structures at BYU.

Industrial Collaboration and Technology Transfer

Interdisciplinary teamwork. Students and faculty from various disciplines work closely on an array of diverse, yet related, research projects that have many practical applications in industry. Qualified ACERC professionals play key roles in software management, technology transfer, and industrial relations.

Comprehensive model development. One very important way to transfer ACERC-developed technology to industrial users is to create comprehensive computer-guided models for controlling combustion in particular combustion systems such as utility boilers. For each, the model's computer software is tailored to attain what is expected to be maximum combustion efficiency and to provide feedback on the particular successes and failures of the results actually attained. Such results can lead to fine-tuning of the model. ACERC places special emphasis on preparing models for coal-fired systems.

Other ways of transferring technology. Hosting industrial fellows. Seminars. Conferences. Campus workshops to introduce new software products. Visits of ACERC personnel to industrial sites. An annual technical review meeting. Joint research projects with other universities.

Results of ACERC research are presented annually to ACERC participants and are published in prominent journals. A list of active research projects in each thrust area is available on request.

Facilities

ACERC has available 38,000 square feet of administrative, computational, and laboratory space at the two universities, including significant new space completed since ACERC was initiated. The value of research laboratory and computing equipment exceeds $16,000,000.

ACERC investigator conducting incineration experiment in lab-scale, rotary-kiln combustor at the University of Utah.

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Offshore Technology Research Center (OTRC)

Texas A&M University and the University of Texas at Austin

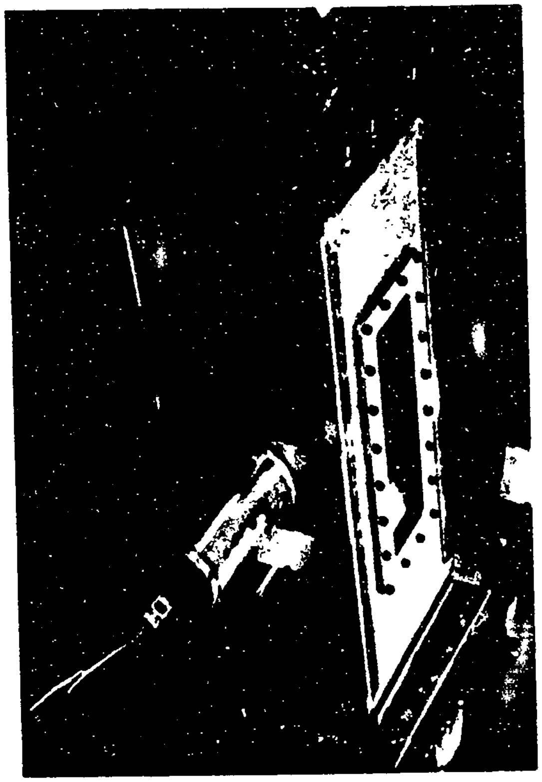
Innovative technology for developing deep ocean natural resources

A National Science Foundation Engineering Research Center since 1988

The oceans, a rich source of energy and minerals, now supply 27 percent of the world's oil and gas. As terrestrial resources are depleted, the development of the oceans' potential is crucial to the industrial and economic future of the United States. Much of this development will occur in the deep (to 10,000 feet) oceans.

OTRC facilitates building and maintaining the United States' competitive edge in the offshore arena through education, research, and technology transfer. OTRC researchers study problems involving hydrocarbon production in the deep waters of the Gulf of Mexico and apply technology developed through this research to other ocean-based activities globally.

In addition to seeking novel approaches for reducing the costs of offshore oil production, the Center provides a unique opportunity for an industry-university interface, with industry involved in identifying research interests, reviewing progress, and providing strong financial support.



Apparatus for detailed velocity field mapping of the wake phenomena around a cylinder subject to random oscillatory flows.

Research

OTRC research is pursued under three thrust areas.

Fluid/Structures Interactions

As production platforms are designed for ever deeper locations, the combined forces of waves, currents, and winds become more critical. Not only are the forces greater, but the uncertainties in defining them increase and the penalties for improper design become prohibitively large. The environmental loads combine in a nonlinear fashion that is not well understood at this time — particularly the attributes associated with differing directions. Structures that are more than a mile in length will be required to attach floating production platforms to the seafloor. These structures will necessarily be rather flexible and certainly will be highly stressed. One of the critical conditions affecting structural reliability is the resistance to fatigue resulting from millions of cycles of alternating loads caused by waves or the eddies and vortices shed from ocean currents acting on the structure.

Research in this area is concentrated on the development of numerical models to predict the loads, deflections, and responses of structures subjected to combined environmental loads. A parallel program is devoted to the creation of high-quality data sets for large scale models in the wave tank. In addition to modeling directional deepwater waves, the capability to model currents and wind forcing also will be added. These data sets will then be used to validate the numerical models to insure their suitability for predicting full-scale performance.

Integrity of Materials and Structures

Research in this area is concentrated on the application of fiber-reinforced plastic-matrix composites for the long, slender, highly stressed members. Initial studies have shown a potentially strong economic advantage arising from the high strength and low density of these materials. Very little is known about the degradation of these constructions under combined fatigue loading and immersion in sea water. Investigations will be made into the fundamental mechanisms of strength loss, including the potential for attack by living organisms and the electrochemical effects of graphic fibers (an effective conductor) in contact with metallic structures. Again, numerical and analytical models will be developed and verified against laboratory results with combined corrosion and fatigue testing.

One of the critical design problems arises from the difficulties in creating a mathematical representation of repeated loads which vary in magnitude and frequency in a random pattern over the life of the structure. This

OTRC students from both campuses converged on the Mobil Corporation offices in Dallas for a recent poster session.

field of structural reliability is perhaps most significant in the ocean, because of the environmental loading, and is a major element in the research thrust.

Seafloor/Structures Interactions
Reliable attachment of the structure to the seafloor is a major engineering research problem. First, the loads are very high and are cyclic in nature. Second, no experience exists with the engineering properties of the sediments that are found at the great depths contemplated. Thirdly, well-known techniques such as driven piles will probably be prohibitively expensive at these depths. Finally, natural gas hydrate is known to exist in these cold, high-pressure sedimentary environments, and the potential for disruptive melting of the frozen gas requires the ability to locate and characterize the deposits. Research in this field is concentrated on characterizing the engineering properties of the seafloor in typical sites of interest, including such overall properties as slope stability. Further activity is directed toward the evaluation of innovative foundation configurations, such as suction anchors. A major effort has been devoted to the identification of gas hydrates (methane ice) through both in-situ and remote sensing techniques. This research area will follow the same general procedures as the other two. Numerical predictive models will be developed and subjected to rigorous validation against large-scale physical data sets.

Education
A major goal of the Center is to advance undergraduate and graduate education in offshore technology and related areas. The Center has set priorities to develop new courses, instructional materials, industrial field trips, and cooperative education programs. Students and postdoctoral researchers have the opportunity to work with university and industry practitioners to identify and investigate real-world problems. Results are shared through publications, software, workshops, short courses, and exchange of professionals. There are substantial outreach programs to undergraduates at predominantly minority institutions, including an NSF-sponsored summer Research Experiences for Undergraduates program and a special outreach program with Prairie View A&M University.

Industrial Collaboration/Technology Transfer
Industry collaboration has been strong and continues to grow. Most major energy and offshore engineering companies in the United States are among the Center's charter supporters.

Technology transfer is an important aspect of the Center's agenda. Annually, more than 160 industry representatives and 100 students and faculty participate in eight workshops and seminars that address the three thrust areas. The Industry Advisory Board reviews the direction and emphasis of the current program and provides suggestions for additional research thrusts.

Facilities
The University of Texas at Austin and Texas A&M University — the two leading research institutions of higher education in the state — provide facilities support for OTRC. The centerpiece of the Center's program is an administration and research building located in the Texas A&M Research Park. Foremost among the Center's unique equipment is a wave tank capable of providing 3-D waves, current, and wind to develop a new nonlinear 3-D modeling "culture" and to test tension leg and compliant platforms at various scaling factors. In addition, extensive laboratory, shop, and computer complexes at both universities are available to OTRC researchers and students.

Performance evaluation of a semi-submersible drilling platform in the OTRC wind, wave, and current model basin.

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