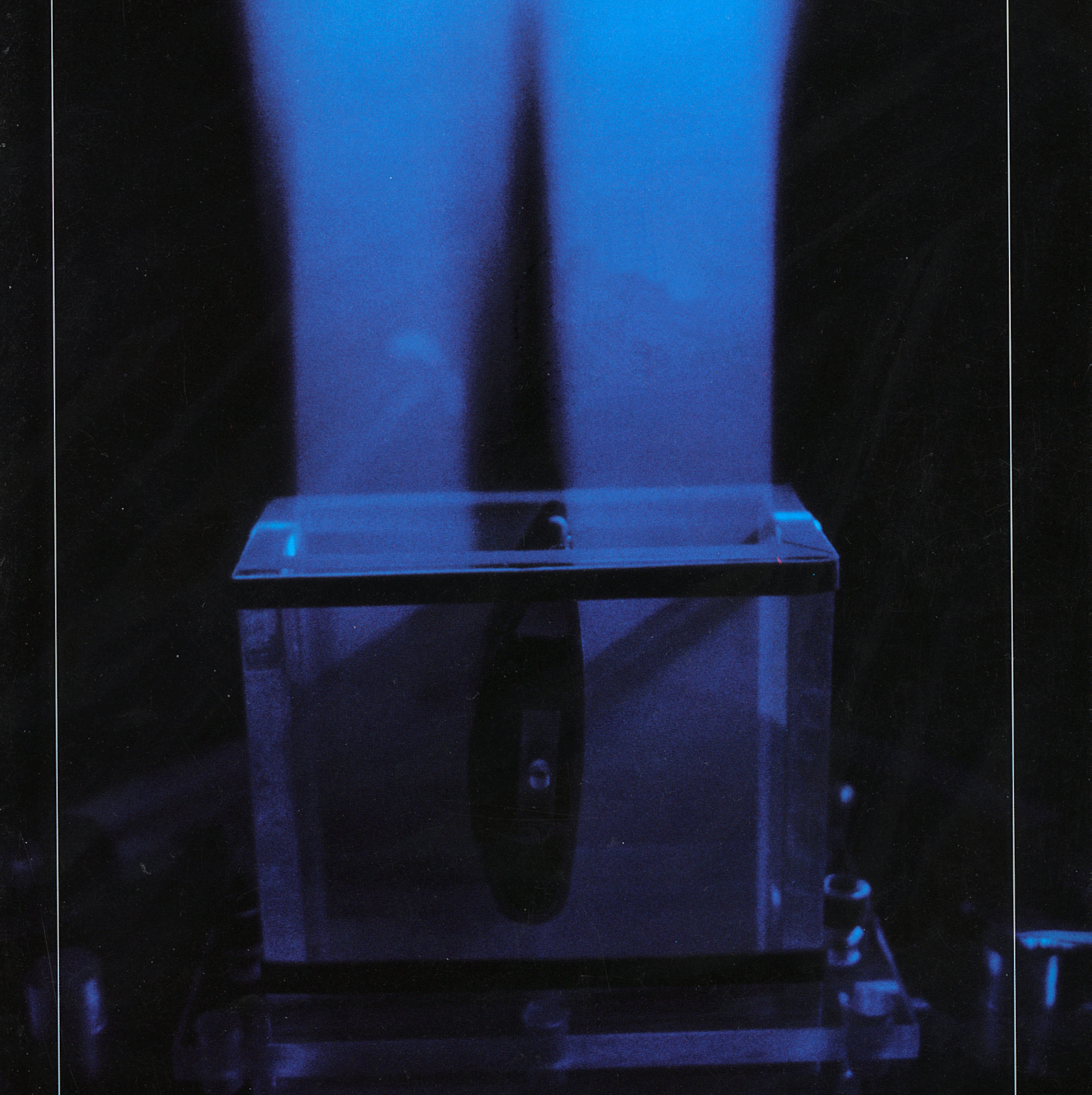
GEORGIA TECH RESEARCH INSTITUTE

1990 Annual Report



Georgia Institute of Technology

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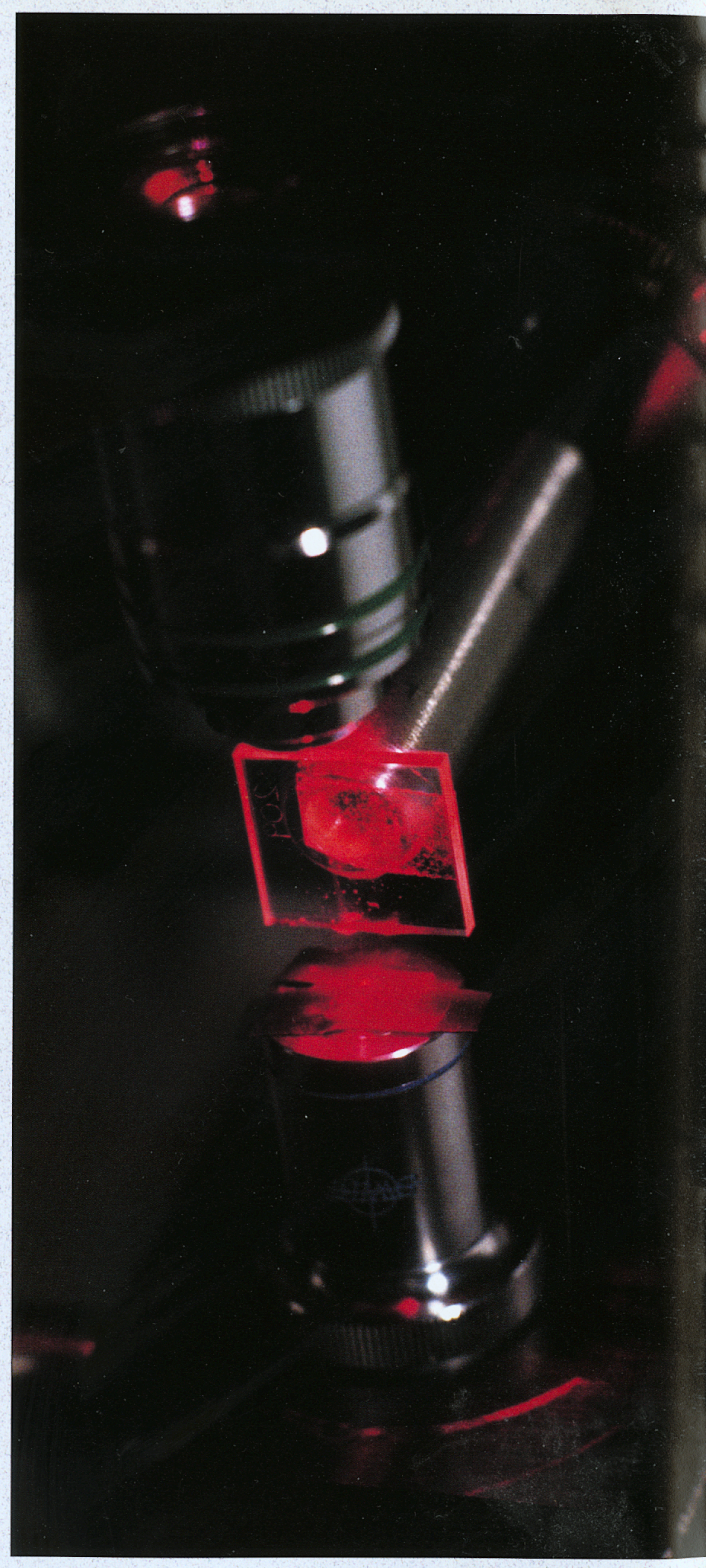
COVER: Researchers in GTRI's new aeroacoustics facility use a pulsed laser flow visualization technique to study noise patterns generated by air flowing around automobile roof racks.

RIGHT: GTRI's advanced integrated optic chemical sensors feature high sensitivity and freedom from electromagnetic interference.



THE DIRECTOR'S MESSAGE

Perhaps nothing is so reliably constant as change. As the first fiscal year of our new decade draws to a close, the Georgia Tech Research Institute (GTRI) continues evolving to meet new challenges and opportunities. However, our missions, as chartered by the Georgia General Assembly, remain unchanged and perhaps bear repeating here: "Conduct scientific, engineering, and industrial research; participate in national programs of science, technology, and preparedness; encourage the development of the natural resources of Georgia; aid industrial and economic development; furnish technical advice and assistance to business and industry; and provide a statewide industrial extension service."

Donald J. Grace

In performing these missions, GTRI is contributing substantially as a full partner in Georgia Tech's overall research, educational, and service goals.

As the new fiscal year begins, we have implemented a restructuring of GTRI which we expect to make us more flexible in adapting to the changing needs of the external market for R&D, more responsive to the broader interdisciplinary interests of our sponsors, and more cost-effective in our performance. We have essentially eliminated a layer of line management and simultaneously centralized a number of comprehensive functions that link all the research operations of GTRI. The restructured organization is presented in some additional detail in a later section.

Major organizational changes are simultaneously being orchestrated in the academic structure of Georgia Tech, and we intend to correlate our evolution with theirs to create stronger bonds and a more accessible environment for our existing and potential research sponsors.

In total expenditures, GTRI's volume was about $100 million for the second consecutive year, but our primary emphasis remains dedicated to quality of research and outreach.

The Department of Defense remains, by far, our largest group of sponsor agencies, and we are, of course, concerned about the potential impact of major reductions in their budget. We are hopeful that their R&D expenditures at GTRI will not decrease—even increase—in the new political climates of the early 1990s, but we also intend to exploit other opportunities to apply our technological base of capabilities toward other pressing national and international needs, such as the environment, manufacturing technology, industrial competitiveness, the war on drugs, economic assistance, space technology, bioengineering, communications, computer applications, and data management.

To guide us in our strategic planning, we have complemented our National Advisory Board with a 32-member State Advisory Board chosen from a diversity of geographical, political, industrial, governmental, and technological resources. Both groups are tasked to evaluate what we now do, what we should add to our future agendas, how we can best communicate our activities, and how we should seek new discretionary resources to accomplish our missions.

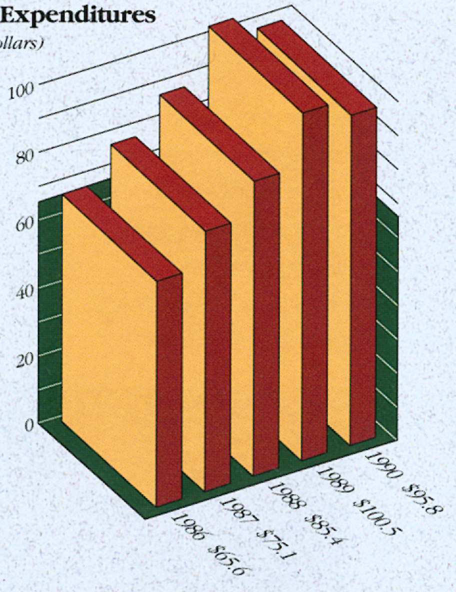
It is traditional, but totally fitting, that I should end this letter with a heartfelt expression of gratitude to our dedicated professional and support staff, without which we would be nothing but a name. They *are* GTRI, in the most tangible sense, and I commend them all to you for their continued service to GTRI, to Georgia Tech, to the state, the nation, and the world.

Donald J. Grace

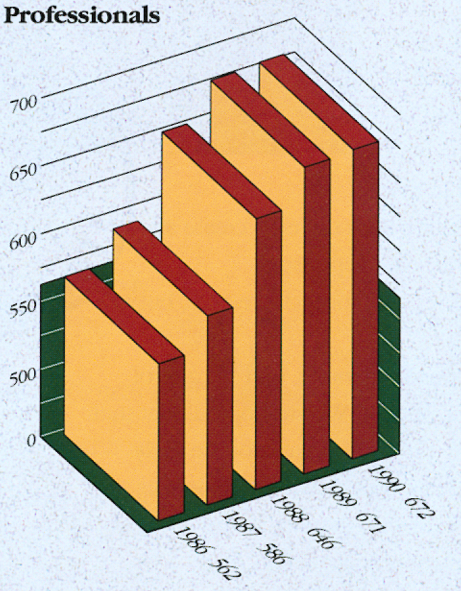
Donald J. Grace
Director
Georgia Tech Research Institute

THE YEAR IN REVIEW

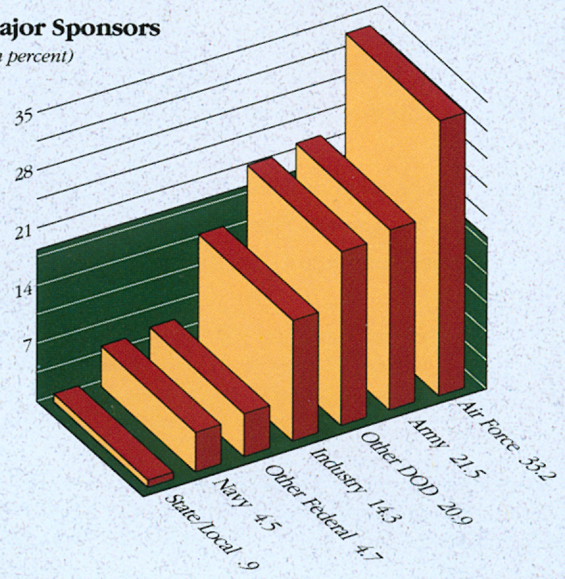
Research Expenditures
(Millions of dollars)



Research Professionals



Major Sponsors
(In percent)



Through a healthy combination of maturing technologies and new initiatives, the Georgia Tech Research Institute (GTRI) experienced another vigorous year of R&D activity. Though research expenditures fell slightly to $95.8 million, GTRI's contract backlog remains firm.

In FY 90, GTRI's principal base of sponsorship remained the Department of Defense (DoD), which provided 80.1 percent of GTRI's total revenues. Contract research from the three services (Army, Navy, and Air Force) composed 59.2 percent of GTRI's total revenues, down slightly from 63.4 percent the previous year. Funding from other DoD sources increased to 20.9 percent, becoming the Research Institute's fastest growing budgetary component — nearly doubling in the last two years.

Other federal agencies provided 4.7 percent of GTRI's contract research, up from 3.9 percent the previous year. Research sponsored by industry rose from 13.5 percent to 14.3 percent, while sponsored research from state and local sources remained nearly constant at about 1 percent.

During the past fiscal year, a major restructuring of GTRI's management and research operations was implemented. The new organizational structure should improve GTRI's operational interaction and provide greater programmatic flexibility in meeting the needs of tomorrow's research.

EXTERNAL RESEARCH

GTRI's externally funded research during the past year ranged from antenna fabrication to zeolite development. Research highlights included the delivery of one of the world's largest outdoor compact ranges, new advances in materials growth and characterization techniques, and the design of low-cost, integrated optic chemical sensors.

Last year, Lockheed Aeronautical Systems Company donated a multimillion-dollar complex of advanced aeroacoustics, fluid dynamics, and aerodynamics research facilities to Georgia Tech. These new facilities coupled with GTRI's traditional expertise in aerospace engineering provide comprehensive tools for theoretical analysis and experimental validation of new aerodynamics concepts and configurations.

In FY 90, GTRI began a major three-year program with the NASA Langley Research Center to investigate a variety of acoustic phenomena. Projects include studying the effects of sonic booms on buildings and humans, and examining the effects of atmospheric disturbances on sound propagation.

During the year, GTRI researchers also continued to work actively with colleagues from academic schools at Georgia Tech as well as other institutions. A prime example of these collaborations was the Apparel Manufacturing Technology Center (AMTC), which completed its first three-year phase and won federal support for a second phase of two years. The AMTC is demonstrating and developing new technology so American apparel manufacturers can make better use of automation and computer integrated management systems.

These are just a few examples of the many research projects conducted at GTRI during the past year. Summaries of other program highlights appear on the following pages.

Internal Research

GTRI continued to invest in an internal program of wide-ranging R&D initiatives designed to reinforce its existing technology base and to stimulate new endeavors. In the past two years, this program has resulted in 21 completed projects, in technology areas such as information sciences, material and propagation sciences, device and component technologies, system and interface technologies, and environmental and industrial technologies.

Last fiscal year, $1.8 million was spent on 37 innovative research projects. Seventeen of these projects involved the participation of academic faculty members. The total program activity was supported by 36 graduate research assistants and two post-doctoral students.

Education

An important part of GTRI's mission is augmenting Georgia Tech's educational program. In the last fiscal year, 32 GTRI researchers held appointments as adjunct faculty members at Georgia Tech. In addition, 20 GTRI research engineers or scientists served on Institute thesis advisory committees. GTRI professionals also taught 12 academic courses and a growing number of education short courses.

Through numerous R&D activities, GTRI serves as a training ground for future scientists and engineers. Last fiscal year, 158 graduate students, including 95 doctoral candidates, and 433 undergraduate students participated in GTRI research projects. As part of the Research Institute's ongoing effort to meet the growing — and changing — demands of tomorrow's research, 131 professional employees pursued advanced degrees through GTRI's tuition reimbursement program.

Service to Georgia

GTRI continued to be a key force in strengthening Georgia's economy. An economic impact study prepared during FY 90 showed GTRI attracted $85.2 million in research funding to the state from external sources during the preceding fiscal year. The same study reported that the state's $2.9 million allocation for GTRI research resulted in additional tax payments of $6.8 million to state and local authorities — a 234 percent return on investment.

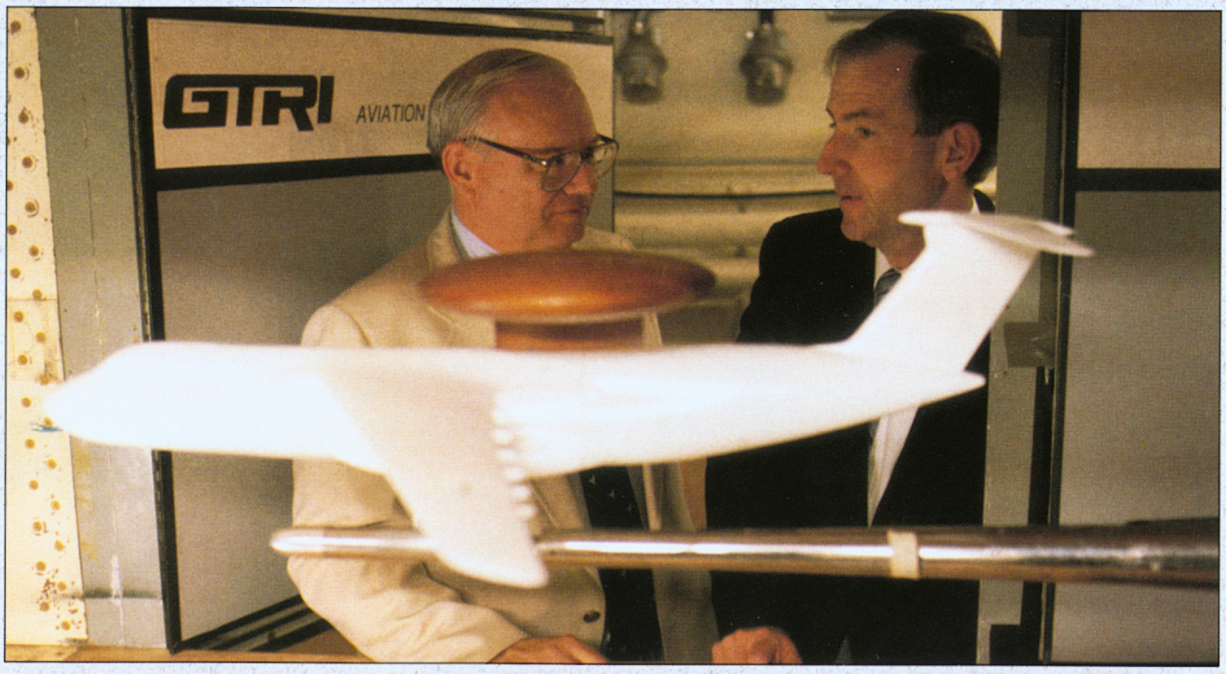
For many years, GTRI has conducted research and development to assist the poultry industry, one of the state's key manufacturing sectors. In FY 90, GTRI used a $250,000 grant from the Georgia General Assembly to establish a laboratory that will investigate new applications of automation technology for poultry processors. Tech's Agricultural Technology Research Program is operating this new laboratory.

As a complement to its National Advisory Board, last year GTRI constituted a State Advisory Board with 32 members. This group will provide continuing advice on ways that GTRI can strengthen its impact on the health, safety, and economic growth of Georgia. ■

GTRI maintains 12 field offices in Georgia and a number of Federal off-site activities throughout the United States.

RESTRUCTURING

GTRI's new organizational structure promises to streamline procedures and improve the research environment.



GTRI's new model test facility is used for advanced aerodynamic concept development.

A major restructuring of GTRI's management and research operations was completed during the past fiscal year. This process had its roots in an intensive self study which was begun in 1987. The goal of the restructuring was to position GTRI for successfully meeting the challenges of the future by increasing organizational flexibility and responsiveness, and by reducing operating costs.

The previous organization was conceived in 1978, and has served GTRI well. During this period, total professional employment rose from 383 to 672, and total expenditures increased from $19.1 to $100 million. In 1978, there were only several individual programs with funding larger than $1 million; today, there are 67 larger than $1 million, and five larger than $10 million.

Since 1978, GTRI has complemented its programs in electronics by developing microelectronics, manufacturing technology, remote sensing, and environmental science and engineering. As we look to the future, however, we see a more competitive and dynamic sponsored program market environment, characterized by frequent changes in funding directions, technological content, and procurement processes for federally funded research programs. GTRI will require additional organizational flexibility to respond to this environment.

The new GTRI organization consists of 22 laboratories with relatively focused technical missions, linked by a smaller number of coordinated broad program thrusts. At the GTRI Director's level, we have added offices for quality assurance, strategic planning, program development, fiscal operations, and economic development and technology transfer for increased executive emphasis and oversight, while retaining internal research, academic interaction, professional development, and legislative and external interface activities. The new organization should provide our sponsors with improved access to technical personnel and facilities, and allow us to rapidly convene interdisciplinary technology teams to address complex systems programs. The new organization will also facilitate the linking of Georgia Tech's academic research programs with GTRI's applied research, thereby amplifying another important dimension to our overall research capability.

With the changes that have been made, we look forward to a rewarding future.

Robert G. Shackelford

Robert G. Shackelford
Executive Associate Director

INTEGRATED OPTICS

For several years, GTRI has pursued the development of advanced integrated optic chemical sensors for the detection of hazardous chemicals and industrial sensing and inspection operations. These novel devices consist of two-dimensional optical circuits fully integrated onto compact planar substrates. They feature high sensitivity, active or passive measurement techniques, and freedom from electromagnetic interference.

With funding provided by the Department of Energy, researchers at GTRI and the University of Georgia are developing a gaseous ammonia sensor for agricultural applications. The sensor would monitor the amount of ammonia rising from a field and determine the optimum time for applying fertilizer. By preventing over-fertilization, the sensor would reduce costs and help preserve the environment. Researchers are currently demonstrating the technical feasibility of the sensor and characterizing basic device performance.

GTRI researchers used degenerate four-wave mixing to evaluate the nonlinear refractive index of new organic compounds synthesized at Georgia Tech.

In a project for an industrial sponsor, researchers designed a surface inspection system for detecting and classifying defects in products that are produced in a continuous web. For another sponsor, researchers explored new optical waveguide switching techniques as a means of controlling an array of diode lasers to produce a high-resolution display.

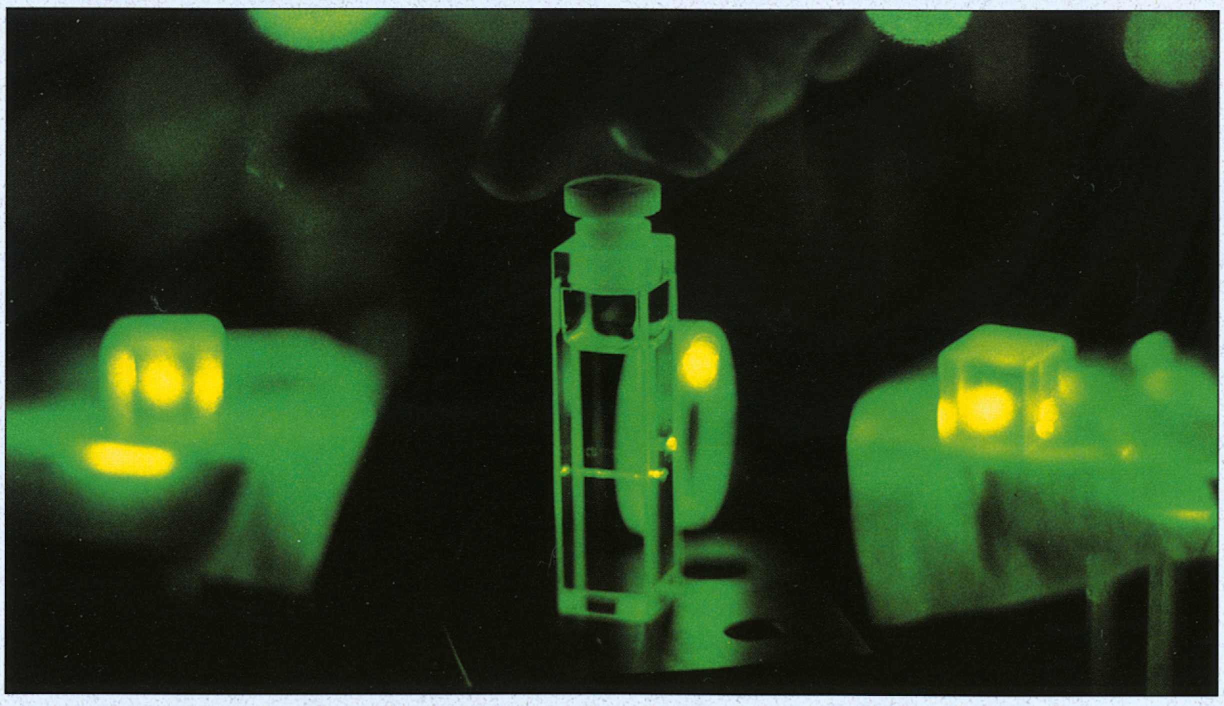
Integrated optics offers new approaches for the control and synchronization of phased-array radars. As part of an internally funded program, researchers are examining gallium arsenide and other III-V semiconductor materials for monolithic integration of both optical and electronic components for use in these radar systems. New phased-array architectures utilizing integrated-optic circuits will be explored, and prototype components will be fabricated and tested. Potential benefits of this technology include lower overall system cost through highly reproducible integrated devices, reduced size and weight, and enhanced performance.

NONLINEAR OPTICS

In a joint project with the School of Electrical Engineering, GTRI researchers are evaluating the third-order nonlinear susceptibilities of a new class of organic compounds synthesized at Georgia Tech. Degenerate four-wave mixing, in which three laser beams interact to produce a fourth beam, is being used to measure the nonlinear refractive index of these dipolar molecules. Researchers are using structure-activity correlations to predict new candidate molecules.

Nonlinear optical effects are also being investigated in multiple-quantum-well and modulation-doped superlattice structures built of aluminum gallium arsenide (AlGaAs) and gallium arsenide (GaAs). In an internally funded program, researchers are fabricating and evaluating bistable etalon structures for low-power, fast-switching applications in optical computing. ■

Integrated optics offers innovative approaches for the control and synchronization of phased-array radars.



MICROELECTRONICS

During the past fiscal year, GTRI continued to investigate new materials and growth characterization techniques.

GTRI has broad experience in the chemical and molecular beam epitaxial growth of advanced semiconductor materials. Structures such as atomically abrupt heterojunctions, multiple quantum wells, and modulation-doped semiconductors have been grown for a wide variety of millimeter-wave and optoelectronic applications. During the past fiscal year, GTRI continued to investigate new materials and growth characterization techniques as a means of producing more efficient and high-speed electronic and optoelectronic devices. Researchers also examined the micromechanics of solder connections and surface mount technology, and developed a novel laser detection technique to identify silicon atoms.

QUANTUM-WELL DEVICES

High-electron-mobility transistors (also known as MODFETs — modulation doped field effect transistors) fabricated at GTRI during the past year have demonstrated device performance up to 60 GHz. The inherent higher mobility and associated transconductance of these transistors make possible the fabrication of high-frequency devices, including monolithic millimeter-wave integrated circuits, with less stringent requirements on processing steps such as gate lithography.

Two years ago, GTRI researchers successfully demonstrated resonant tunneling in multiple-quantum-well structures. To better understand and utilize device physics, researchers are now examining the manner and time frame in which an electron tunnels from one quantum well to the next. Potential applications for this technology include electro-luminescent displays, high-frequency microwave oscillators, and electron filters.

Researchers also continued to develop multiple-quantum-well avalanche photodiodes, considered the key to very-high-clarity electronic imaging devices for next-generation video equipment. In FY 90, researchers used an infrared mask aligner to accurately position patterns on both sides of a wafer. This procedure allows more precise measurement of device characteristics.

The reflection high energy electron diffraction (RHEED) technique plays a critical role in producing high-mobility, high-quality materials. During the past year, researchers developed an image-processing system that captures and stores RHEED oscillations. Analysis of the images provides more accurate materials characterization and a better understanding of the molecular beam epitaxial growth process.

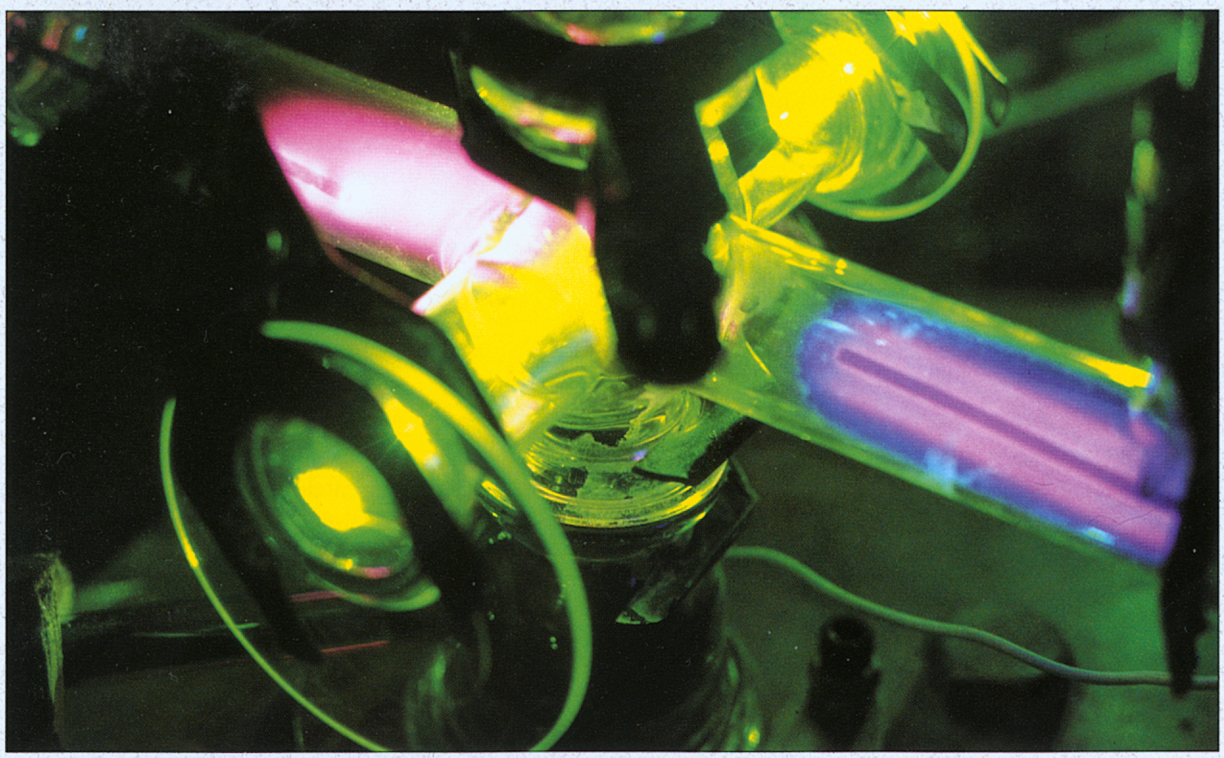
Using internal funds, researchers demonstrated the use of laser-induced fluorescence to optically detect silicon atoms and silicon monoxide molecules. In addition to providing new information about the photodynamics of electronically excited silicon monoxide molecules, the novel laser detection technique could become a useful diagnostic in the plasmas and flames used for the manufacture (growth) of semiconductors and optical fibers.

GTRI researchers use this vacuum chamber to evaporate thin metallic layers onto crystalline surfaces.

II-VI MATERIALS

The class II-VI materials, such as cadmium telluride and mercury cadmium telluride, have significant semiconductor applications, including high-efficiency solar cells and infrared detectors. Their consistent growth, however, has been difficult to achieve because of their extreme volatility. The flexibility of conventional molecular beam epitaxy has been limited because little control is possible over the atomic species applied to the growth surface or its temperature. In FY 90, GTRI researchers reported the first growth of high-quality II-VI materials by chemical beam epitaxy, and developed an accurate method for consistently measuring the growth surface temperature.

In chemical beam epitaxy, the use of hydride or metal-organic sources enables greater flexibility and more precise control to be achieved over the chemical reactions occurring during the growth process. GTRI's chemical beam epitaxy system includes pressure-controlled, direct-injection flow



GTRI scientists developed a novel laser-induced fluorescence technique to optically detect silicon atoms and silicon monoxide molecules.

controllers for accurate and reproducible flux settings, separate cracking injectors for II and VI materials, and a pressure-controlled mercury vapor source. The growth of cadmium telluride and mercury cadmium telluride is being investigated, along with the appropriate growth chemistry.

Researchers also developed a new *in-situ* method for accurately measuring the growth surface temperature of II-VI substrates. The highly sensitive technique is based on changes that occur in the RHEED pattern of the epilayer when a source element sublimates from an effusion cell and condenses on the substrate surface.

Interconnection Technology

As integrated circuits become increasingly complex, leads and solder joints must become ever smaller, yet provide greater mechanical support. In FY 90, GTRI researchers explored the durability of new solder materials as well as new methods of applying solder and cleaning up after the soldering process. Using state-of-the-art micromechanical instrumentation, researchers also investigated creep, fatigue, tensile, and other mechanical characteristics of solder alloys and their interfaces.

The individual assembly and testing of many transmit/receive elements is a major cost in the construction of phased-array antennas. During the past fiscal year, GTRI assisted the U.S. Air Force in evaluating a program to build cost-effective solid-state transmit/receive modules and integrate them into a 100-element phased array. Researchers monitored module performance, investigated premature failures, and analyzed package resonance problems.

For a major producer of high-power fuse links used in power distribution systems, GTRI researchers investigated the potential effects of age deterioration on service reliability. Microstructural characteristics of new fuses were compared with samples that had seen years of extensive use. Researchers also examined the susceptibility of fuse elements to sharp, short-duration power surges caused by nearby lightning strikes.

Other Research

In other activities, GTRI researchers:

- Explored new optically active semiconductor materials for potential use as microwave phase shifters;
- Examined the applicability of surface-mount technology to the very high reliability and long-term storage requirements of missile electronics; and
- Investigated the phenomenon of electromigration, a fundamental wear-out mechanism in microelectronics, including mechanical stress and strengthening phenomena in thin metal films on semiconductors. ■

Infrared/Electro-Optics

During the past fiscal year, GTRI researchers continued to develop and apply new technology for light detection and ranging (LIDAR) systems, including compact airborne units and a novel eye-safe system. Researchers also developed more realistic infrared scene simulation models, assessed the susceptibility of aircraft to particular infrared missile threats, and investigated numerous issues related to the successful fusion of diverse electro-optical sensors.

Researchers continued to study the effects of clouds on radiative heat transfer in the atmosphere.

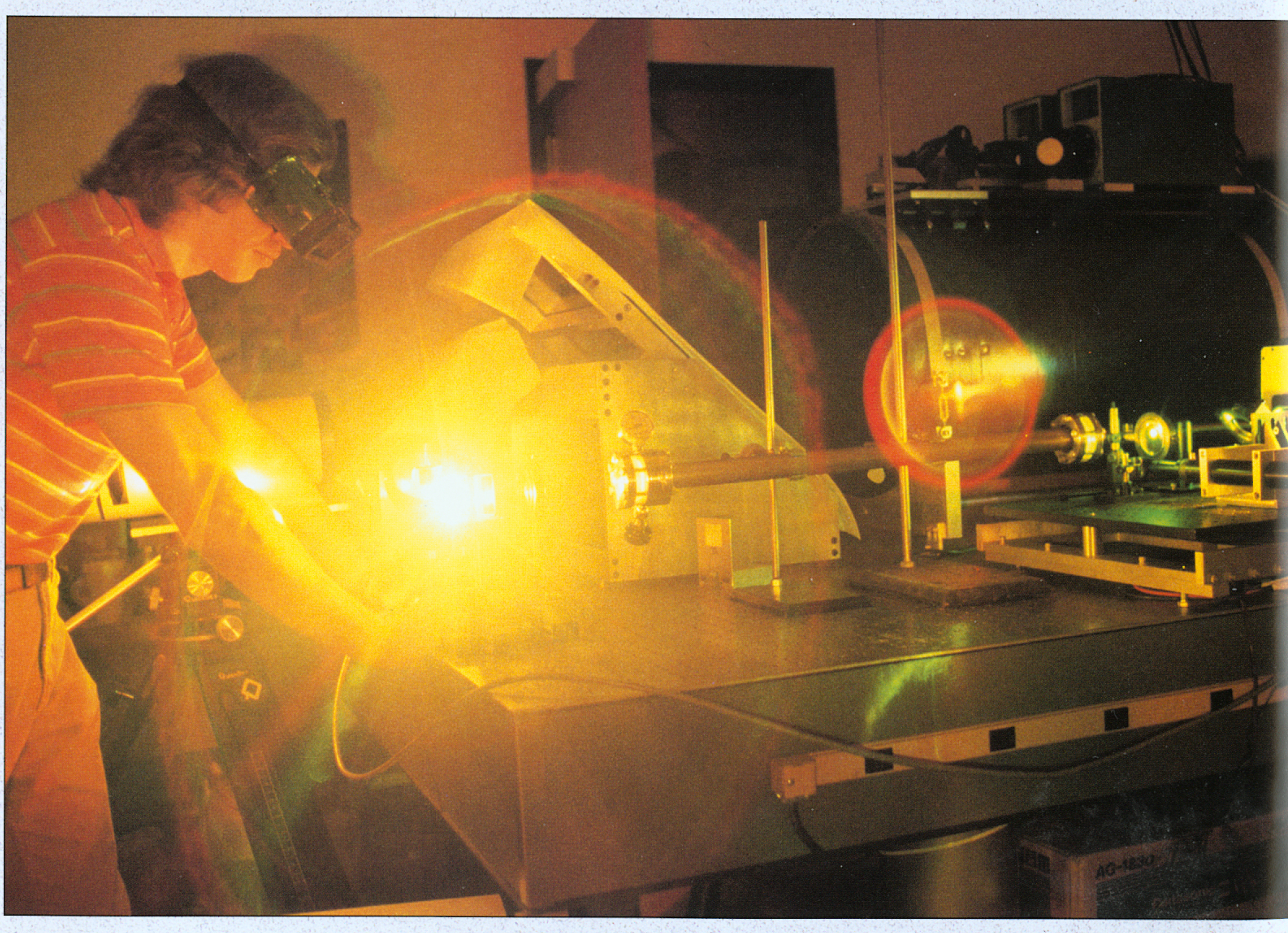
Remote Sensing

In a joint project with the University of Washington, GTRI researchers designed a compact airborne lidar to detect and measure the spatial distribution of dust particles and aerosols in the boundary layer of Earth's atmosphere. This instrument has been used in ground-based atmospheric characterization studies at the White Sands Missile Range and in airborne studies of arctic haze layers.

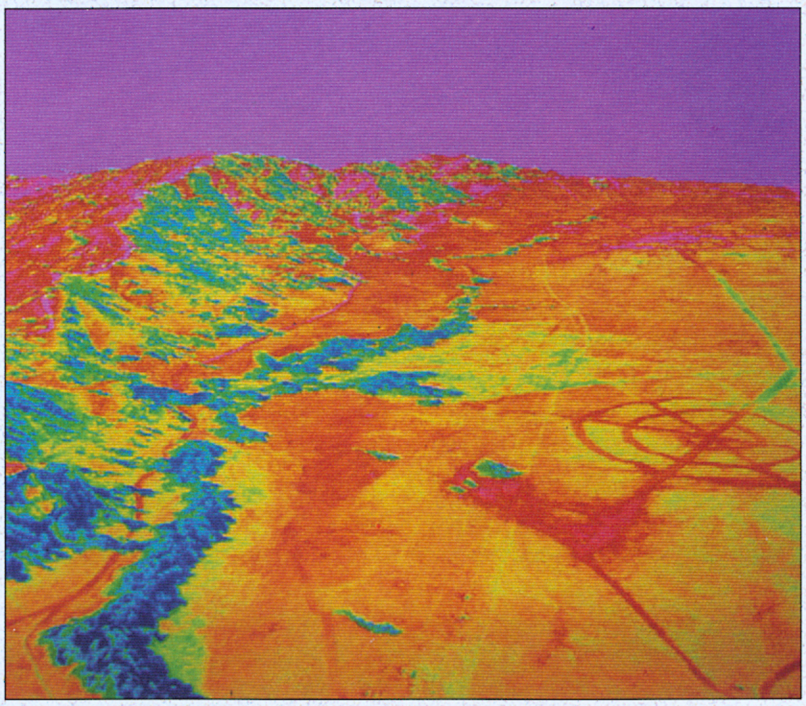
In another lidar project, researchers participated in an international Experimental Cloud Lidar Pilot Study. A worldwide network of lidar stations coordinated ground-based measurements with satellite overflights to determine cloud base heights, optical depths, and structural properties.

The powerful lasers normally employed in lidars are potentially harmful to eyesight up to several miles away. During FY 90, GTRI researchers designed, built, and demonstrated a reliable and low-cost eye-safe lidar system. The internally funded prototype used a methane-filled gas cell to shift the output of a neodymium-YAG laser into the infrared portion of the spectrum.

During the past fiscal year, researchers continued their study of the effects of various types of clouds on radiative heat transfer in the atmosphere. To determine interactions between clouds and



radiation, researchers are combining data from four independent sensors: a visible-light lidar, an infrared spectro-radiometer, a television camera, and a thermal imager.



GTRI analysts used a high-resolution database to create this thermal infrared model of a mountainous region in California.

Scene Simulation

During FY 90, researchers enhanced the capabilities of the Georgia Tech Visible and Infrared Synthetic Imagery Testbed (GTVISIT). This software package can generate three-dimensional scenes in the visible through infrared bands, using standard computer graphics algorithms for perspective projection, hidden surface removal, and pixel shading. Improvements include the addition of a mountain desert scene and new foliage models which use fractal subdivision to conserve data storage and increase processing speed.

In a project for the U.S. Air Force at Warner Robins Air Logistics Center, GTRI researchers examined the susceptibility of helicopters to infrared missile threats. Researchers combined key simulation resources, including GTVISIT, GTSIG (Georgia Tech Signature Code), and DISAMS (Digital Infrared Seeker and Missile Simulation), to produce highly accurate models for assessing susceptibility and evaluating potential countermeasures. In addition, computational fluid dynamics codes were used to calculate the helicopter exhaust plumes for predicting realistic infrared signatures.

GTRI also continued work on the Project Manager, Training Devices (PMTRADE) program for the U.S. Army. Using GTVISIT, researchers are developing realistic infrared models of selected ground and aerial targets to be used as tools for training soldiers in their proper identification. Atmospheric disturbances, as well as battlefield obscurants such as dust, clouds, and smoke, are being incorporated in the scene simulation models.

Sensor Fusion

The successful fusion of several sensors operating in different regions of the electromagnetic spectrum has the potential of providing greater target-identification capability than a single sensor alone. During FY 90, GTRI researchers developed special simulation software that can generate multi-spectral sensor data for both targets and clutter. Called GTSPECS, this internally developed software package provides new modeling capabilities for multi-spectral sensors containing millimeter-wave radars, infrared sensors, and synthetic-aperture radars.

In a project for the Rome Air Development Center, researchers coupled the superb spatial resolution of infrared sensors with the excellent ranging ability of radar systems. Such fusion can maximize the probability of detecting low-flying targets at long range while significantly reducing the number of false alarms. In addition to developing techniques for proper scene registration between the two sensors, researchers incorporated a number of spatial and velocity checks to ensure accurate target motion prediction.

In a sensor fusion project for the Wright Research and Development Center, GTRI researchers are developing sensor modeling tools to predict signature characteristics that could be used to uniquely identify targets. This Multi-Attribute Identification and Analysis (MAIDA) program will ultimately combine features from signatures obtained with a variety of sensors to automatically identify fixed-wing aircraft. ■

GTRI researchers continued to develop new light detection and ranging (LIDAR) systems.

Computer Science & Information Technology

In FY 90, major emphasis was placed on designing knowledge-based systems for autonomous vehicles.

During the past fiscal year, GTRI researchers explored new concepts in computer systems and technology to enhance the traditional roles of command and control, route planning, and mission support. Major emphasis was placed on developing expert systems to assist pilots of semi-autonomous aircraft and designing knowledge-based systems for fully autonomous vehicles. Researchers also investigated the application of neural networks to problems in vision recognition and radar signal processing.

In one major program, state-of-the-art computer system development technologies were utilized to support the U.S. Army Light Helicopter (LH) acquisition process. Proposed designs for LH mission equipment packages are nearing the end of the demonstration and validation phases, and will soon go into full-scale development. GTRI provided systems engineering and technical assistance to the LH Program Office to aid in evaluating competing designs and assessing their ability to meet anticipated mission needs.

GTRI researchers also assisted the Joint Integrated Avionics Working Group (JIAWG) with the development of advanced avionics systems and software that allow the three military services to reuse components and transfer technology between programs. This year, JIAWG released a landmark set of documents entitled the Common Avionics Baseline III. Consisting of military standards and specifications, the baseline defines tri-service common modules that should aid in the development of all future military aircraft.

In FY 90, GTRI's new Route Evaluation Module was delivered to the U.S. Air Force and became one of six tools composing the Central Tactical Air Planning Systems workstation. Developed jointly with Morris Brown College in Atlanta, Georgia, the module consists of a decision-support system designed to assist force-level planners in the day-to-day battle management of all flying units within a theater of operation.

In a project with Litton Computer Services and the Army Research Institute at Fort Benning, GTRI provided design and implementation support for a multipurpose arcade combat simulator. This inexpensive, but effective, training device uses a rifle-mounted light pen to "shoot" simulated range targets. The system encourages skills improvement by providing feedback on weapon steadiness, trigger squeeze, and aim.

Artificial Intelligence

GTRI has become a recognized leader in the development of knowledge-based autonomous vehicle systems. To address the dynamic requirements of real-world route planning, researchers developed the Heuristic Autonomous Route Planning Oracle. This system consists of five independent knowledge sources which utilize a blackboard architecture to generate adaptive routes based on factors such as terrain constraints, tactical requirements, and vehicle characteristics.

Unmanned aerial vehicles have advanced from experimental prototypes into fully operational units capable of reconnaissance and munition delivery. New applications are directed towards missions involving multiple relay and penetrator aircraft. But as the utilization of these vehicles increases, so does the workload on the human operator.

For the U.S. Army Missile Command, researchers developed a Multiple Aerial Vehicle Expert (MAVE) system that allows a single ground station operator to monitor and control up to six unmanned aircraft. GTRI's Generic Expert System Tool forms the architectural core of the MAVE system, while the Heuristic Autonomous Route Planning Oracle provides the reactive mission replanning capability. Using MAVE, an operator can integrate aircraft control to achieve overall mission goals.

During the past year, researchers continued development of a software testbed in which artificial intelligence techniques can be applied to the management of electronic countermeasures (ECM) resources. Called TECAIM (Testbed for Electronic Combat Artificial Intelligence Methods), this project represents the initial step in a program of research with the ultimate goal of developing intelligent ECM systems capable of continuous resource planning, real-time ECM resource allocation, and real-time ECM effectiveness monitoring.

In other work, researchers developed an expert system capable of evaluating images and determining which algorithms are most appropriate for any given task. Known as Blackbox, the system looks for cues in the environment surrounding the image of interest that make recognition easier and less computationally intensive. By varying its selection based on the types of imagery it receives, Blackbox could serve as an adaptable front end for existing vision systems.

Contextual cues play an important role in another expert system developed by GTRI. TANKS (Target Analysis Through Non-Deterministic Knowledge-Based Systems) can represent motion in images as they are recorded, a feature of significant value in target recognition. As a result, TANKS can assign image enhancement, segmentation, and other recognition algorithms to separate processors, seeking out further clues to an object's identity.

Neural Networks

In FY 90, researchers continued to explore neural network technology as a potential solution to problems in computer vision and speech recognition, and as a means of rapidly performing radar classification. Using internal funds, GTRI acquired a transputer to support parallel processing and software development.

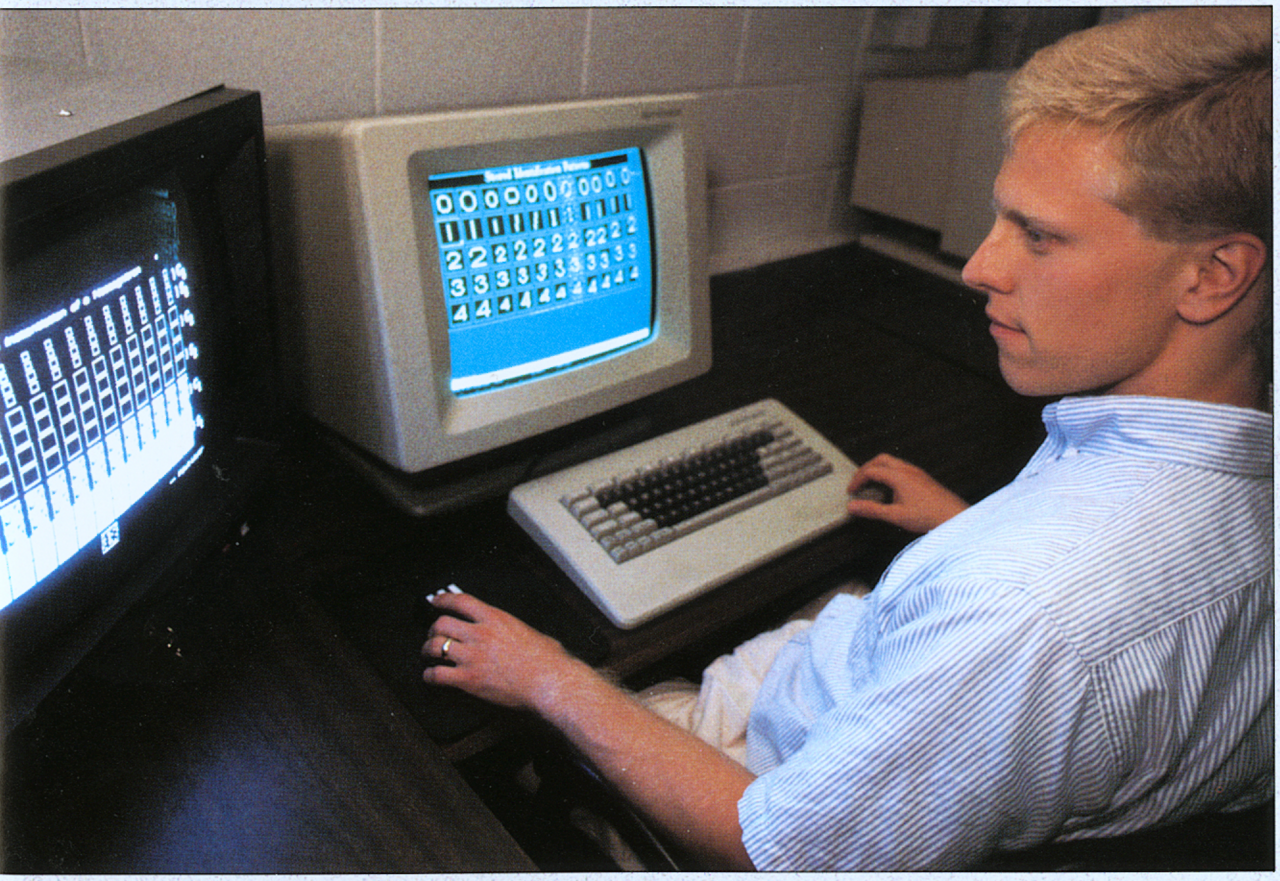
The massive parallelism offered by neural networks holds considerable potential for near real-time identification of pulsed emitters in a crowded battlefield environment. In a program funded by the Wright Research and Development Center, researchers are examining the characteristics of radar data and selecting a set of paradigms suitable for analysis.

In a similar, internally funded project, researchers used the neural network approach to identify emitters from conventional data collected with radar warning receivers. Using back-propagation techniques, researchers developed software that simulates both the training and functional modes of a neural net system.

Other Research

Other significant research efforts included:

- Developing an expert system to perform three-dimensional machine-vision classification and recognition tasks;
- Exploring object-oriented programming as an alternative approach for threat penetration and route assessment;
- Enhancing and integrating software used in the U.S. Air Force Mission Support Systems;
- Investigating the translation of autonomous route-planning and threat-response software simulations into real-time hardware systems; and
- Designing a uniform user interface to assist in the development and application of new software packages at the Material Handling Research Center. ■



GTRI researchers investigated the application of neural networks to problems in vision recognition and radar classification.

Aerospace Sciences & Technology

New facilities coupled with GTRI's traditional expertise in aerospace sciences provide comprehensive tools for theoretical analysis and experimentation.

In the past year, Lockheed Aeronautical Systems Company donated a multimillion-dollar complex of advanced aeroacoustics, fluid dynamics, and aerodynamics research facilities to Georgia Tech. Formerly part of Lockheed's Advanced Flight Sciences Department, the facilities include a unique anechoic flight simulation chamber, flow visualization laboratory, hot jet flow facility, and two low-speed wind tunnels. Coupled with GTRI's expertise in electronics, aerospace engineering, and computational fluid dynamics, these facilities provide comprehensive tools for theoretical analysis and experimental validation of new aerodynamics concepts and configurations.

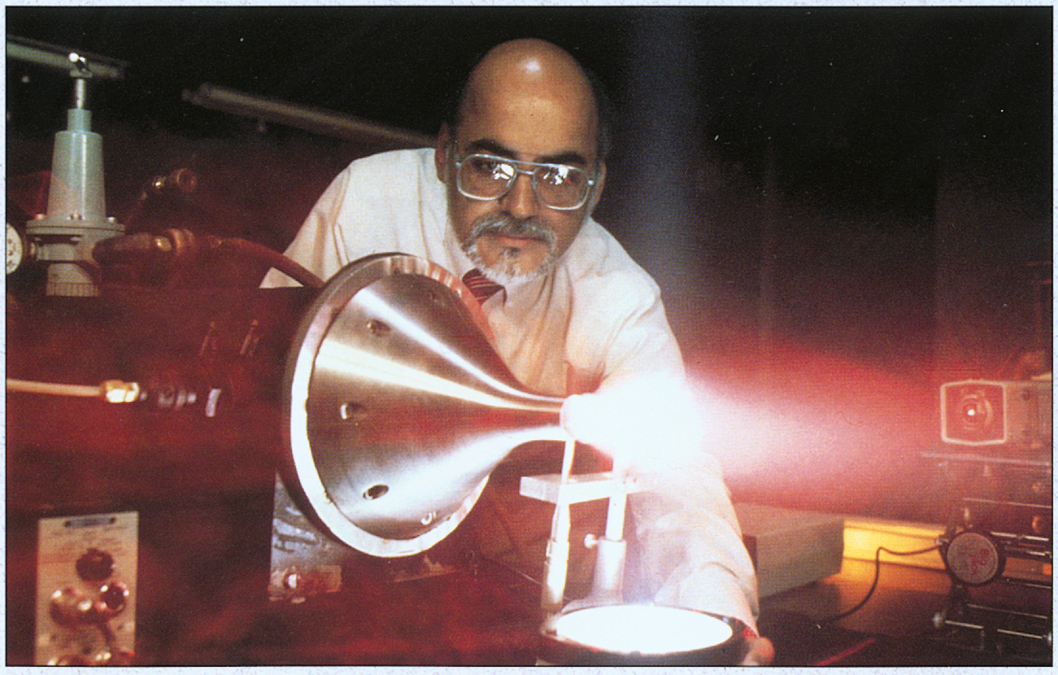
Aerodynamics

In a project for Martin Marietta Missile Systems, GTRI is using the new facilities to analyze the aerodynamics of a novel air induction system for an advanced cruise missile. Using computational fluid dynamics, researchers are generating three-dimensional models of flow fields through various inlets and studying their efficiency, as well as their effect upon external aerodynamic performance.

In two separate projects for Lockheed, GTRI researchers used the subsonic wind tunnels to optimize the aerodynamic configuration of an advanced tactical transport aircraft and to examine the effects of various antenna configurations on the flight performance of a proposed surveillance airplane.

Using internal funds, researchers are combining complex computational fluid dynamics codes and experimental techniques such as laser velocimetry to develop and evaluate advanced airfoils.

GTRI researchers use this low-speed flow visualization technique to conduct preliminary studies of flow interactions.



Structural Dynamics

GTRI is a recognized leader in the development of high-temperature materials for radome applications. During the past year, researchers continued to support the U.S. Army Strategic Defense Command in the structural and thermal analysis of silicon nitride radomes and actively cooled metallic radomes designed for high-speed interceptor missiles.

In a similar project for the Rome Air Development Center, researchers are analyzing a variety of candidate materials for potential use as aircraft communications radomes. Samples are being measured for electromagnetic transmission, mechanical strength, and thermal sensitivity before and after extended exposure to various environmental effects, including moisture, ultraviolet radiation, and sulfur dioxide.

For the U.S. Special Operations Forces at Warner Robins Air Logistics Center, GTRI engineers analyzed the capability of the MH-53J (PAVE LOW) helicopter to be operated at gross weights substantially higher than originally designed. Through analysis of structures, aeroelasticity, and flight performance, engineers identified improvements that would significantly enhance vehicle responsiveness and operational safety.

As part of a Service Life Extension Program, engineers examined ways to improve the operating life of the MH-53J through specific design changes and incorporation of appropriate new technology.

Aeroacoustics

With the acquisition of the Lockheed facilities, GTRI initiated a major research thrust in aeroacoustics. In a project for NASA, researchers investigated the use of mechanical tabs as a means of reducing the temperature and velocity of heated plumes emanating from jet engines. When properly inserted in the exhaust nozzle, the tabs aid in the rapid mixing of plume gases with air flowing past the aircraft.

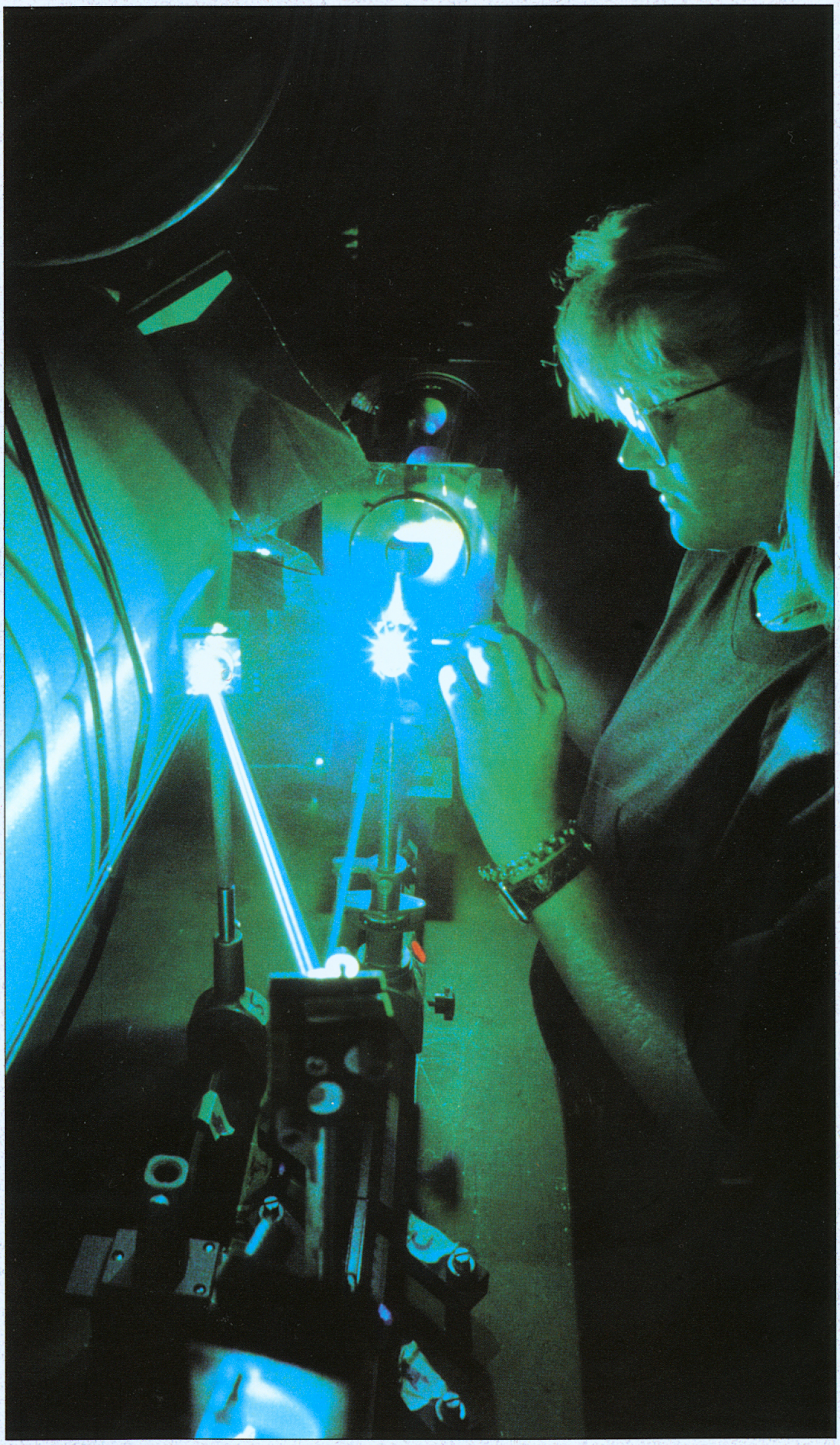
In another NASA project, researchers are exploring various concepts for reducing noise generated by supersonic jet engines. This research has already shown significant noise reductions through the use of novel noise suppressors, coaxial rectangular engine nozzles, and special entrainment devices. This technology could be applied to existing supersonic aircraft, as well as the proposed high-speed civil transport.

GTRI recently began a major three-year program with the NASA Langley Research Center to investigate a variety of acoustic phenomena. Projects will include studying the effects of sonic booms on buildings and humans, examining the effects of atmospheric disturbances on sound propagation, and improving existing aircraft noise prediction codes through new experiments and theoretical modeling.

Other Research

Other significant areas of research included:

- Investigating missile guidance and control problems associated with small, lightweight interceptors;
- Using computational fluid dynamics to model the infrared signatures of helicopter plumes;
- Developing new models for active noise control and adaptive cancellation techniques; and
- Exploring new methods for reducing wind noise generated by automobile antennas, roof racks, and mirrors. ■



GTRI aeroacoustics engineers used a laser schlieren setup to investigate ways of reducing noise generated by jet engines.

ELECTROMAGNETIC COMPATIBILITY

New redesign and retrofit programs help adapt electronics to tight spaces without sacrificing performance.

In aircraft and other operating environments where large amounts of electronic equipment must be co-located, the potential for electromagnetic interference (EMI) is high. Engineers must be concerned with the electromagnetic effects that existing and added equipment will have on one another.

During FY 90, GTRI engineers continued to support several redesign and retrofit programs that adapt electronics to tight spaces without sacrificing performance or reliability. Activities included EMI assessments of proposed designs, troubleshooting of reported problems, detailed analyses of electromagnetic field coupling to antennas and wires, and extended on-site measurements of radiated electromagnetic field levels and signal-coupling levels between critical equipment.

Electromagnetic interference from high-energy field transients external to an aircraft can also cause electronic systems to malfunction. A major GTRI study assessed the EMI susceptibility of integrated circuit devices having electro-optic, acousto-optic, or magneto-optic interfaces similar to those planned for use in photonic-based military systems. Researchers will develop a test methodology, characterize representative devices, and specify circuit design techniques to reduce EMI effects on military systems employing these devices.

AUTOMATED TESTING FACILITY

Many critical electronic systems on aircraft must operate in the presence of electromagnetic fields produced by commercial and military sources such as traffic-control radars and radio or television transmitters. To preclude the upset of critical electronics, realistic testing must be performed.

In the past fiscal year, GTRI continued work on designing, procuring, and installing an automated testing facility. The system will provide a well-defined and carefully controlled test environment that duplicates the electromagnetic fields produced by typical high-powered transmitters. In addition to supplying the overall systems engineering and integration, GTRI engineers are writing the software for controlling the exposure environment and monitoring test results.

CONDUCTIVE SEALANTS

In another program, GTRI researchers completed development and laboratory testing of special conductive sealants designed to protect aircraft joints from metal corrosion and maintain the electromagnetic interference requirements. Researchers assessed electrical resistance, shielding effectiveness, and corrosion resistance of two types of conductive sealants that demonstrated superior protection. These two sealants were applied to U.S. Air Force aircraft for field tests and further evaluation.

A related, internally funded project examined the effects of corrosion and aging on radio frequency bonds and gaskets. Three kinds of gaskets were exposed to benign, normal weathering, and highly corrosive environments. Electrical resistance, shielding effectiveness, and transfer impedance tests were conducted to determine the effectiveness of various mounting and surface protection techniques.

OTHER RESEARCH

Other significant research included:

- Evaluating new wiring concepts for the "smart house" of the future; and
- Expanding the ongoing testing program for pacemakers to include defibrillators. ■

GTRI engineers conducted electromagnetic interference tests on monolithic microwave integrated circuits.

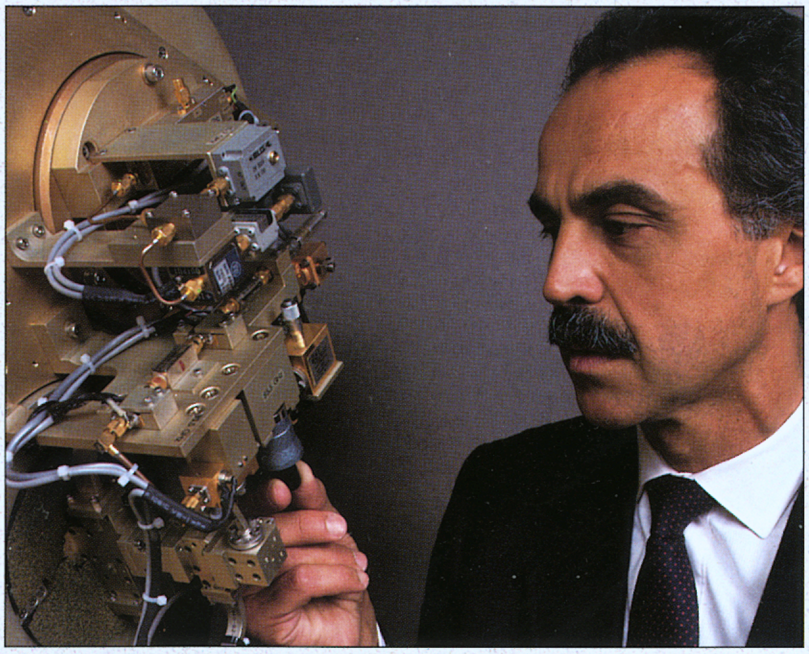
MILLIMETER-WAVE TECHNOLOGY

For the past 25 years, GTRI has made significant contributions to basic and applied research in the millimeter-wave spectrum. In the last fiscal year, researchers continued to pursue a variety of projects covering radar, communications, missile guidance, target identification, and imaging radiometry for remote sensing applications.

In one notable effort, researchers developed an advanced microwave precipitation radiometer that will operate at 10.7, 19.35, 37.1, and 85.5 GHz on future airborne measurements for NASA. The instrument will fly on the ER-2 research aircraft at an altitude of 20 kilometers, measuring the scattering and emission signals of precipitation and providing information on the intensity of storms. With capabilities to image at the identical millimeter wavelengths as the Special Sensor Microwave/Imager, the radiometer will also be used in conjunction with that spaceborne instrument.

In another NASA-related project, GTRI has teamed with Electromagnetic Sciences in Atlanta, Georgia, to design a unique microwave reflectometer ionization sensor. This instrument, to be flown as part of NASA's Aero-assist Flight Experiment, will probe the critical electron density, reflectivity, and other characteristics of a plasma that forms around reentering spacecraft. These measurements will be useful in determining better ways to utilize Earth's atmosphere in slowing down space vehicles on reentry.

During the past fiscal year, GTRI researchers continued to investigate the reception characteristics of substrate-mounted millimeter-wave antennas. These miniature antennas are manufactured on the same substrate as the integrated circuit electronics, so the incoming signal can be received and processed on a single chip. Potential applications include free-space power transmission and millimeter-wave imaging.



GTRI researchers designed and built an advanced microwave precipitation radiometer to provide information on storm intensities.

Researchers have developed an advanced microwave precipitation radiometer that will aid studies on NASA flights.

SPECIAL RADAR SYSTEMS

In a project for White Sands Missile Range, engineers are designing a special radar system to determine target motion characteristics of smart munitions. The radar must track a large carrier vehicle, identify when the dispersion event occurs, select and initiate tracking on an individual submunition, and record relevant motion data until impact.

In FY 90, GTRI participated in the joint Army/Air Force "Chicken Little" program designed to evaluate existing seeker sensor systems. Simultaneous millimeter-wave and infrared measurements of tactical vehicles were obtained and analyzed.

In related work, GTRI is assisting Eglin Air Force Base with the development of an airborne 95 GHz instrumentation radar. When completed, this system will be flown concurrently with "Chicken Little" captive flight tests to better understand seeker performance and to collect high-resolution measurements of targets and clutter.

OTHER RESEARCH

Other significant areas of research included:

- Assisting the U.S. Army in defining the weather conditions in which a smart munition can operate effectively;
- Correlating superconducting ceramic properties at centimeter-wave and millimeter-wave frequencies with physical and chemical properties; and
- Validating theoretical models for temperature dependence of dielectric/magnetic mixtures. ■

ANTENNA DEVELOPMENT

In the past fiscal year, GTRI continued to develop new technologies for making near-field measurements, beam-forming radars, and antenna-performance and target-scattering analyses. Using internal funds, researchers began exploring new initiatives involving fundamental properties of modern phased-array radars. The year's highlights included delivery of one of the world's largest compact ranges and the start of a major new program thrust with the U.S. Army.

GTRI's modulated scattering technique can reduce measurement times by a factor of 25 or more.

The Army's tactical satellite sensor system of the future could play a vital role in providing forward battlefield information to field commanders. The ability to interconnect several major range and test facility bases into a geographically distributed testbed would facilitate assessment of these space-based sensors against a variety of targets. In FY 90, GTRI engineers began an extended effort to provide technical support to the Army Space Systems Test Bed. Tasks include designing specialized communications systems, exploring new testing technologies, and determining range integration requirements. GTRI is also assisting the Army by providing input to the Defense Space Test Capability Initiative, to develop a national test capability for the combined forces.

GTRI designed and built the first compact range in 1967. In the past year, engineers completed delivery, installation, and initial testing of one of the world's largest compact ranges. Built for the U.S. Army Electronic Proving Ground at Fort Huachuca, Arizona, the range will allow testing of microwave and mil-

GTRI engineers completed delivery and installation of one of the world's largest compact ranges at Fort Huachuca, Arizona.

limeter-wave antennas mounted on full-size aircraft, tanks, and other vehicles. The system includes an offset-fed parabolic reflector 75 feet in diameter, a novel positioner capable of supporting up to 70 tons, and a set of five feedhorns to cover frequencies from 6 to 40 GHz.

When assembled in orbit, the NASA space station will bristle with diverse antennas. Due to the station's complex geometry, scattering effects from nearby structures and components could seriously degrade antenna performance. In a project for the Johnson Space Center, GTRI engineers examined proposed antenna locations, functions, and space station geometry to determine which features might interfere with proper antenna operation, and identified appropriate methods for analyzing antenna performance.

Near-Field Technology

GTRI has been advancing the theory and practice of near-field measurements since the early 1960s. To facilitate continued development of this important technology, in FY 90 researchers implemented a new 10- by 12-foot planar near-field range. Capable of operation up to 40 GHz, the range is designed to use an active laser compensation system for accurate z-axis correction. Experience gained with the new range will assist in advancing practical applications for near-field testing, such as on-site measurements using a portable facility.

Near-field measurements of antenna fields help predict how antennas will perform in actual use. However, measurement times associated with conventional near-field techniques can become excessively long for electrically large or sophisticated antennas. In a project for the U.S. Army Communications - Electronics Command, GTRI researchers demonstrated laboratory prototype measurement systems based on the modulated scattering technique that can substantially reduce measurement times.

The technique, developed jointly with researchers from the Ecole Superiéure d'Electricité (SUPELEC) in Paris, France, uses a 128-element array of modulated scattering probes to vertically scan an antenna's field or a target's scattered field by electronic means while moving in a horizontal direction. The new technique can reduce measurement time by a factor of 25 or more over conventional methods. A portable unit for field use is now under development. The feasibility of using optically switched materials such as vanadium dioxide to eliminate the present hard-wired multiplexing network is also being explored under an internal research and development program.

Phased Arrays

New technological demands have placed increased requirements on phased-array antennas to accurately position a beam and precisely measure the location of a target. Researchers at GTRI and the School of Electrical Engineering are developing algorithms to analyze and predict the effects of beam-positioning errors on phased-array performance. Calibration methods are being formulated to provide optimal beam-pointing accuracy with the fewest measurements.

To sort out the jumble of electrical returns striking an antenna, researchers are constructing an eight-element beam-forming array that will operate in a bistatic configuration. Unlike conventional phased arrays, digital beam-forming radars are phased in the data processor. By mathematically manipulating the signal received at each element, the array can be "steered" for simultaneous processing of multiple targets.

Researchers are also investigating problems associated with phased-array radars operating with wideband signals. These systems experience significant problems created by frequency dispersion in the antenna and other distortions imposed by the beam-forming hardware. Efforts include modeling these effects for a variety of antenna architectures and signal waveforms, and quantifying them as a function of the antenna specifications. Knowledge of how different signals and processing schemes affect array performance may lead to identification of optimal signal synthesis and processing techniques for these systems.

Other Research

Other major activities included:

- Developing models to predict performance characteristics of a stacked periodic array and element impedance in an infinite-array environment;
- Examining methods of sharing vehicular antennas between multiple subsystems while maintaining minimal radar scattering;
- Designing a multi-element interferometer that conforms to highly curved aircraft surfaces;
- Seeking ways to characterize and predict the mechanisms of cross-polarization in phased-array radars; and
- Developing a novel strip-line lens capable of sorting microwave signals by angle of arrival. ■

RADAR

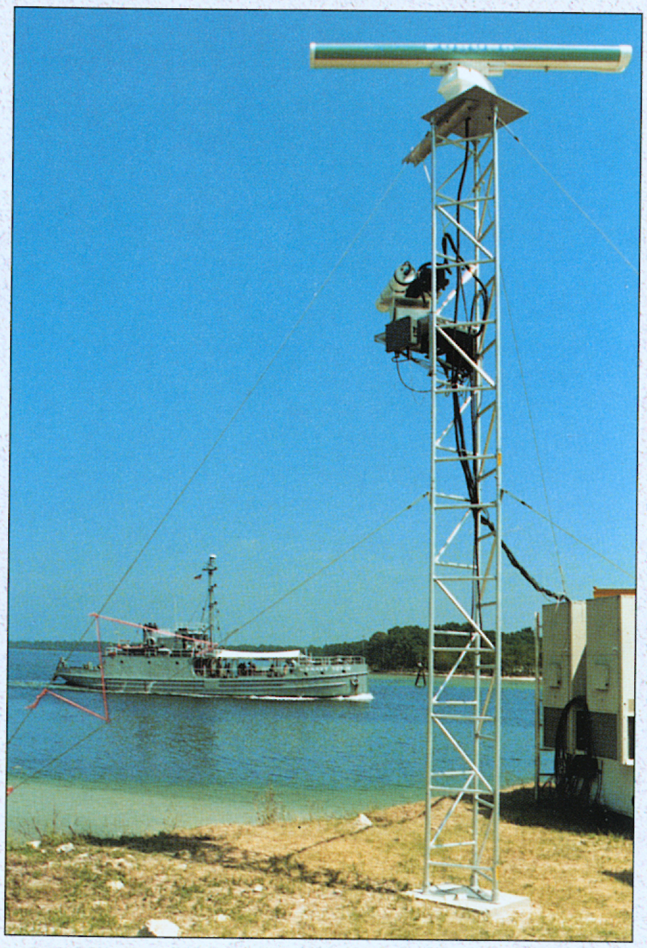
Researchers are exploring new program thrusts involving acoustic sensors and the detection of deadly atmospheric downdrafts.

In fiscal year 1990, GTRI continued a number of radar-related projects, including the development of unique radar algorithms for non-cooperative target identification and the evaluation of electronic devices for physical security applications. In addition, researchers explored several new program thrusts involving acoustic sensors and the detection of deadly atmospheric downdrafts.

Sudden downdrafts associated with severe thunderstorms occurring near airports have contributed to a number of air disasters. The Federal Government has mandated that appropriate wind-shear radars be installed on all commercial aircraft by 1992. In a project with the Research Triangle Institute, GTRI engineers are examining current problems associated with the accurate detection of these dangerous and elusive downdrafts.

In a project for the U.S. Army Missile Command in Huntsville, Alabama, researchers investigated several design performance areas for the Fiber-Optic Guided Missile (FOG-M). A microprocessor-controlled strain sensor was developed to measure tensional forces within the optical fiber during missile flyout. By transmitting modulated signals on an optical carrier, the unit functions much like a radar. In other FOG-M work, researchers studied fiber strength degradation, examined the effects of the adhesive binder on fiber payout, and explored low-expansion bobbins that more closely match the thermal expansion of the fiber.

GTRI researchers also made a substantial contribution to the radar field in fiscal 1990 with the publication of *Radar Reflectivity Measurements: Techniques and Applications*. Edited by GTRI engineer Nicholas Currie, this book deals with the practical problems of measuring and understanding radar reflectivity.



GTRI engineers are helping the U.S. Navy develop new waterside security systems to protect high-value seaside assets.

Physical Security

GTRI has been advising and assisting the government in the evaluation of electronic devices for physical security applications since 1977. Past efforts have included developing radar sensor concepts to protect nuclear production facilities against airborne intrusion, devising techniques for detecting aircraft illegally entering the United States, and designing novel radar interfaces that suppress clutter and automatically recognize and track multiple aircraft and marine targets.

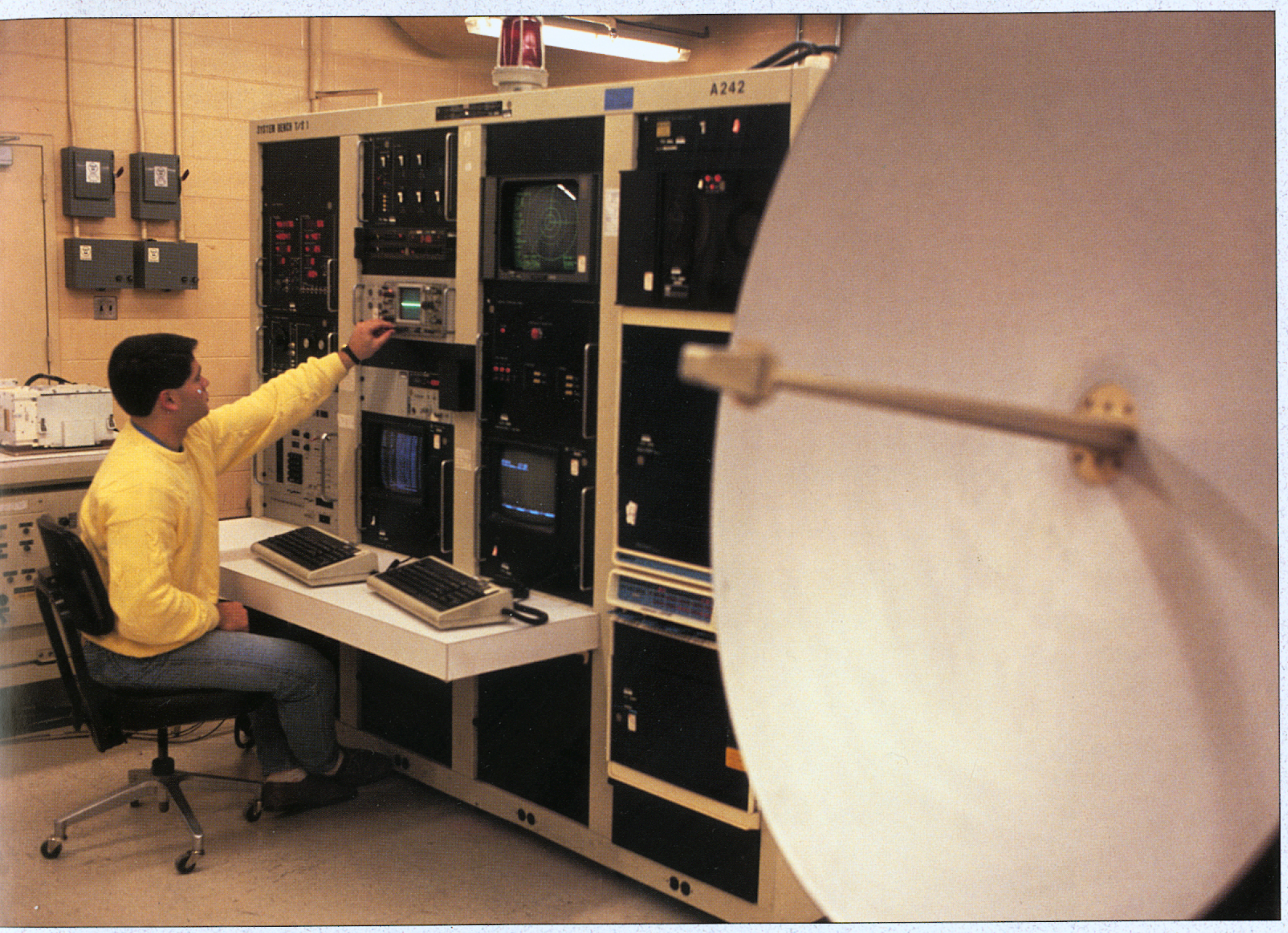
In FY 90, GTRI engineers helped the U.S. Navy decide issues of technical merit concerning waterside security systems. The program mission is to develop a set of sensors and a command and control network to protect high-value seaside assets. Engineers also helped the U.S. Customs Service evaluate components used in a balloon-borne radar that detects aircraft of smugglers along the Mexican-American border.

Airborne Pulse-Doppler Radar

During FY 90, GTRI researchers continued to develop detailed computer simulations of modern airborne pulse-Doppler radars. Modeling efforts for the Wright Research and Development Center included the assessment of electronic countermeasures (ECM) on state-of-the-art fire-control radars and the evaluation of potential electronic counter-countermeasures (ECCM) techniques.

In another project for the Wright Research and Development Center, researchers prepared an ECM vulnerability assessment data base that provides information on past, present, and future ECM/ECCM testing and the availability of data summaries or data archives for specific tests.

The Warner Robins Air Logistics Center supports and upgrades the F-15 fighter aircraft. This advanced aircraft uses a number of programmable computers in the radar and other avionics. GTRI is specifying an F-15 avionics integration support facility for



developing new enhanced versions of the computer programs.

Target Identification

Modern weapons systems can detect a potential threat long before the target can be identified as friend or foe. To prevent accidents, considerable emphasis has been placed on the earliest possible identification of these targets.

In the past year, GTRI continued to support the TAAWS (Target Acquisition for Army Weapons Systems) Program Office in the evaluation of promising target recognition techniques. Radar, infrared, and other non-cooperative target identification systems were evaluated under realistic field conditions.

Researchers also participated in the Multi-Attribute Identification and Analysis (MAIDA) program with the Wright Research and Development Center. This multi-spectral program utilizes sophisticated radar waveforms and electro-optical techniques to extract fine-grained features from target signatures to assist in the long-range identification of fixed-wing aircraft.

Other Research

In other FY 90 programs, GTRI researchers:

- Continued to support the U.S. Army Strategic Defense Command in the development of Ground Based Radar—Experimental;
- Examined the performance of coherent radar systems operating in the presence of internal contaminating elements and clutter;
- Measured the signal reflectivity and attenuation characteristics of space shuttle tiles at very high temperatures; and
- Studied the feasibility of building a common processor to handle multiple sensor-identification technologies. ■

GTRI engineers are assembling an in-house pulse-Doppler radar laboratory for prototype testing of proposed electronics counter-countermeasures techniques.

ELECTRONIC DEFENSE

GTRI continues to evaluate the effects of electronic countermeasures on radar systems and investigate new techniques for electronic counter-countermeasures.

Mission survivability of U.S. military aircraft can be greatly improved through the use of electronic means for self-defense against radar-controlled weapons and heat-seeking missiles. During the past year, GTRI researchers continued to evaluate the effects of electronic countermeasures (ECM) on radar system performance and investigated new techniques for electronic counter-countermeasures (ECCM). Projects included ECM vulnerability assessments, electronic warfare hardware evaluation, and radar warning receiver upgrades. Researchers also developed a new high-speed Doppler radar processor and explored new approaches in optical processing for signal-identification purposes.

In FY 90, GTRI continued work on an Air Force program to enhance the performance, reliability, and maintainability of the AN/ALR-69 radar warning receiver through technology upgrades. Engineers designed and built improved circuit-card assemblies and translated the operational flight-program for software compatibility.

In a program for the U.S. Special Operations Forces at Warner Robins Air Logistics Center, engineers performed modifications and flight tests on radar and ECM hardware used on the PAVE LOW helicopter. To optimize defense avionics activities on the helicopter, engineers are also integrating five independent electronic warfare sub-systems into a single package. The enhanced system features a consolidated display and will provide additional system capabilities, including potential autonomous operation. Technology developed during this phase of the program may also be implemented on other aircraft.

Under the direction of Warner Robins Air Logistics Center, GTRI is designing a high-performance crystal video receiver for the AN/ALR-69 radar warning receiver system. A rigorous engineering analysis of this system will culminate in a segment specification. An additional investigation will determine the best approach for implementing this design using microwave integrated circuit and monolithic microwave integrated circuit technology.

ELECTRONIC COUNTERMEASURES

In the past year, GTRI published preliminary results from one of the most extensive studies ever sponsored by the U.S. Government to determine ECM requirements. The three-year study defined conceptual jamming strategies and techniques which should be considered in developing new ECM systems or in upgrading systems that are already fielded. GTRI engineers worked closely with government intelligence agencies to develop an in-depth understanding of hostile weapons systems and performed detailed mathematical analyses of the most promising theoretical ECM techniques. Recommendations are now being reviewed by several government agencies and ECM equipment manufacturers to determine which techniques should be implemented and tested.

GTRI is assisting the Grumman Melbourne Systems Division in defining a self-defense electronic warfare suite for the Joint Army/Air Force Surveillance and Target Attack Radar System (Joint STARS). This airborne multi-mode radar would look deep into enemy territory from a standoff position to detect both stationary and moving battlefield targets. GTRI engineers are assisting in recommending necessary electronic warfare capabilities and in evaluating the performance of candidate components against projected threats.

NEW PROCESSING TECHNIQUES

The advent of commercially available high-speed digital signal processing chips has suggested the possibility of producing a relatively low-cost digital processor for advanced pulse-Doppler radar systems and simulators. Using internal funds, GTRI engineers are constructing a proof-of-concept generic Doppler processor to replace the special-purpose, high-cost, pulse-Doppler signal processors currently being fielded. The new processor is highly parallel and may be configured to implement fast Fourier transform, filter-bank, and correlator-type Doppler processing.

The application of optical technology to signal-classification problems is the focus of another internally funded program. Researchers from GTRI and the School of Electrical Engineering are developing optical processors to extract parameters such as emitter frequency and pulse-repetition rate from passively received radar signals. These parameters can then be compared optically against stored templates for emitter-identification purposes.

TEST FACILITIES

Accurate testing in a realistic threat environment is crucial to the evaluation of today's sophisticated electronic defense equipment. Ensuring quality control in such an environment, however, has posed serious problems.

In the past year, GTRI engineers developed an emitter mode verification instrumentation system that provides real-time quality assurance of an intended test and evaluation signal environment. The system allows immediate verification of continuous-wave signals and inter-pulse characteristics of pulsed radar signals. Designed to provide automated monitoring capability of threat-radar simulators during both flight and laboratory tests, the system is currently being used in test facilities at the Wright Research and Development Center and Eglin Air Force Base.

In a project for the Warner Robins Air Logistics Center, GTRI engineers designed novel laboratory compatibility test equipment to measure electromagnetic interference effects between systems without resorting to costly anechoic chambers or flight tests. A full-scale mockup containing a one-channel prototype was constructed and tested.

Other Research

In other programs, researchers:

- Determined improvements needed for aircraft tests of avionics, electro-optical, and electronic warfare systems by the Canadian Forces Aerospace Engineering Test Establishment;
- Evaluated, in an operational ECM environment, several candidate designs for the Army's improved FIREFINDER radar system; and
- Designed a software testbed to support the application of artificial intelligence techniques to the management of ECM resources. ■

GTRI engineers are applying optical processing techniques to radar signal classification problems.

COMMUNICATIONS

GTRI researchers are studying adaptive communications waveforms and analyzing a special high-frequency data network.

Communications systems for commercial and military applications continue to provide the basic means for reliable and effective transmission of messages among people, machines, institutions, and governments. During the past fiscal year, GTRI communications engineers investigated techniques to increase the capacity of communications networks, reduce implementation costs, and improve performance in the presence of both natural and deliberate sources of disruption.

In a two-year program for the U.S. Air Force, GTRI engineers are studying adaptive communications waveforms. Major emphasis is being placed on techniques which adapt to changes in the electromagnetic environment. Utilizing a new communications waveform invented at GTRI, engineers will design, build, and evaluate two airborne communications transceivers.

For the U.S. Army, GTRI is analyzing a special high-frequency data network. Technical concerns being addressed include the topology of the network, its performance in the presence of jamming and interference, and low-probability-of-intercept waveforms. In another Army project, researchers are assessing the vulnerability of an airborne data link which supports an area surveillance and target acquisition system.

The growing use of millimeter-wave radars has created a demand for equipment to detect and track hostile radar signals. In FY 90, engineers completed the development of a millimeter-wave direction-finding system for the U.S. Army. The direction finder can track several sources simultaneously, measuring signal parameters such as repetition rate, angle of arrival, frequency, and amplitude.

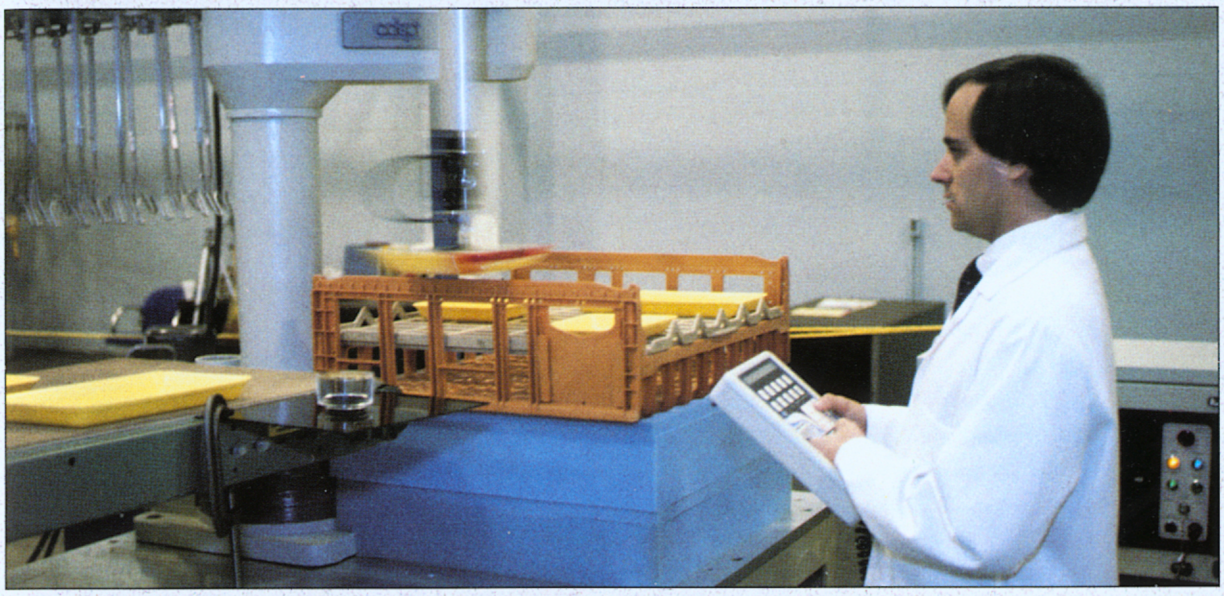
VULNERABILITY ANALYSIS

FY 90 saw the expansion of vulnerability and susceptibility analysis of communications, command, control, and intelligence (C3I) systems. Several new projects made extensive use of formal analysis procedures, including radio-electronic combat vulnerability analysis and data link vulnerability analysis. In support of this work, GTRI communications engineers are developing and applying mathematical models for computing propagation loss, the effects of a wide array of jamming waveforms, and the detectability of emissions in C3I systems. Theoretical results being incorporated include detection algorithms, statistical communications theory, and stochastic processes.

GTRI continues to serve as the prime contractor for a major Air Force program which involves more than a dozen industrial subcontractors. Research topics span most areas of C3I technology, including optical communications and large networks. ■

GTRI communications engineers built a millimeter-wave direction-finding system that can detect and track hostile radar signals.

Agricultural Technology



GTRI's work in the poultry industry seeks to adapt new technologies to immediate and anticipated needs.

Researchers in GTRI's advanced automation research laboratory investigated new applications of robots for the poultry processing industry.

As the poultry industry entered the 1990s, GTRI continued to expand and update its applied research program, seeking to adapt new technologies to the industry's immediate and anticipated needs.

Advanced Automation

One of GTRI's newest projects in processing plant technology involves the use of robots. With increased competition for labor and a growing reported incidence of repetitive motion injury, the poultry processing industry has become increasingly concerned about the impact of these factors on overall operations. Fixed automation has provided only partial solutions to these problems.

Initial research at GTRI indicates that robotics may provide answers to these concerns.

GTRI researchers purchased a commercial robot for experiments involving a variety of applications, with the goal of developing improvements to make it more suitable to perform the tasks required in the poultry processing industry. Studies in FY 90 focused primarily on material transfer tasks.

GTRI's machine vision initiative continued to produce exciting results for the poultry industry. In-plant tests of a sizing and whole-bird grading system were completed, and work continued on improving product lighting. Work also began on true-color image processing, three-dimensional imaging, and X-ray imaging of deboned poultry carcasses.

Wastewater Treatment

Another major concern of the poultry industry is compliance with increasingly stringent environmental standards. GTRI engineers continued development efforts on anaerobic packed bed reactor wastewater treatment technology. In laboratory and field tests, the GTRI-developed technology demonstrated excellent treatment efficiency on poultry processing wastewater, but had high capital and operating costs. In FY 90, researchers investigated substituting less costly packing materials, reducing the volume of these materials, and lowering the reactor temperature as ways to lower costs. They also experimented with using this technology to treat other types of wastewater, and explored methods to treat wastewater without generating huge amounts of sludge.

Other Research

Other research activities included:

- Conducting three special environmental studies to evaluate alternative uses of broiler litter; to improve dissolved-air-flotation waste treatment systems; and to examine methods for disposing of dissolved-air-flotation skimmings;
- Continuing studies of ways to reprocess contaminated birds, including evaluating on- and off-line reprocessing techniques and rapid detection methods for obtaining sample bacterial counts; and
- Providing approximately 50 technical assists to poultry processors and presenting three major workshops. ■

Materials Sciences

Two new patents highlighted GTRI's year of advances in materials sciences, including important new work supporting the Strategic Defense Initiative.

In FY 90, Georgia Tech was awarded two patents for its self-propagating, high-temperature process for synthesizing titanium diboride powder. GTRI engineers began developing applications for a company that has an exclusive license to commercialize the technology. A laboratory-scale hot press was built and installed to establish the parameters of the thermite process, and microanalysis studies were initiated to improve understanding of titanium diboride formation mechanisms. The work was expanded to include synthesis and hot pressing of composite materials.

GTRI continued as a member of a team of materials research contractors which is working on the Army's Materials and Structures effort in support of the Strategic Defense Initiative. Ongoing tasks included developing advanced heat shields for high-speed flight vehicles, evaluating the reliability of solenoid-driven valves which control the flow of fuels, improving design methods for lightweight structures, and evaluating failure mechanisms and long-term reliability of electronic circuit connections.

Asbestos research included work on developing encapsulant materials and standards for testing encapsulants as an alternative to asbestos removal, as well as investigating chemical treatment of *in-situ* asbestos to make the fibers coagulate and render them safe.

Polymeric Materials

Polymer scientists developed several products from trioxane for an industrial sponsor. They also developed a technique for making polyoxymethylene copolymers from trioxane for use in manufacturing magnetic recording tape. The tape's volatile organic content is very low, an improvement over tapes currently used. A patent is pending, and the process is nearing commercialization. Another project involved development of a porous membrane for water purification using trioxane-induced porosity in polymer films.

The electroactive polymeric technology developed by GTRI for use as touch-sensitive pads for industrial robots was investigated for other applications, including orthopedic devices for persons with spinal disorders. Two conductive aircraft sealants designed to fight corrosion, electromagnetic interference, and fire hazard began undergoing field tests by the U.S. military.

Ceramic Composites

Engineers continued their pioneering research into fabrication of advanced fiber-reinforced silicon nitride composites for high-temperature structural applications. Composites demonstrating improved fracture toughness were made both with discontinuous silicon carbide whiskers and with silicon carbide cloth layers, using an ultrafine silicon powder that reacts much more rapidly and at lower temperatures in the nitriding furnace than conventional powders.

A new project began in FY 90 to model chemical vapor deposition of oxidation protection coatings for carbon/carbon composites to be used in building the National Aerospace Plane. The model will be used to guide scale-up of the process for manufacture of large panels.

Scientists investigated continuous processing of carbon fibers in a solar furnace and characterized the structural changes caused by the rapid thermal processing made possible by intense solar radiation. The treated fibers appear to have increased oxidation resistance, making them attractive as components in metal matrix, ceramic, and carbon/carbon composite materials for use in numerous aerospace applications.

Thin Films

Diamond films are of great interest for potential electronic and tribological applications, including high thermal conductivity insulators for microelectronic devices, coatings for infrared and other electromagnetic windows, and biological implants such as heart valves. During FY 90, GTRI researchers successfully deposited high-quality diamond coatings using a plasma-assisted chemical vapor deposition process. They investigated the influence of such process variables as temperature, pressure, reagent concentration and type, and the addition of oxygen and fluorine on coating attributes, such as nucleation behavior, coating rate, and coating microstructure.

In FY 90, Georgia Tech applied for a patent on an improved chemical vapor deposition process for continuous coating of flexible fibers with a thin film of superconducting yttrium barium copper oxide for use as magnet and motor windings. In the new process, a mixture of powdered reagents is fed directly into the furnace, resulting in a deposition rate up to 200 times faster than the conventional vaporizer approach. The powder feeder reduces the number of process variables, providing better control of the mixture and making it easier to achieve repeatable results.

Scientists also experimented with simultaneous co-deposition of boron nitride containing aluminum nitride whiskers by chemical vapor deposition to create dispersed-phase coatings that are tougher and stronger than single-phase materials. The composite coatings were characterized to gain understanding of the nucleation and growth factors that control the microstructure and to learn how to vary the structure to achieve properties desirable for various applications.

Molecular Sieves/Zeolites

In a unique collaboration, scientists at GTRI, Lawrence Berkeley Laboratories, and the University of Oslo, Norway, succeeded in identifying and characterizing the aluminophosphate molecular sieve $AlPO_4$-8. They were the first to discover that this synthetic material contains very-large-pore 18-member rings similar to those in VPI-5. An understanding of the structure and instabilities of these materials will aid in synthesizing similar large-pore molecular sieves for use in petroleum refining.

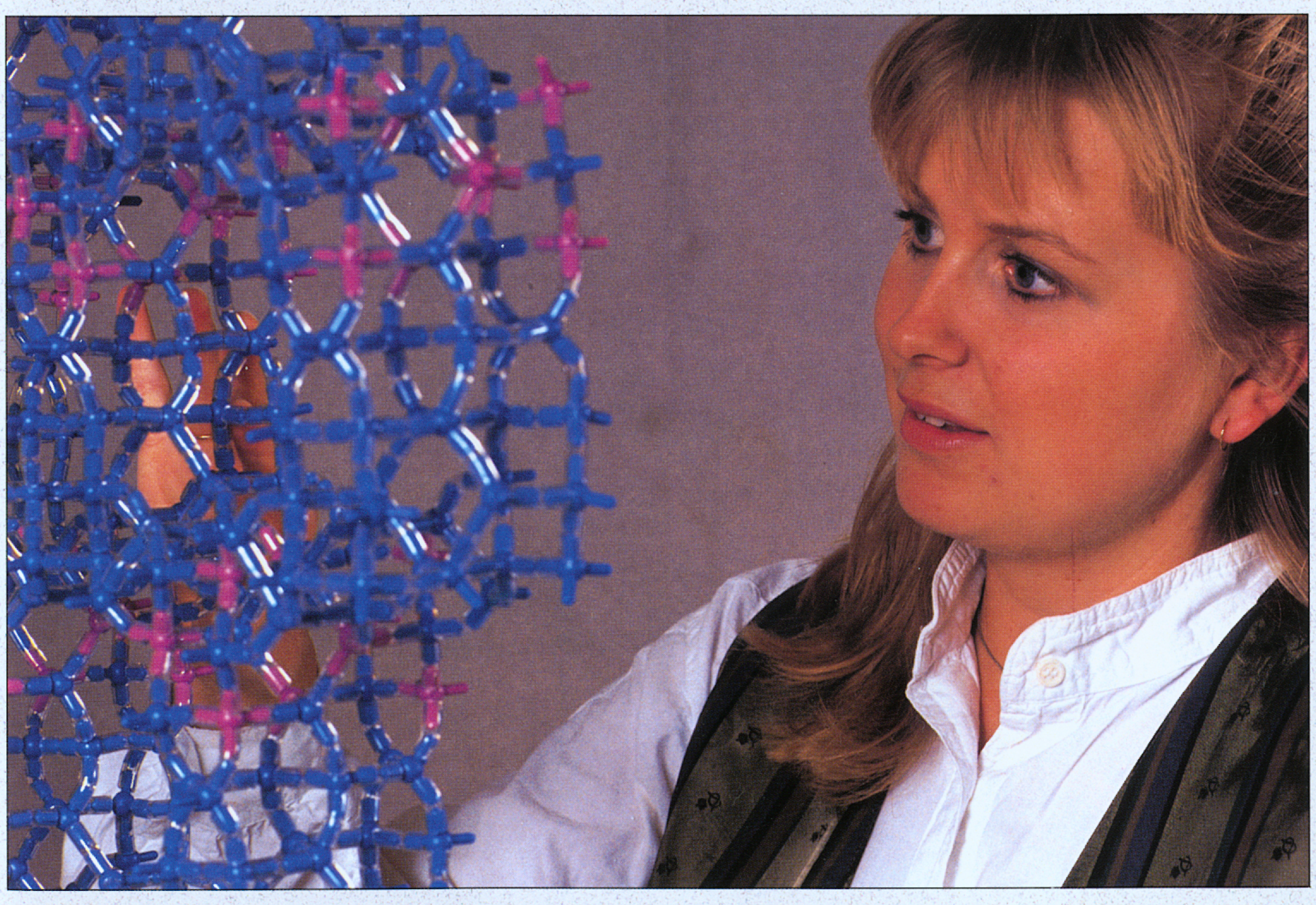
GTRI scientists developed a new aluminophosphate molecular sieve incorporating cobalt to improve a one-step process for converting gasified coal directly into gasoline. They also continued work on modifying zeolites and other adsorbents for better pickup of carbon dioxide from the air in spaces totally dependent on recycled air, such as submarines and space stations.

Other Research

Other significant efforts included:

- Continuing work on three-dimensional modeling of a forced-flow chemical vapor infiltration process for fabrication of ceramic composites that makes it feasible to infiltrate thick parts and speeds infiltration from days to hours;
- Developing the capability for high-temperature solid-state diffusion reactions needed for new antenna window materials; and
- Tailoring the reflectivity and emissivity of materials surfaces, particularly their angular characteristics. ■

Scientists at GTRI continued to synthesize molecular sieves and zeolites with new crystal structures, pore sizes, and chemical compositions.



Environmental Sciences & Engineering

In FY 90, GTRI continued its comprehensive program of research, technical assistance, and training in a broad spectrum of environmental issues — among the most urgent problems facing today's society.

GTRI's research into air quality and other issues is among the institute's most urgent, considering the environmental dangers facing society today.

Indoor Air Quality

Testing of emissions from man-made products was expanded with the design and construction of another large-scale environmental chamber and six small-scale chambers. Products tested included carpet samples for the American Textile Manufacturing Institute. Two highly specialized chambers were built and used to evaluate solid sorbent samplers for radon measurements. GTRI also established an indoor air quality research consortium in cooperation with Emory University and Virginia Polytechnic Institute.

Asbestos research included investigation of techniques to minimize the release of fibers during removal and evaluation of encapsulants as an alternative.

Atmospheric Chemistry

Atmospheric chemistry studies have been ongoing at GTRI for more than a decade to gain understanding of such problems as acid rain, climate modification by greenhouse gases, and catalytic destruction of stratospheric ozone. In FY 90, researchers added a new method of studying chemical reactions, including several that are important in the atmospheric sulfur cycle. The method — time-resolved, high-resolution infrared spectroscopy using tunable diode laser light sources — allows chemical kinetics studies of unstable radicals that are undetectable by other methods, as well as identification of their oxidation products.

The stratospheric-ozone-destroying effects of freons have been widely recognized, but the environmental effects of potential freon substitutes (a number of hydrogen-containing fluorocarbons and chlorofluorocarbons) are not well understood. GTRI scientists participated in the Alternative Fluorocarbons Environmental Acceptability Study sponsored by the World Meteorological Organiza-

tion, investigating whether significant amounts of hydrochlorofluorocarbons, hydrofluorocarbons, and their degradation products can be removed from the atmosphere by dissolution in seawater or cloudwater followed by hydrolysis or chemical reaction.

The OH radical is probably the single most important atmospheric cleansing agent and is essentially the sole atmospheric removal mechanism for many otherwise stable tropospheric pollutants. But its highly reactive nature limits its concentration, making it extremely difficult to measure. GTRI scientists built a prototype of a new, highly sensitive measuring apparatus and tested it in August 1989 at Mauna Loa Observatory, with promising results.

Scientists continued to monitor ions in the troposphere, using tandem mass spectrometric techniques developed over the past eight years. In addition to looking for new ion species and long-term variations in specific species, they searched for large clusters that might be related to aerosol growth. Researchers at GTRI and in the School of Earth and Atmospheric Sciences also filed a record of invention for an interface device that directly couples a gas chromatograph with a mass spectrometer, yielding sensitivity two to three orders of magnitude greater than otherwise achievable.

Hazardous Materials/Safety

The hazardous waste technical assistance program for industry continued with increased emphasis on waste reduction and minimization. A 20 percent sample of the hundreds of companies assisted since 1983 reported total waste reduction for all firms ranging from 245,000 to 338,000 pounds per year and annual per-firm savings of $12,700 to $260,000.

GTRI also assisted the Georgia Environmental Protection Division in devising a training program for its employees and in developing a pollution prevention program for industries in Georgia. The Georgia Department of Labor commissioned a new program, the first of its kind in the U.S., to provide training and on-site assistance to state agencies and their employees in identifying and controlling chemical hazards.

Ongoing lead-based paint research focused on techniques for removing lead, and a new program of technical assistance to contractors was started. Researchers also began looking at the incidence of lead poisoning among Georgia's wildlife.

In response to numerous requests from Georgia farmers, safety engineers began working with the University of Georgia Agricultural Extension Service to develop a technical assistance program to reduce the risk of injury and illness on the farm.

GTRI scientists used a mobile mass spectrometer to identify and monitor ions in the troposphere.

GTRI indoor air specialists continued to test office furnishings and construction materials for the emission of volatile organic compounds.

Continuing Education

A survey by the U.S. Department of Health and Human Services revealed that GTRI has the largest hazardous waste and related sciences training program in the U.S., with some 6,000 participants attending more than 100 course offerings each year. New courses were added to deal with estimating the cost of removing asbestos from buildings, environmental resource management, industrial process engineering, and hazardous waste. The Southeastern Safety and Health Conference returned to the agenda for the first time in four years. Other major conferences sponsored by GTRI included the annual Indoor Air Quality Symposium and Food Processing Waste Conference.

Other Research

Other significant activities included:

- Researching the causes and prevention of cumulative trauma disorders in the apparel and poultry industries; and
- Serving on numerous advisory bodies on the national and state levels. ■

Manufacturing Technology

Through a new interface with industry, workshops and newsletters, GTRI introduces advanced technology and offers advanced techniques to apparel manufacturers.

In FY 90, the Apparel Manufacturing Technology Center (AMTC) completed its third year of research and technology transfer under sponsorship by the Defense Logistics Agency. Fourteen research projects were conducted in the areas of human factors, automated manufacturing, and management and production systems during the year. The Center began interfacing with industry to implement the results of some of these projects and started a new program of problem-solving technical assistance to introduce advanced technology to apparel manufacturers. AMTC also transferred technology via quarterly workshops, a quarterly newsletter, and technical tips sheets. Opportunities were offered for students to take apparel-related coursework and to get hands-on experience with the equipment in the demonstration center at the Southern College of Technology, a partner in the AMTC.

Robotics and Machine Vision

GTRI opened a new advanced automation research laboratory late in the year. The state-of-the-art facility is equipped with two robots, three machine-vision systems, and a variety of industrial and computer support tools. It will be used for a range of initiatives in manufacturing technology, but work in FY 90 principally involved robotics research and machine-vision inspection for the poultry industry and development of commercial vision technology to detect fabric flaws in automated apparel fabrication plants. Engineers worked on developing special "end effectors" for robotic handling of soft or non-rigid materials in these industries. They also began investigating the use of color in machine vision for both food and fabric inspection.

While these engineers investigated advanced automation as one answer to cumulative trauma disorders in the human workforce, other researchers approached the problem from the viewpoint of modifying the work environment for increased worker comfort and safety. They surveyed workers in three apparel plants and made recommendations for ergonomic improvements.

Computer Controls for Manufacturing

Engineers worked on developing a high-speed, low-cost parallel processing computer system for image analysis using transputers. The objective is to maintain flexibility while achieving high speeds for applications such as product inspection, automatic target recognition, and pattern recognition. Unlike conventional sequential image processors, a transputer-based system can process information simultaneously at very high speeds without special hardware.

Ongoing work concerning off-wire automated guided vehicle systems concentrated primarily on computer controls, looking at simultaneous consideration of dispatching and traffic management aspects of assigning vehicle tasks and routes. Engineers designed an AGV fleet computer simulation model to evaluate the relative performance of several different fleet control algorithms. They also wrote new control software for the vehicle itself and began testing and debugging it.

Metals Processing

GTRI engineers continued their metals processing studies, principally in continuous casting, hot rolling, and drawing of aluminum alloys and copper. They conducted process improvement studies in the area of aluminum alloys for mechanical applications, with the objective of improving the cast structure to eliminate surface defects from the hot-worked metal. For a multi-client group, they studied the effect of surface conditions of continuously cast and rolled copper rod manufactured by different systems upon its drawability, using different drawing lubricants and die materials, and the formation of metallic fines. They also began working on use of ultra-high-purity copper bonding wire for microelectronics applications.

Ferrous metal studies included work to improve the anti-corrosion properties of nodular cast iron in a steam environment, and another project to improve the surface quality of bare steel wire to replace galvanizing for baling applications. The latter involved micro-alloying of steel — adding minute amounts of rare earth metals — to improve toughness and hardness.

Microelectronics/Sensors

Advanced microelectronic circuits are complex structures that must remain stable while subjected to electrical, chemical, thermal, and mechanical stresses. The minute dimensions of microcircuit features introduce special problems for maintaining reliability. GTRI researchers continued theoretical and experimental investigations directed toward developing materials and techniques to enhance the reliability and durability of fine microcircuit features. Work included the micromechanics of surface-mount technology solder interconnections, wire bonds, and polymeric materials;

electromigration phenomena in metallization layers; and mechanical characteristics of semiconductor crystals, package and printed wiring board materials.

GTRI scientists began developing a low-cost integrated-optical sensor to monitor chemical changes in the soil as a way to save energy and lower the cost of fertilizing cropland. The device miniaturizes an entire optical instrument on a chip similar to an integrated circuit. Industrial sensor development progressed with assembly of an optical head for a new surface inspection system and work on optical waveguide switching techniques for display-type applications.

Other Research

Other significant activities included:

- Initiating research on marker making and cut-order planning to determine the feasibility of greater automation of pattern piece layout to minimize fabric waste;
- Studying the dynamics of the modular work group system as a way to add flexibility to apparel manufacturing;
- Developing a substantially improved algorithm for palletizing unequal-sized containers, extending the understanding of mechanical stability in stacking, and moving toward commercialization of the software; and
- Investigating application of software developed to control automatic test devices for the military to manufacturing, which would allow the concurrent engineering of both the part to be manufactured and the process by which it would be fabricated and tested. ■

GTRI researchers developed new micromechanical systems to investigate the reliability and durability of fine microcircuit features.

Economic Development & Technical Assistance

Studies by GTRI's Economic Development Research Program range from the economic impact of a hazardous waste facility to the tourism potential of Southwest Georgia.

In FY 90, the state-funded Economic Development Research Program began its fifth year of promoting the economic development of counties and communities outside metropolitan Atlanta. Studies completed during the year included an assessment of markets for remanufacturing hardwood lumber, a Georgia educational telecommunications study, and evaluation of the economic development potential of a hazardous waste management facility.

New studies commenced on the economic impact of not having a hazardous waste facility in Georgia, the potential for establishing a retirement community in the state, and the tourism potential of an eight-county area in southwest Georgia. Researchers also inventoried the high-tech companies and research facilities available in the Atlanta area as a tool for recruiting high-tech industry, evaluated the feasibility of establishing a regional industrial park in the Chattahoochee Regional Development Center area, and investigated Georgia's potential for using biomass to generate electricity. For the Defense Logistics Agency, economists began developing an investment decision model for use by apparel manufacturers.

More than one third of Georgia's manufacturers responded to a survey conducted by GTRI to determine their problems and needs. Researchers analyzed the results and are using them as the basis for strategic planning for future programs.

GTRI researchers helped apparel manufacturers make better use of computer integrated management systems.

Assistance to Development Groups and Industry

In FY 90, GTRI's statewide network of 12 regional offices and technology centers continued to provide technical assistance to industries, advise community and area development groups, and answer numerous information requests. Assistance ranged from conducting labor surveys and target industry analyses for development groups to helping industrial firms design plant layouts, improve material handling, and upgrade marketing efforts. Assistance was provided by field-office engineers and on-campus experts in both GTRI and the academic schools of the university. In-depth database research services were provided as well as answers to routine information requests. In addition, Georgia Tech was named the official agent to transfer technology from NASA-Huntsville to Georgia industry.

In December, GTRI played a prominent role in Georgia Tech's first economic development briefing for Georgia legislators and policymakers. Staff also coordinated events showcasing Georgia Tech's services to the Bibb-Houston County, Dalton, and Dublin areas of the state.

Joint programs included collaborating with the University of Georgia on assistance to companies and planning a cooperative venture with the state's vocational-technical schools that would set up major manufacturing demonstration and technical assistance centers.

The Energy Analysis and Diagnostic Center, operating under contract to University City Science Center, continued to focus on small and medium-size industries in Georgia, Alabama, and South Carolina. Engineers performed energy audits for some 30 plants in FY 90 and recommended conservation measures that would trim energy consumption by 144 billion Btu, with an average cost saving of 12 percent of a company's energy bill.

The Governor's Office of Energy Resources continued to sponsor three programs to provide energy audits, engineering assistance, and educational services to Georgia industries, schools and hospitals, and agricultural processors. In FY 90, energy audits were performed for 30 industries, 20 schools, and 15 agricultural processors, and 25 boiler tune-up tests were conducted. In addition, GTRI offered workshops on boiler and steam system efficiency improvement and industrial lighting, and an energy efficiency seminar for schools and hospitals.

The Georgia Productivity Center continued to focus on quality, employee involvement, and technology utilization as strategies to strengthen the competitiveness of Georgia industries. In FY 90, the Center emphasized total quality management, developing a new assessment process that provides management with an objective review of its quality management system and procedures on a company-wide basis. Total quality management seminars were conducted in Atlanta, Columbus, Macon, and Rome.

The Georgia Procurement Assistance Center entered its fifth year of helping Georgia firms sell their goods and services to the federal government. Since 1985, the center has assisted more than 600 companies, resulting in $28 million in contracts awarded and another $4 million in contracts pending.

Since 1984, the Southeastern Trade Adjustment Assistance Center (TAAC) has provided in-depth assistance to 111 companies in declining industries faced with severe import competition, and 43 of these companies have shown a total increase of 1,330 jobs. Other specialized technical assistance programs included hazardous waste management, workplace safety and health, and technology transfer to apparel manufacturers.

Education and Training

The industrial education program featured in-plant quality improvement courses in statistical process control, which were taught to managers and supervisors at companies throughout the state. Other courses included applied principles of industrial engineering for the textile industry, textile processing, and a variety of development courses for managers and supervisors. GTRI staff also conducted a trainers' course on carpet installation for the Floor Covering Installation Training Council. In addition, GTRI presented the American Economic Development Council-accredited Basic Economic Development short course for the twenty-third consecutive year. ■

The Apparel Manufacturing Technology Center completed its third year of research in the areas of human factors, automated manufacturing, and management and production systems.

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