

1989
ANNUAL
REPORT

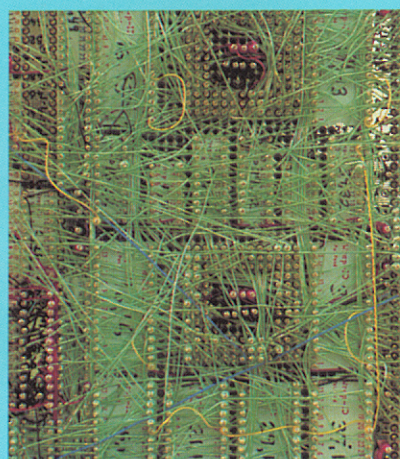
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LETTER FROM THE DIRECTOR

■ ■ Top, GTRI continued its popular course in hazardous material control and emergency response. Bottom, engineers design printed circuit boards by first building wire-wrap prototypes.



CONTENTS

Agricultural Technology	19
Antenna Development	24
Chemical Sciences	10
Communications	16
Economic Development/ Industrial Assistance	20
Electromagnetic Compatibility	17
Electronic Defense	26
Environmental Sciences and Engineering	11
GTRI Directory	28
Infrared/Electro-Optics	6
Intelligent Systems	12
Letter from the Director	1
Manufacturing Technology	14
Materials Sciences	8
Microelectronics	4
Millimeter Wave Technology	18
Radar	22
Year In Review	2

The continued economic strength of our state and nation depends on technological innovation. For this reason, national research organizations such as the Georgia Tech Research Institute (GTRI) have taken on roles of unprecedented importance. They are providing society with the technically sophisticated professionals to manage our nation's new economy and making the research breakthroughs essential for updating basic industries. Beyond this, they are extending the potential of research into development and application.

GTRI is a nonprofit organization that is best-known as the applied research arm of the Georgia Institute of Technology. For 55 years, its engineers and scientists have specialized in expediting the utilization of basic knowledge in technological applications. As one consequence of this process, GTRI has become one of America's leading sources of expertise in electronics for national defense. It is also well-known for its successful approach to economic development, through a system of regional offices that offers Georgia business and industry the equivalent of "technology field agents."

In recent years, the Research Institute's role has broadened its scope of activities beyond these traditional missions. Today's GTRI engineers and scientists are creating more basic knowledge, and playing an increasingly active role in the education of the students who will manage industrial innovation in the coming decades.

In today's world, no organization can operate in a vacuum and remain strong. Recognizing this, GTRI has greatly expanded its internally sponsored research program,



Donald J. Grace

so that its staff can be prepared to meet new technical challenges as they arise. The Research Institute is also strengthening its resources through cooperative relationships with academic departments on the Georgia Tech campus and with other neighboring universities, such as the University of Georgia, Emory University, Georgia State University, and the Southern College of Technology.

In the following section of this booklet, you will read a brief synopsis of the year in review, containing the trends and issues of greatest importance to GTRI as a whole. The remainder of the report focuses on program highlights in the varied technical areas that GTRI researchers are active.

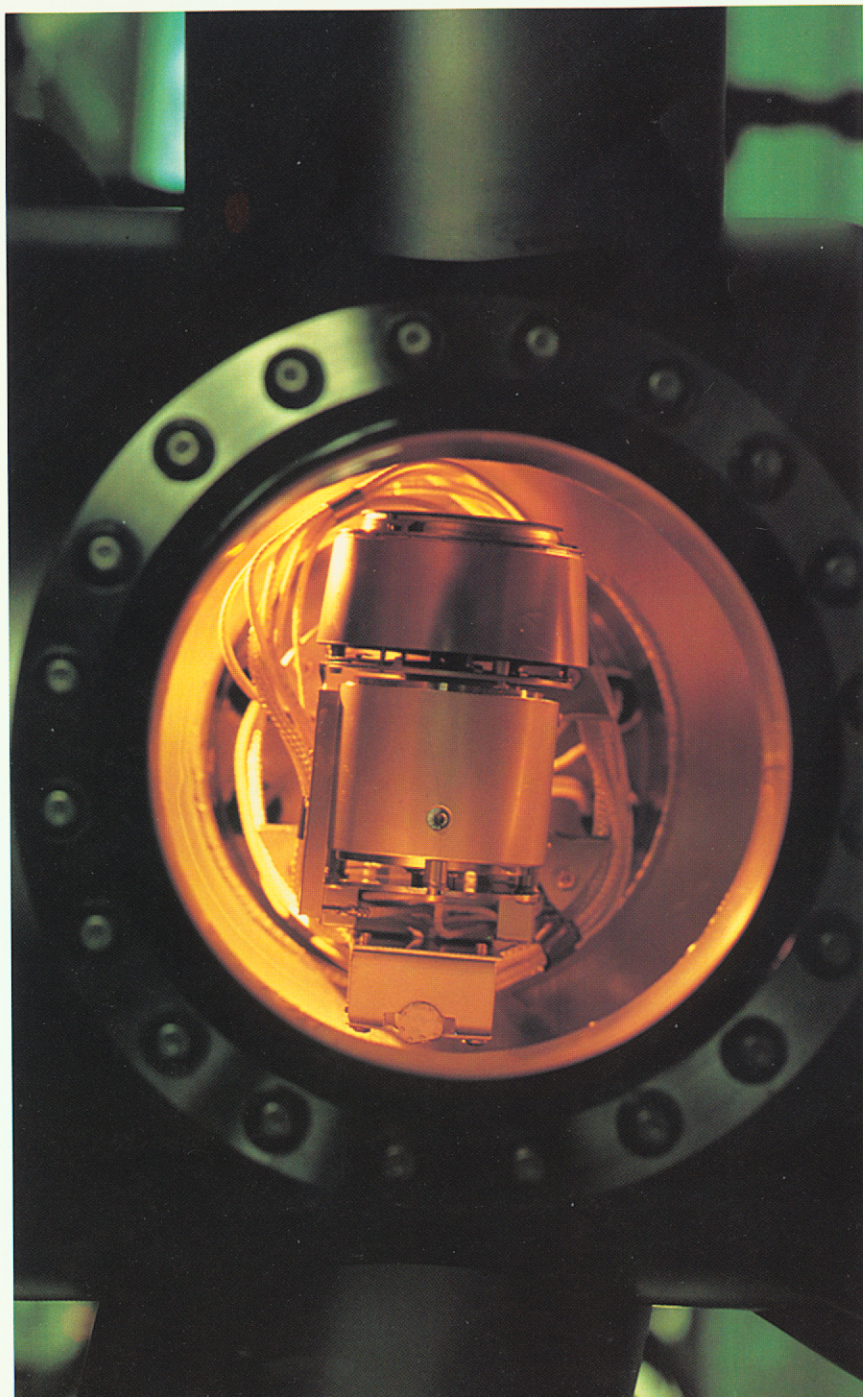
As always, my deepest thanks go to the dedicated researchers and support staff who have made FY 89 another highly successful year. And to all the readers of this report, please feel free to be in touch with me with your questions, comments and suggestions.

Donald J. Grace

Donald J. Grace
Director
Georgia Tech Research Institute

■ ■ On the cover, GTRI researchers performed a principle components transformation on original Landsat data to generate this color-enhanced image of a region in north-central China.

■ ■ Below, molecular beam epitaxy is used by GTRI researchers to grow advanced semiconductor materials for microelectronic devices.



The Georgia Tech Research Institute (GTRI) continued to experience significant expansion in research activity in fiscal 1989. Research expenditures rose approximately 10 percent to \$94.2 million, while the professional staff increased substantially for the third consecutive year, reaching 675 full-time researchers.

Though the Research Institute's principal base of sponsorship remained the Department of Defense (DoD), the percentage of GTRI contract research funds derived from DoD dropped from 72 to 63 percent, with accompanying increases in other government and industrial funding.

Other federal agencies provided 20.7 percent of GTRI's contract income, up by 4.7 percent since the previous year. Research sponsored by industry rose from 11.0 percent to 15.3 percent, partly because of successes in industry-GTRI teaming approaches for DoD contracts. Sponsored research funds from state and local sources remained approximately constant at about 1 percent.

GTRI senior administrators spent much of the fiscal year laying the groundwork for a major reorganization of working research units. One intent is to remove existing laboratory boundaries and create a new organizational structure that is more flexible in meeting the needs of tomorrow's research. The Office of the Director plans to have broad guidelines for this change in place by the beginning of FY 90.

Internal Research

In the past year, GTRI accelerated the pace of internally funded research, an activity that is now the organization's capstone for future planning. The main objectives of this internal research program are to reinforce GTRI's technology base in key fields of current activity and to initiate new endeavors. It also serves as a vehicle for broader interaction between GTRI researchers and their academic colleagues.

Last fiscal year, 30 innovative projects were in progress, thanks to an infusion of some \$2 million in GTRI-provided funds.

These projects were endorsed and monitored by the Senior Technology Guidance Council, which is composed of ten senior researchers at GTRI. Main technology areas under investigation are information sciences, material and propagation sciences, device and component technologies, system and interface technologies, and environmental and industrial technologies. Through this continuing effort, the Research Institute is stimulating the growth of embryonic R&D areas, so that they can become strong enough to attract external support in selected emerging technologies.

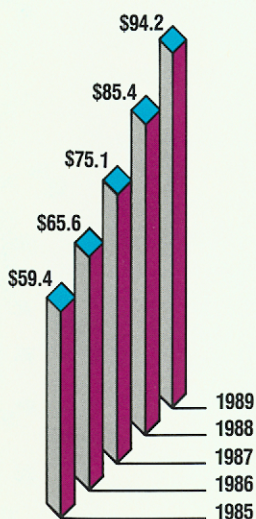
As a result of this program, strong linkages between GTRI and academic research groups at Georgia Tech are already beginning to show. Eight of the initial 30 projects have the active participation of academic-side faculty members. The total program activity is supported by 22 graduate research assistants and one post-doctoral student.

Interaction and Outreach

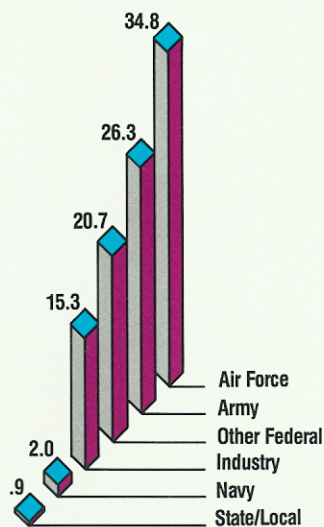
Through its existing programs, GTRI has fostered other important external linkages. At Georgia Tech, the Research Institute is an active participant in three campus-wide research centers that are working in advanced manufacturing, apparel automation, and microelectronics. In all, there were 34 academic-GTRI sponsored research projects underway in 1989.

Outside the Tech community, GTRI administrators have met with their counterparts in the University of Georgia Extension Service to seek more productive collaborative working relationships. One early result of these ties was an economic development conference at Milledgeville that was jointly sponsored by the two institutions. GTRI and Georgia State University researchers also are working together, most prominently in a project to develop an optical telescope with unprecedented resolving power. GTRI researchers have also participated with medical scientists at Emory University and the Medical College of Georgia in a variety of bioengineering programs and with the Southern College of Technology in the Apparel Manufacturing Technology Center.

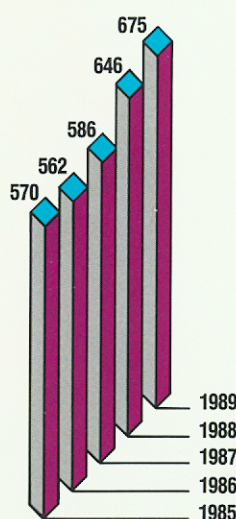
RESEARCH EXPENDITURES
(Millions of Dollars)

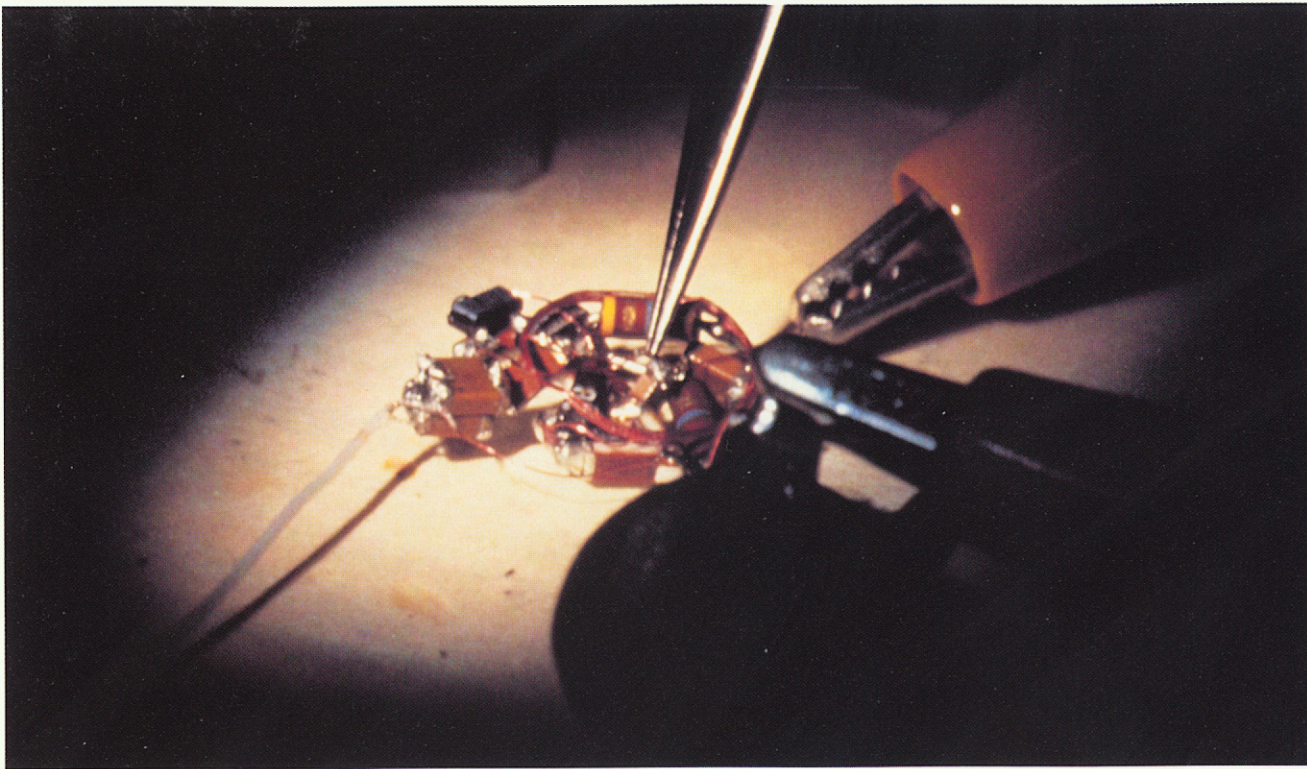


MAJOR SPONSORS
(In Percent)



NUMBER OF RESEARCH PROFESSIONALS





Gary Meek

Education

Though GTRI's principal mission is applied research and development, it actively participates in Georgia Tech's educational programs. In FY 89, 15 GTRI researchers held appointments as adjunct faculty members at Georgia Tech. In addition, 28 GTRI research engineers or scientists served on Institute thesis advisory committees. GTRI professionals taught 14 academic courses and also participated in many continuing education short courses.

Last year, GTRI employed 144 graduate research assistants, including 55 doctoral candidates, as well as 155 undergraduate co-op students. In FY 89, GTRI's tuition reimbursement program allowed 130 employees to pursue advanced degrees at Georgia Tech and other area educational institutions.

Service to Georgia

GTRI is an important part of Georgia's economy, as is shown by the more than \$92 million it attracted to the state in FY 89 from

external research funding sources. A preliminary estimate is that these funds will ultimately result in an increase of Georgia's economic activity by more than \$200 million, with an increase in the incomes of Georgians of almost \$57 million and additional tax payments to Georgia governments of more than \$6 million. This estimate does not take into account the benefits that Georgia firms received as a result of GTRI assistance.

An important part of GTRI's mission is service to the state of Georgia's needs for economic development and resource conservation. To better fulfill this role, GTRI won legislative approval to add another resident engineer to its Columbus regional office. The state legislature also approved a new allocation of \$250,000 to develop robotics for poultry processing plants.

In FY 89, GTRI sought out the counsel of prominent Georgians in finding more effective means of serving the state. Four Georgia members were named to the Research Institute's External Advisory Board: Mr. John Henry Anderson, Rep. Larry Walker, Sen.

■ ■ GTRI engineers assisted academic researchers with the development of a novel cone electrode, an artificial electrical connection used to bypass damaged nerves.

GTRI accelerated the pace of internal research, reinforcing its technology base in key fields. ■

Terrell Starr, and Mr. Joel Cowan. In addition, plans were discussed to establish a Georgia Advisory Board, which will advise GTRI on how it can further enhance its contributions to the state.

FY 89 was a year of exciting progress in a number of research areas. The remainder of this annual report presents these results in topical format.

Microcircuit failure due to electromigration continues to plague sophisticated electronic equipment. High current densities across narrow interconnecting thin-film conductors act as an "electron wind," causing atoms in the film to creep forward. The resulting voids and whiskers can eventually lead to device burnout. In FY 89, GTRI researchers explored new theories involving dislocation mechanisms in an effort to explain the electromigration process, and sought ways to reduce this undesirable phenomenon.

Gallium arsenide field effect transistors fabricated at GTRI on conventional epitaxial materials have demonstrated device performance up to 20 GHz. GTRI researchers

GTRI scientists are fabricating miniaturized optical waveguide circuits for potential use as optical switches. ■



■ ■ Above, GTRI scientists used modern photolithographic techniques to fabricate miniaturized optical waveguide circuits for potential use as optical switches.

are now growing selectively doped heterostructures of aluminum gallium arsenide and gallium arsenide by molecular beam epitaxy, and fabricating field effect transistors with near 0.5 micron gate geometries on these materials. Benefits include higher frequency operation (up to 60 GHz), improved device performance, and greater wafer yields.

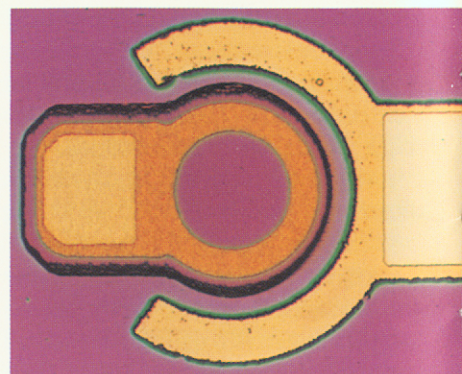
New Growth Techniques

The consistent growth of high-quality mercury cadmium telluride epitaxial layers by molecular beam epitaxy has posed a serious challenge to scientists using conventional mercury vapor sources. Precise control of the mercury flux is necessary to achieve reproducible doping densities and minimize

structural defects. In FY 89, GTRI scientists designed a new fast-response mercury vapor furnace incorporating a special pressure-controlled manometer system. The new furnace provides extremely accurate flow rates and permits precise modulations in flux intensity.

The inability to reproducibly dope II-VI semiconductors has been a major obstacle preventing their technological development. Because they are extremely volatile, materials such as cadmium telluride and mercury cadmium telluride must be grown at very low temperatures. During FY 89, GTRI researchers examined the photonic enhancement of doping effects in these materials by using an active growth process called photon-assisted molecular beam epitaxy. This technique utilizes a laser beam to supply additional energy to the growth surface without raising the temperature. It provides improved control and reproducibility over crystal growth, quality and doping.

GTRI researchers also developed a new technique for reducing carrier profile



■ ■ Superlattice avalanche photodiodes are being fabricated for use as high-gain, low-noise photodetectors.

widths while increasing doping density in gallium arsenide and aluminum gallium arsenide materials. Called delta doping, the technique permits the epitaxial growth of an extremely thin layer of silicon or beryllium atoms. By accurately localizing the doping concentrations, the material interface properties can be adjusted for improved device performance. Saw-tooth superlattice structures with potentially useful nonlinear optical properties can also be grown.

Integrated Optics

During FY 89, GTRI researchers continued to develop advanced integrated optics chemical sensors. The new electro-optic devices consist of two-dimensional optical circuits fully integrated onto compact planar substrates. They offer very high detection sensitivity, active or passive measurement techniques, and freedom from electromagnetic interference. Applications include detecting hazardous chemicals and monitoring production processes.

Working in the Microelectronics Research Center, GTRI scientists are also fabricating miniaturized optical waveguide circuits on planar aluminum gallium arsenide epitaxial layers grown by molecular beam epitaxy. By incorporating aluminum gallium arsenide multiple quantum well structures in the substrate, researchers are investigating techniques to enhance nonlinear optical device characteristics for potential use as spatial optical light modulators and optical switches.

Other significant areas of research included:

- Fabricating doped superlattice avalanche photodiode structures for wide-bandwidth,

high-gain, low-noise photodetectors;

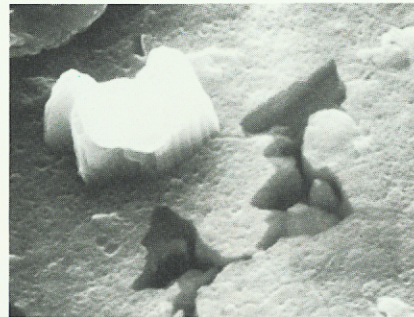
- Investigating thermal, mechanical, and electrical properties of various solder alloys;

- Exploring advanced photoluminescent techniques for rapidly characterizing materials; and

- Developing resonant tunnel devices for microwave applications, and as a means of injecting low-energy electrons into wider bandgap materials.

- *GTRI researchers continued to examine electromigration, a phenomenon which causes metal atoms in thin-film conductors to creep forward, resulting in destructive voids and whiskers.*

- *Below, researchers used an active growth process called photon-assisted molecular beam epitaxy to reproducibly dope mercury cadmium telluride semiconductors.*



Extending our knowledge of the Earth's upper atmosphere is of paramount importance to the safe operation of high-flying aircraft such as space shuttles and the proposed National Aero-Space Plane. In FY 89, GTRI engineers assisted the Air Force with converting a huge test collimator at Wright Patterson Air Force Base into the world's largest light detection and ranging system (LIDAR). By emitting a vertical laser beam and recording the resulting backscatter, this sophisticated system can measure concentrations of various molecules, particulates and aerosols in the stratosphere and mesosphere to a height of 80 kilometers. GTRI engineers

Climatology

Radiative heat transfer between clouds and the Earth's surface is a significant, but poorly understood, climatological mechanism. To clarify the role various cloud types play in affecting the climate, scientists from GTRI and Georgia Tech's School of Geophysical Sciences are combining a visible-light LIDAR, infrared spectro-radiometer, thermal imager, and television camera in a unique multi-spectral remote sensing project. In addition to characterizing clouds and determining base heights and rates of energy exchange, researchers are using the instruments to evaluate

a passive technique for estimating winds aloft by measuring cloud motion.

In FY 89, GTRI engineers also investigated the feasibility of sensing industrial atmospheric pollutants using frequency-modulated laser spectroscopy. Based on a technique developed years ago for visible-light lasers, a tunable carbon dioxide laser is being tested for the detection of potentially harmful agents, such as benzene and ozone, with spectral signatures in the mid-infrared.

Sensor Fusion

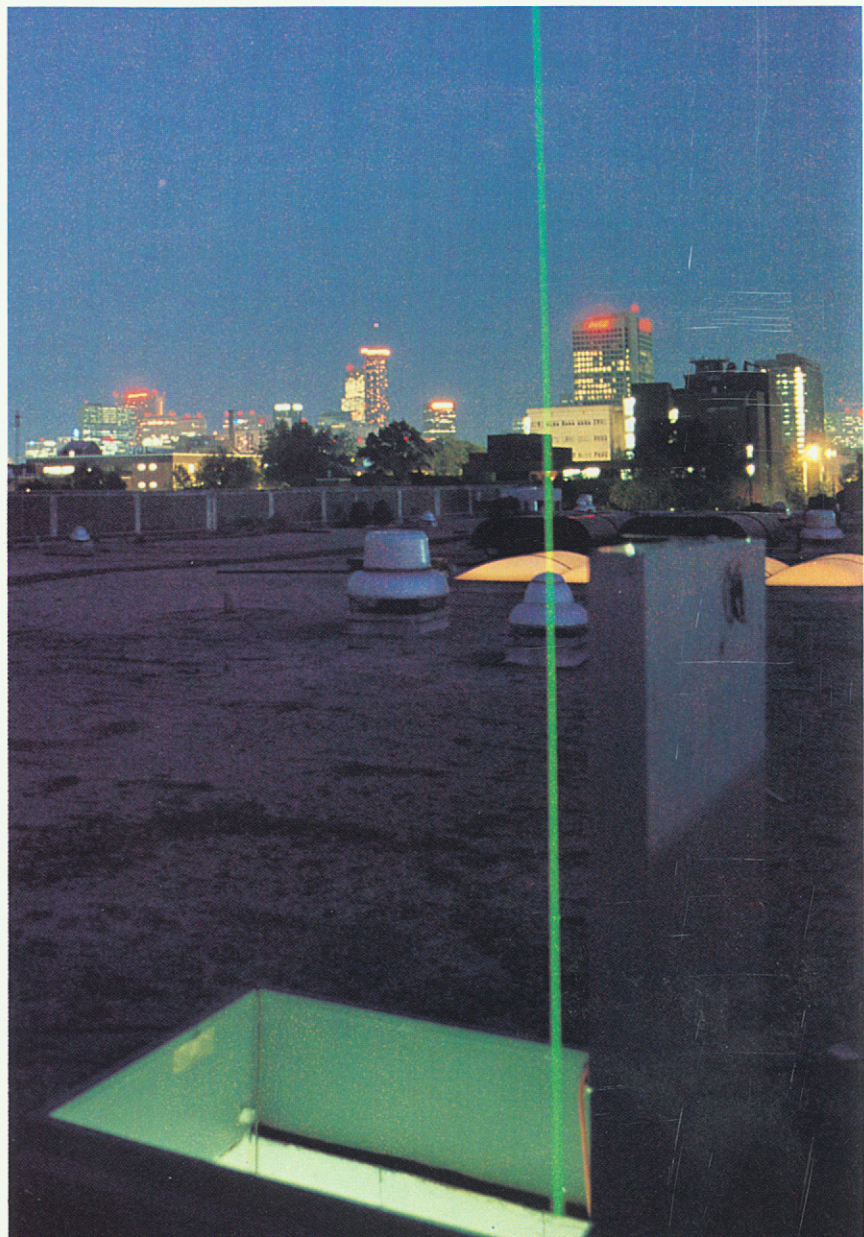
To assist pilots in the rapid identification of potential threats, targets, and features in the

In a major program, GTRI assisted the Air Force with converting a huge test collimator into the world's largest LIDAR system. ■

designed the laser transmitter, receiver, and supporting instrumentation.

In a similar program with the University of Washington, GTRI researchers developed a compact airborne LIDAR for locating tenuous dust layers in the atmosphere. Using this novel instrument, scientists are investigating the height and concentration of a mysterious arctic haze layer that forms each year during the arctic spring. The fully automated mobile laser radar is also useful for monitoring the presence of sub-visual cirrus clouds. Invisible to the human eye, these clouds can seriously affect the performance of current state-of-the-art infrared sensors.

■ ■ *GTRI researchers are developing powerful new light detection and ranging systems, and exploring new applications for this remote-sensing technology.*



terrain, GTRI researchers are developing methods to correlate multi-spectral satellite data with images from side-scanning radars and forward-looking infrared sensors. A multi-sensor, multi-platform simulation system is being developed for use in sensor fusion algorithm development.

In another sensor fusion project for Atlantic Research Services Corporation, GTRI engineers are exploring the feasibility of coupling the excellent spatial resolution of infrared detectors with the superb ranging ability of radar systems. Such synergism could maximize the probability of detecting low-flying targets at long range while

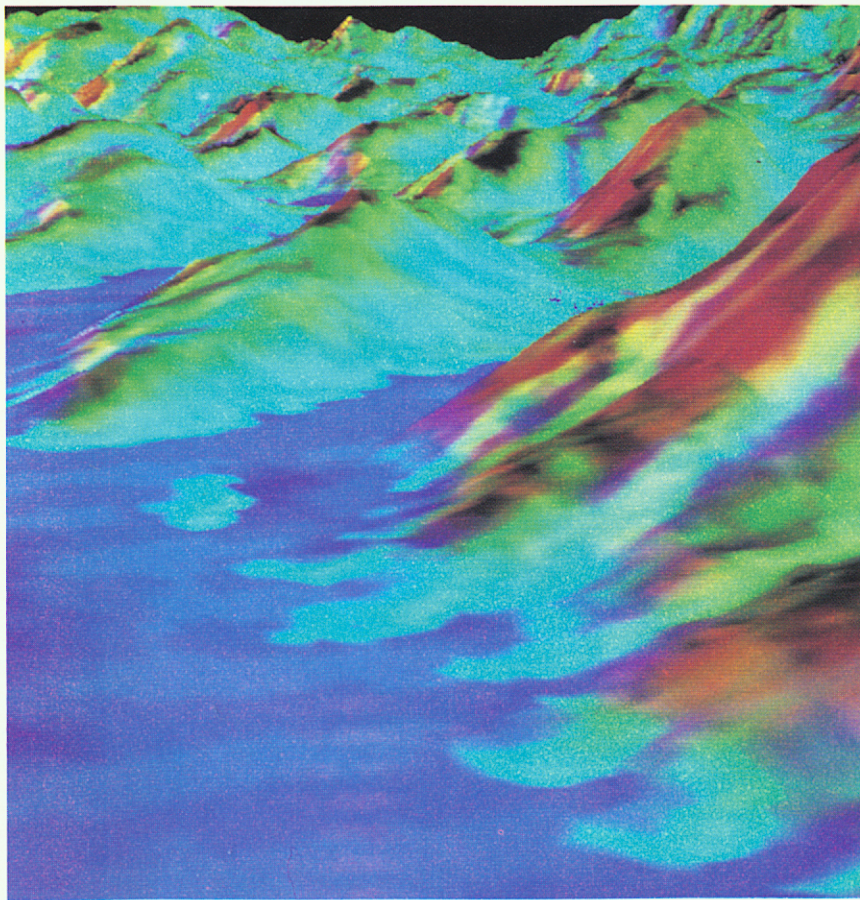
significantly reducing the number of false alarms.

In related work, GTRI researchers are seeking ways to improve the identification capabilities of target acquisition systems by combining features extracted from signatures taken with various types of sensors. Active sensor modeling tools are being developed to predict signature characteristics that could be combined to uniquely identify targets.

Other significant areas of research included:

- Developing software and computer models for Army training system operators

■ ■ GTRI engineers generated this infrared signature of a helicopter from model data.



■ ■ This multi-sensor view of a mountainous region in northern Georgia was produced by combining near-infrared, thermal, and synthetic-aperture radar data.



■ ■ Above, GTRI researchers are combining interactive image processing with scene simulation to develop sensor fusion algorithms.

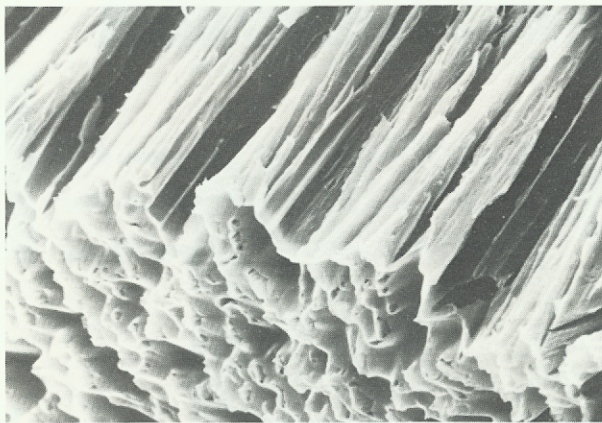
to produce synthetic infrared and visual imagery of targets and backgrounds under various environmental and meteorological conditions;

- Enhancing the multi-spectral scene generation capabilities of modeling software to more accurately depict scenes in the infrared;

- Determining the effectiveness of infrared systems by predicting thermal properties of clutter using Landsat imagery and Defense Mapping Agency data; and

- Modeling the infrared signatures of high-value targets from a generic set of building materials.

In FY 89, GTRI scientists began developing a process for fabricating superconducting wire to be used for magnet and motor windings. The goal is to deposit the desired superconducting material onto commercially available ceramic fibers by chemical vapor deposition to create a flexible wire. The project is a collaboration among GTRI, the schools of Materials Engineering and Chemistry, and a manufacturer of superconducting magnets for research and medical equipment.



■ ■ Above, GTRI researchers developed this porous polymeric membrane for medical applications such as dialysis.

Work began on developing a semi-quantitative model to understand and predict the microstructure of dispersed phase composite coatings. During experiments to validate the model, researchers succeeded in co-depositing boron nitride and aluminum nitride. In one application of this technology, boron nitride can be used as a built-in solid lubricant for moving parts of machinery coated with aluminum nitride for wear resistance. In another, aluminum nitride can be added to harden radomes

made from boron nitride, which has excellent electromagnetic properties, but is very soft.

GTRI also purchased a microwave plasma chemical vapor deposition system that permits the deposition of diamond coatings for microelectronic, tribological, and infrared window applications.

Ceramic Composites

GTRI extended its computer model of the chemical vapor infiltration process developed by Oak Ridge National Laboratory to include an isothermal process. Chemical vapor infiltration is used in making high-temperature, lightweight ceramic composites for use in advanced jet engines. The model also was extended from one dimension to three dimensions, allowing optimization of the process for complex structural components.

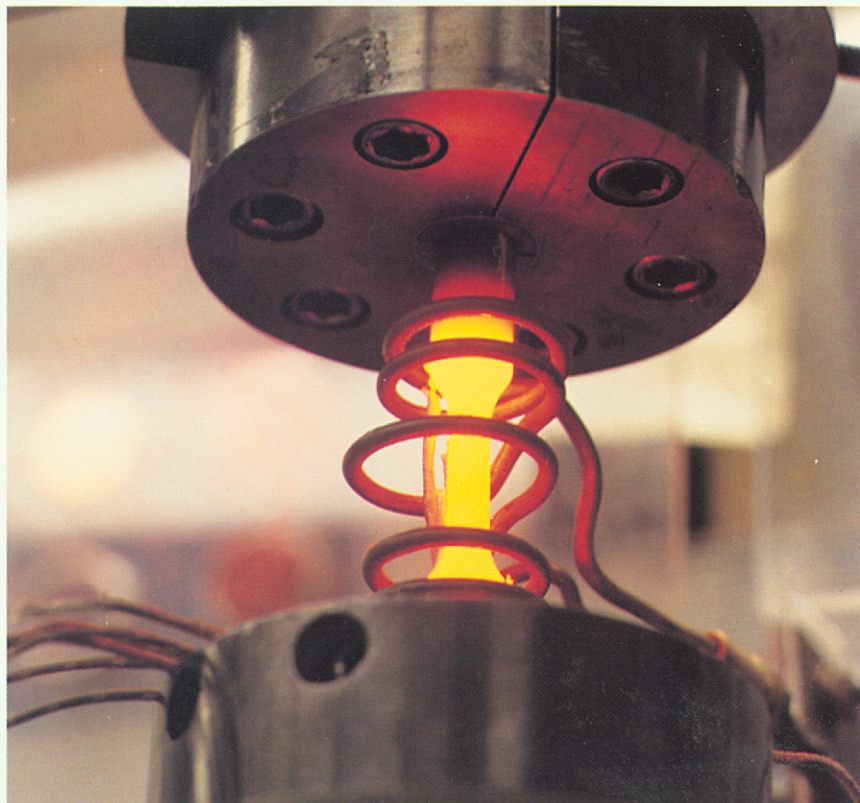
Scientists made several advances in GTRI's reaction sintering process for fabricating silicon nitride composites. They

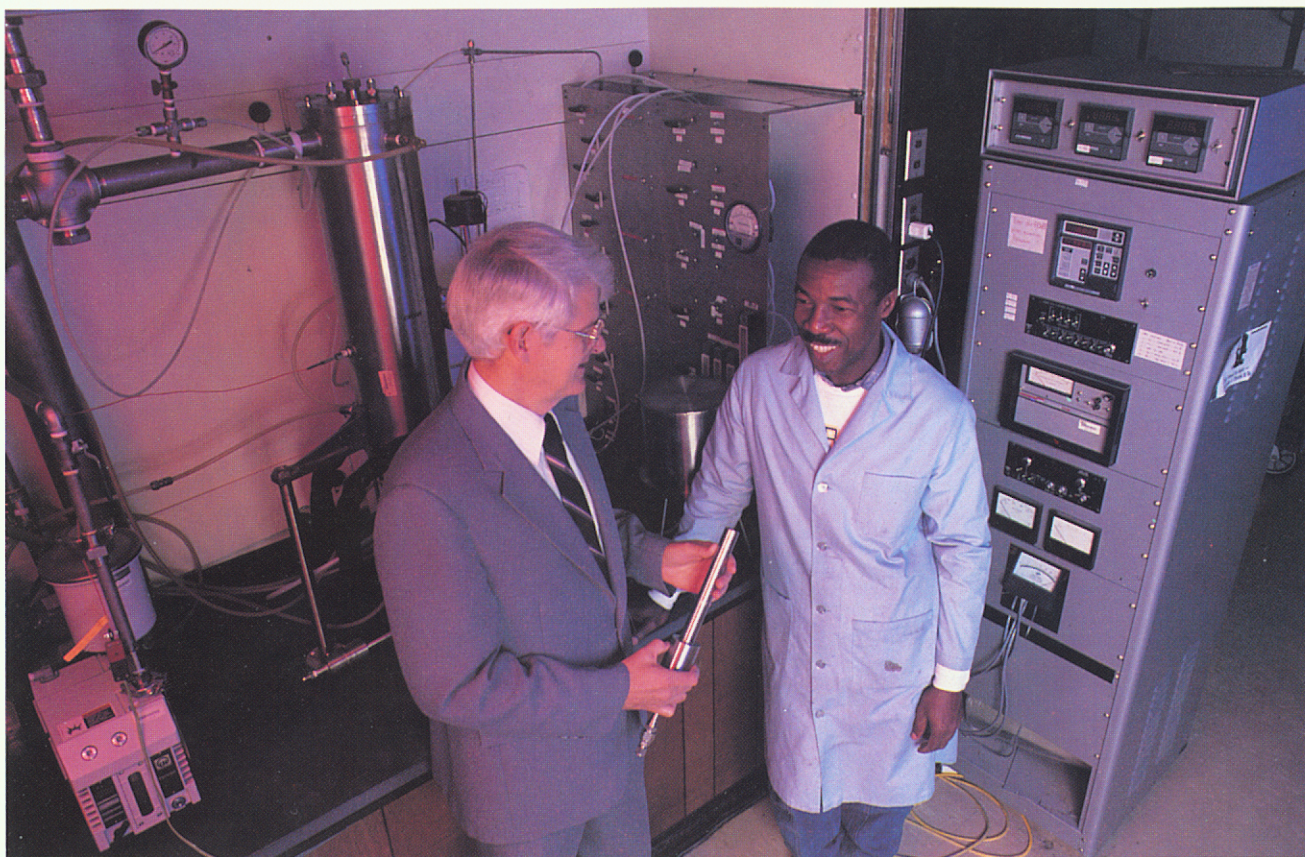
developed an ultrafine silicon powder that converts to nitride more rapidly and at a lower temperature than conventional powders, preventing degradation of fiber properties. They also invented a computer-controlled nitriding system that allows the process to be controlled in real time, based on sensors that evaluate the nitriding rate and degree of conversion of the composite part. A major advantage of this fabrication process is that the density of large, complex components can be enhanced without shrinkage.

Materials Characterization

A major program to assist a government prime contractor in assessing the Army's Materials and Structures Program and recommending changes began during the

■ ■ Below, this high-temperature fatigue test is part of a research effort to extend the life of turbine engine materials.





year. Work included technical analysis and evaluation of advanced thermal and propulsion materials used in lightweight titanium thrusters, ablative propellant tank liners and diaphragms, and flexible heat shields.

In a project for the Air Force Systems Command at Hanscom AFB, researchers began evaluating materials used in radomes to determine their susceptibility to environmental factors such as moisture, ultraviolet radiation, and sulfur dioxide emissions. The dielectric and mechanical properties of approximately 100 materials will be characterized over a two-year period.

In an ongoing radome and antenna analysis program, engineers evaluated the electromagnetic properties of an extended range interceptor for future strategic defense applications.

During FY 89, work continued on tactile sensing using electroactive polymeric materials. The touch-sensitive pads developed by GTRI for industrial robots were adapted and interfaced for computer control.

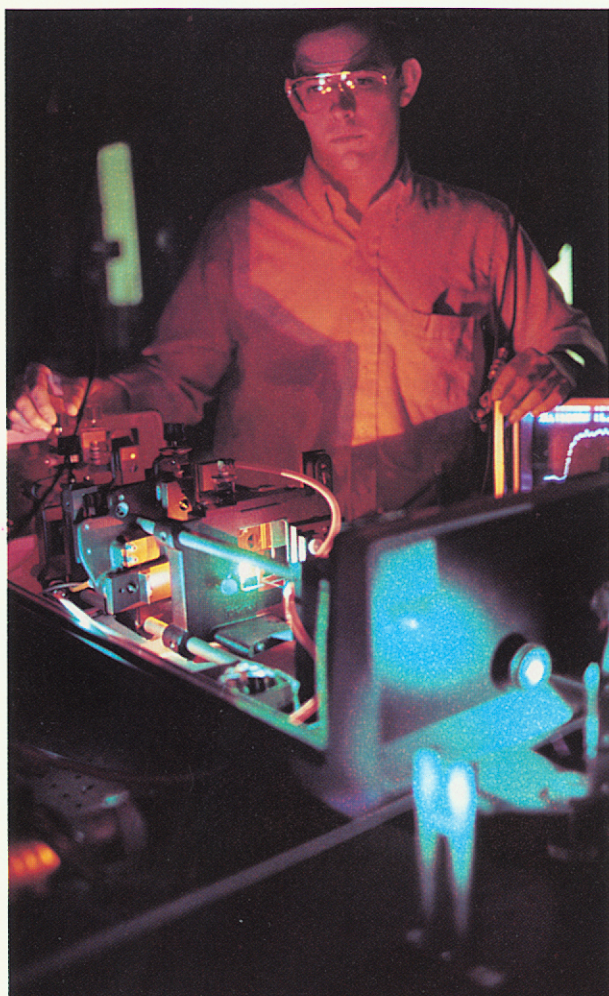
Work also progressed on the development and testing of electrically conductive polymeric sealants for corrosion resistance and electromagnetic interference shielding of aircraft.

Other significant efforts included:

- Broadening Georgia Tech's thermite synthesis process to include other compounds in addition to the titanium diboride already successfully synthesized;
- Adapting GTRI's patented anti-fouling technology to membranes used in electro-dialysis processes, such as removing salt from seawater or industrial salts from a waste stream before discharge; and
- Launching a multi-client program to develop new and improved methods for testing asbestos encapsulants.

■ ■ In FY 89, GTRI scientists began developing a process for fabricating flexible superconducting wire using chemical vapor deposition.

Work continued on tactile sensing using electroactive polymeric materials. ■



■ ■ Researchers use this continuous-wave dye laser to study chemical reactions in the atmosphere.

In FY 89, researchers continued their studies of atmospheric reactions important in understanding such problems as acid rain, climate modification by greenhouse gases, and catalytic destruction of stratospheric ozone.

The hydroxyl (OH) radical is an extremely important photochemical species responsible for initiating much of the photochemistry of the lower atmosphere, but its accurate measurement has eluded researchers for more than a decade. GTRI scientists began developing a new and highly sensitive technique capable of measuring OH in minute concentrations—in the 10 parts per quadrillion range. The method involves combining the extremely sensitive ion sampling capability developed at GTRI over the past seven years with the highly reactive nature of OH. Hydroxyl is an essential cleansing agent in the atmosphere, setting off reactions that remove a variety of pollutants, including methane, carbon monoxide and other greenhouse gases. The ability to accurately measure OH will help scientists understand what happens in both the clean and polluted environment.

Scientists also began monitoring the interactions between aerosols and ions, searching for correlations between ion loss and their reactions with aerosols. A better understanding of ion chemistry will help in calculating concentrations of trace neutral species that cause, or neutralize, acid rain.

In an attempt to understand the gas-phase chemistry involved in the chemical vapor deposition and plasma-etching processes used in fabricating microelectronic devices, GTRI scientists in

FY 89 began using single-photon, laser-induced fluorescence to detect silicon oxide molecules, which may be important in these processes. They hope to establish the utility of this laser detection technique as a diagnostic tool for improving these processes.

Molecular Sieves/Zeolites

Elimination of nitrogen oxides from chemical and utility plant stack gases soon will be required by many governments, but no commercially acceptable process has yet been developed. With the addition of ammonia, platinum is able to reduce these noxious gases to harmless nitrogen. To tap this potential, GTRI researchers began a project to atomically disperse noble metals such as platinum and palladium in the pores of various catalyst bases such as zeolites. These were then screened in microreactors to determine the activity and selectivity of the reactions.

Researchers began exploring the application of molecular sieve synthesis technology developed at GTRI for a completely different purpose: to hydrothermally grow superconducting materials. They are trying to grow crystals from solutions rather than producing them by the usual sintering process.

Other significant activities included:

- Measuring and identifying new ion species in the lower atmosphere using tandem mass spectrometric techniques;
- Starting synthesis of ferri-alumino-phosphate molecular sieves related to caxenite, a rare, natural mineral with an ultra-large pore structure;
- Looking at the application of new zeolite materials as adsorbents to remove carbon dioxide from the air in closed systems like submarines and space stations;
- Working on the GTRI one-step process to convert gasified coal directly into gasoline; and
- Adding two companies to the multi-client zeolite research program, bringing the total to 13, including seven foreign firms.

GTRI scientists began using single-photon, laser-induced fluorescence to detect silicon oxide molecules. ■

In FY 89, governments and businesses continued to turn to GTRI for expertise in an ever broadening range of concerns about the environment. Under the state-supported Hazardous Waste Technical Assistance Program, nearly 300 firms have been assisted in complying with federal regulations concerning waste disposal. A survey revealed that 19 of these firms have reduced their hazardous waste production by a combined total of 153 metric tons a year. With the increasing volume of industrial waste and the tightening of regulations governing its disposal, GTRI emphasized reducing waste production by modification of industrial processes and minimizing the adverse character of the waste generated through such methods as treatment, detoxification and recycling.

GTRI continued to coordinate a study of the transport and fate of environmental contaminants, funded by a grant from the Environmental Protection Agency. In this project, the School of Chemistry focused on controlling pollutant dyestuffs in the textile industry; the School of Geophysical Sciences investigated mineralogic aspects of soils; and GTRI researched health and safety aspects.

Air Quality

GTRI expanded its indoor air quality program of measuring chemical emissions from office furnishings in specially built room-size environmental chambers to include all types of construction and consumer products. In a new radon exposure project, researchers designed and evaluated a solid sorbent sampler for radon measurements and designed a radon environmental chamber. GTRI began assessing the radon problem in public schools, completing a pilot study in a large urban school system. GTRI personnel also played a major role in establishing the National Radon Association.

In collaboration with North Carolina State University, GTRI and Tech's School of Geophysical Sciences began an EPA-funded study of atmospheric pollution and global warming issues as the initial effort in a major southern atmospheric research initiative.



Asbestos and Lead-Based Paint Abatement

During the year, GTRI researchers evaluated methodologies for sealing existing asbestos insulation in Georgia schools as an alternative to removal. They participated in developing and testing new products for reducing exposure to asbestos in public buildings. GTRI received a new transmission electron microscope on permanent loan to use in research on the health effects of dust, asbestos and other fibers.

Engineers attacked the problem of identifying the safest and most effective methods of abating the health hazards of lead-based paint and establishing a standard to determine the success of an abatement job. In October, GTRI presented the first substantive lead-based paint abatement course in the country.

Continuing Education

GTRI continued to expend a major portion of its environmental efforts on information dissemination through workshops, symposia, conferences, and training courses. Some 6,000 persons, more than half of all of Georgia Tech's continuing education participants, attended the 110 courses offered during the year, on campus and in seven cities across the continent. These courses were in the areas of asbestos, hazardous material control, occupational health and safety, and construction safety. New courses added in FY 89 dealt with: supervision of

■ ■ Directly above, GTRI researchers use a scanning transmission electron microscope in their investigation of the health effects of dust, asbestos, and other fibers. Top, these potentially hazardous asbestos fibers are magnified 20,000 times.

asbestos abatement projects in industrial settings and in the roofing industry; lead-based paint abatement; implementation of hazard communication programs; and safety management in biomedical laboratories.

Other major activities included:

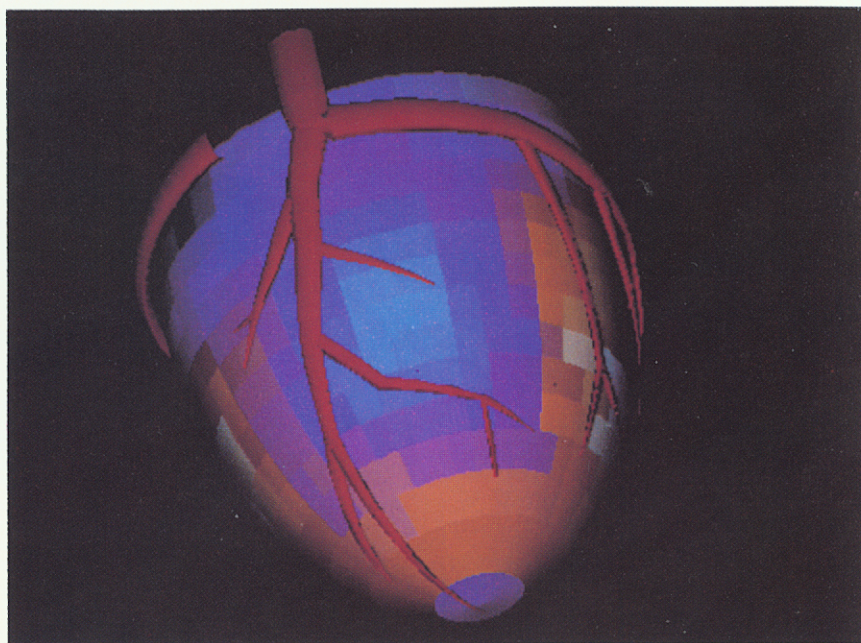
- Continuing the special biosafety technical assistance program for Georgia hospitals and medical laboratories;
- Broadening research into the utility of nematodes for toxicological bioassays of environmental contamination to include the genetic effects of pollutants on DNA;
- Conducting the second annual Food Processing Waste Conference, which drew an international audience of 300 participants and 45 exhibitors;
- Conducting the third annual Indoor Air Quality Symposium and bimonthly radon awareness seminars; and
- Issuing a quarterly newsletter to 7,000 subscribers and developing several brief technical guides on key environmental issues.



GTRI's penetration analysis aiding system (Pen-Aids), now being fielded to all F-16 aircraft units, has become a major component of the U.S. Air Force Mission Support System. Using digital terrain elevation data, threat modeling, and intelligence reports on enemy radar and anti-aircraft systems, Pen-Aids determines the least dangerous route for an aircraft flying through threat-defended territory. In FY 89, GTRI researchers began design and software modifications for a follow-on version which incorporates an enhanced graphics display and high-resolution digital map data stored on optical disks.

Before route planning can occur at the unit level, the Tactical Air Control Center (TACC) must first determine which aircraft should be sent against which targets. In a joint effort with Morris Brown University in Atlanta, Georgia, GTRI researchers are designing a decision-support system to assist in the day-to-day battle management of all flying units within a theater of operation. The new Route Evaluation Module will optimize the matching process between candidate aircraft, munitions, and desired targets by selecting the particular combination that presents the least cost in terms of danger to the air crew and distance to be flown through enemy territory.

In related work, GTRI is assisting Robins Air Force Base with the design and development of enhanced navigation sys-



Gary Meek

■ ■ GTRI researchers are using special vision algorithms to develop a knowledge-based system for rapidly interpreting cardiac images.

tems. Intended for use in helicopters, the new systems will integrate a number of sensor inputs to refine positional data. GTRI researchers are analyzing software to be used in the system and exploring more convenient methods for pilot interaction.

During the past year, GTRI continued to support the U.S. Army Aviation Modernization Plan in the definition of new mission equipment packages. Designed for the lightweight helicopter (LHX), these advanced avionics systems include helmet-mounted displays, forward-looking infrared detectors, and modern target acquisition systems. A major concern has been how to transfer these developing technologies to older Army aircraft. GTRI has been tasked with identifying deficiencies in the existing

helicopter fleet, selecting which LHX technologies are most appropriate for transfer, and providing design guidelines for their use in other aircraft.

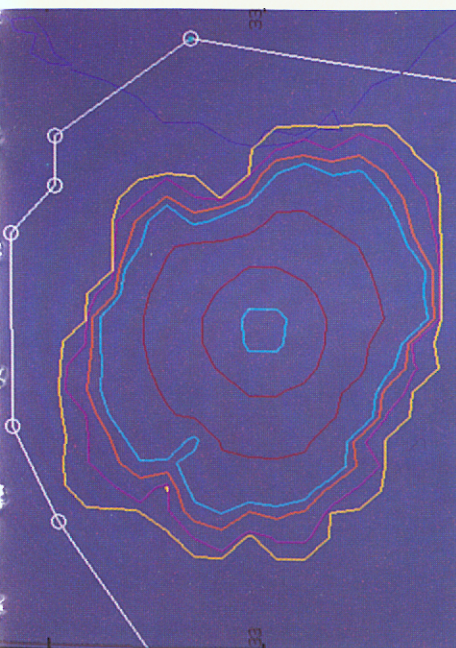
GTRI researchers are also assisting the Joint Integrated Avionics Working Group with the development of advanced avionics software and architecture that allows the three services (Army, Navy, and Air Force) to reuse components and transfer technology between programs.

Artificial Intelligence

During the past year, GTRI continued work on the automation of cockpits in semi-autonomous aircraft and the further development of fully autonomous vehicles. Projects included designing expert systems to assist single pilots, conducting mission effectiveness studies, and exploring new methods for coordinating multiple unmanned aircraft.

Using the new blackboard architecture offered by the Generic Expert System Tool (GEST), GTRI researchers are developing a large-scale route-planning system for autonomous vehicles. Capable of performing flight analysis and replanning, this Heuristic Automated Route Planning Oracle

Computer scientists are developing a knowledge-based system for rapidly interpreting cardiac images. ■



■ ■ Above, GTRI's penetration analysis aiding system (Pen-Aids) determines the least dangerous route for an aircraft flying through threat-defended territory.

(HARPO) consists of a number of expert systems which communicate and share relevant information via the blackboard.

In a project for the National Institutes of Health, GTRI researchers are using GEST and special vision algorithms to develop a knowledge-based system for rapidly interpreting cardiac images.

Neural Networks

The massively parallel processing aspect of neural networks emulates the decision-making functions of the brain. Neural networks are particularly suited for applications which involve making optimal choices from among huge numbers of alternatives. In FY 89, GTRI researchers began developing neural networks for tactical route-planning, rapid pattern recognition, optical signal processing, and other vision-related problems.

These advanced neurological architectures incorporate multi-layer proc-

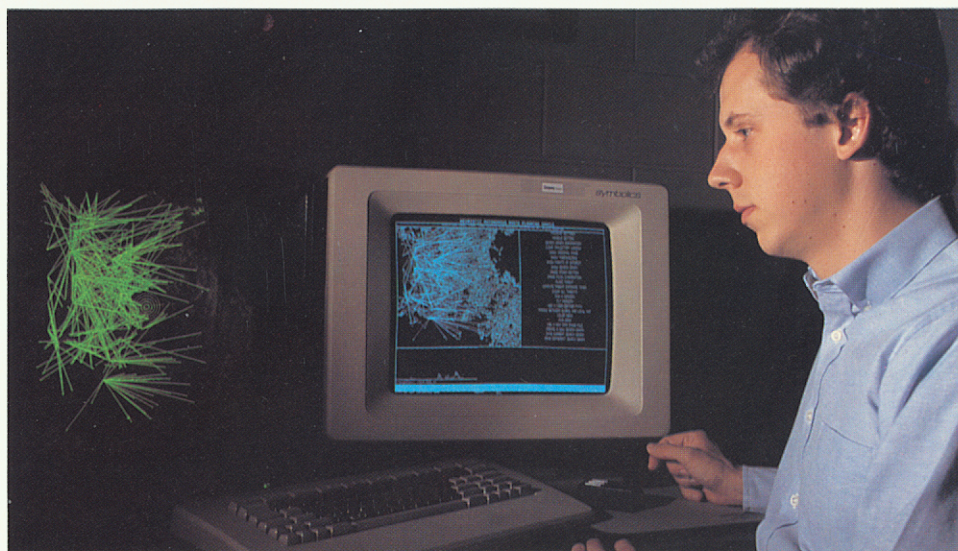
essing and back-propagation techniques to adaptively learn. For example, a route planning system being developed for the Grumman Research Center will learn from examples of effective tactical paths rather than from rigid algorithms.

Real-time identification of pulsed emitters is becoming increasingly difficult to achieve as the number of emitter systems grows and as the variability of parameters increases. Efforts using conventional artificial intelligence approaches have been under way at GTRI for a number of years, but building algorithms to differentiate one emitter from another in a timely manner can still be a nearly impossible task. In a program with the Air Force Wright Aeronautical Laboratory (AFWAL), GTRI research-

compare results between neural network techniques and conventional approaches, and develop recommendations for a neural network technology transition strategy.

Other significant research efforts included:

- Developing an expert system to palletize unequally sized containers for optimized stacking;
- Designing an expert system prototype to address issues concerning software reusability; and
- Developing new techniques for applying the NASTRAN computer database, which describes the physical properties of aircraft, to the structural analysis of helicopters.



ers are addressing the problem of applying neural network technology to intrapulse processing. GTRI will examine characteristics of intrapulse data and select a set of paradigms suitable for the application of pattern recognition. Researchers will then

- ■ Researchers continued to develop a large-scale route-planning system for autonomous vehicles.

A new \$5-million apparel research and demonstration center operated jointly by Georgia Tech and the Southern College of Technology opened early in FY 89 with a pilot-scale demonstration of blue jeans manufacturing using state-of-the-art equipment. Ongoing research focuses on automating entire factories rather than individual processes or specific pieces of equipment. GTRI is involved in computer integration of the center, as well as overall administration of the project, aimed at revitalizing the lagging American apparel industry.

Ground was broken in September for Tech's 120,000-square-foot Manufacturing Research Center, scheduled for completion in 1990. The state of Georgia has allocated \$15 million to the project. Three corporate sponsors donated a total of \$3.25 million to help equip the new facility. A GTRI investigation into knowledge-based systems for manufacturing was one of four

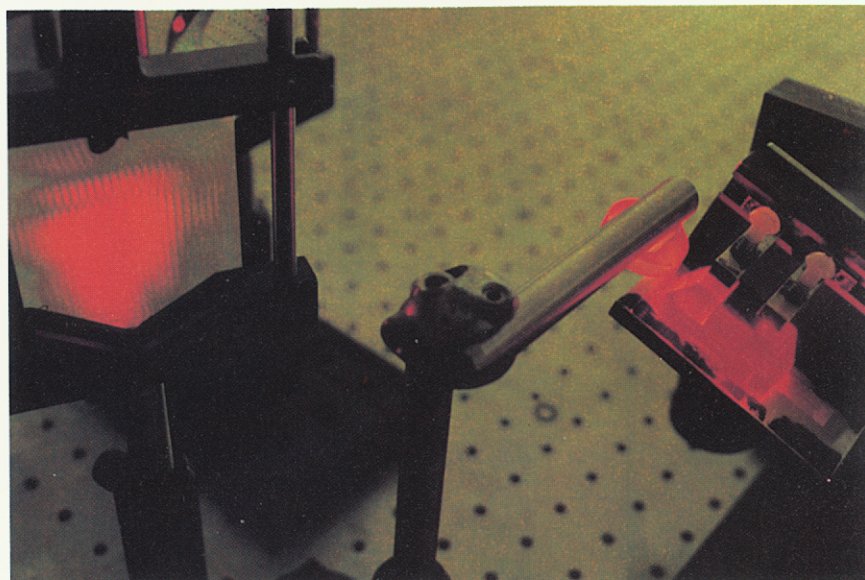
Engineers developed advanced optoelectronic sensors for industrial sensing and inspection operations. ■

research projects undertaken by the center during FY 89.

Machine vision research in FY 89 concentrated on product quality inspection in the food processing and apparel industries. Engineers began assessing the potential of commercial vision technology to grade raw meat and meat products, and to detect fabric flaws in automated apparel fabrication plants.

Automated Guided Vehicles

The Georgia Tech Material Handling Research Center continued to support development of a software-guidepath-based automated guided vehicle system. FY 89 research focused on integrating the design,



■ ■ Above, GTRI engineers continued to develop advanced integrated optics chemical sensors for industrial applications.

implementation, and operation of a prototype, test-bed off-wire system. A set of data files describing the network of paths is generated by an engineering design workstation and placed on board the vehicle. The onboard computer is able to interpret a simple command and extract the appropriate path description from the data files. Engineers also worked on designing a local controller to control a fleet of automated guided vehicles.

To improve navigational accuracy of the vehicle, researchers designed a correlating camera that "watches the floor go by." This non-contact system is an improvement over odometry, which is affected by wheel slippage. A study was begun of wider applications of the camera, such as measuring the velocity of a web in textile mills.

Engineers also worked on a test plan to evaluate competing automated guided vehicle models for an industrial client.

Materials Processing

In the materials development and processing arena, GTRI engineers assisted several producers of nonferrous metal items with production and quality problems. For a large



■ ■ Right, GTRI agricultural engineers began field testing a machine vision system for sizing and grading birds in poultry processing plants.

can-maker, engineers identified the oxides on aluminum sheet used for can stock that were causing excessive tool wear, and proposed methods to eliminate them. They helped a producer of copper rod and wire upgrade its processes and introduce a "total quality concept." After six months of implementation, the company reported considerable savings and greatly increased production. A project sponsored by seven industrial clients was initiated to study tribological phenomena which occur during the drawing of copper wire, including lubrication and metallic fines generation. Other studies included: examining mechanisms by which hydrogen is absorbed into copper during electrorefining, and its effect during casting and hot working; improving the quality of processing equipment for a tire manufacturer; and designing new dies for an extrusion process. Researchers also began assembling an encyclopedia of wire breaks for the ferrous wire industry.

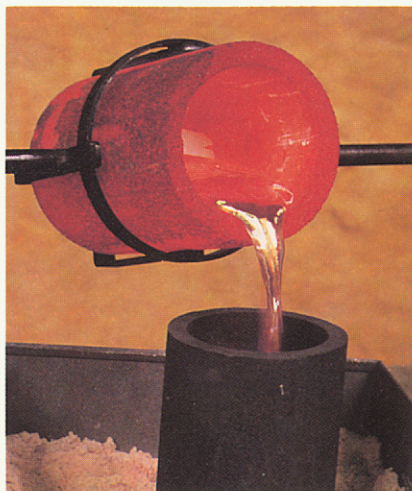
Interconnection Technologies

Emerging interconnection technologies are imposing new high-performance requirements on solder alloys used in the manufacture of high-density microelectronic systems. Smaller connections greatly increase the electrical, mechanical and thermal stresses occurring within the solder material and its interfaces. In FY 89, GTRI scientists continued to employ unique micromechanical techniques to study the performance of available solder and polymer interconnection materials. Relationships between microstructural characteristics and mechanical fatigue, creep and tensile behavior were discovered and analyzed. Scientists also continued to evaluate the significance of particular manufacturing faults on electronic reliability.

Research engineers continued to develop advanced optoelectronic sensors for

use in industrial sensing and inspection operations. They worked on surface inspection systems that will enable industrial clients to detect and classify defects in products that are produced in a continuous web, as well as to measure web speed. Work on integrated optic chemical sensors for process control and hazardous agent detection included efforts to develop waveguides and optoelectronic integrated circuits.

Strategic logistics planning research concentrated on building mathematical models which will become part of an integrated system for planning industrial distribution networks. Researchers attempted to incorporate such costs as location, transportation between warehouse and customer, and inventory into the models, a procedure that has never been done before. Ultimately, this pioneering work will be incorporated into a computer model for use by businesses as a decision-support system.

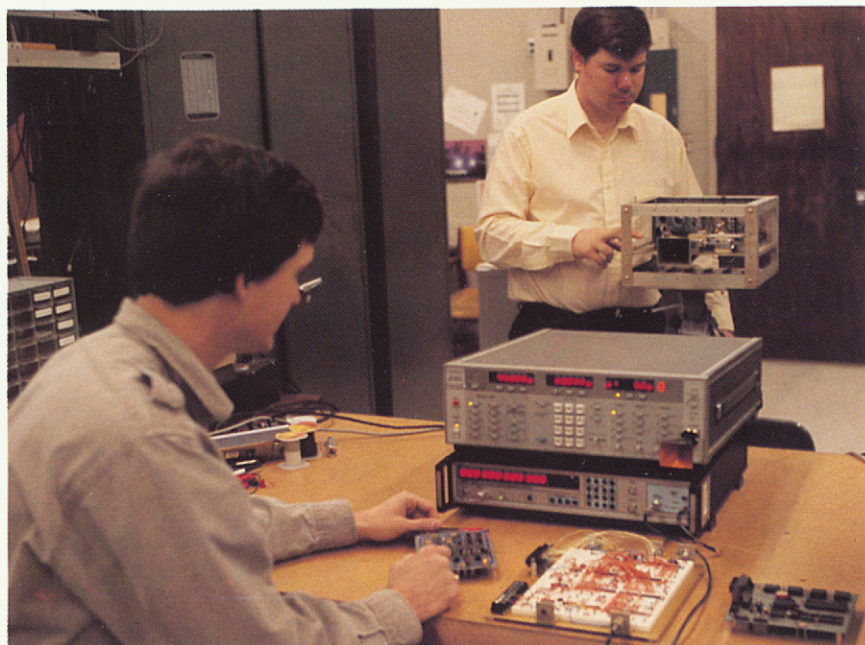


■ ■ Above, researchers investigated new methods of aluminum alloy composite casting to improve material performance and reduce manufacturing costs.

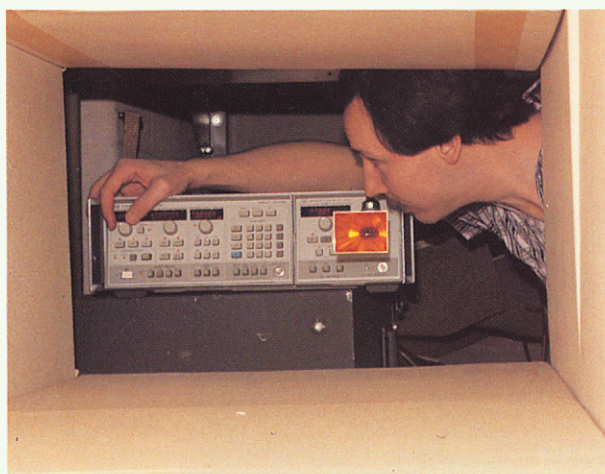


Communications systems are becoming more widespread and complex as the need to move information increases for commercial and military applications. The capacity of systems and networks, as well as their survivability in the presence of countermeasures such as jamming and interception, are critical issues. In FY 89, GTRI engineers continued to develop new communications techniques with the goal of reducing vulnerability and interceptibility, while maintaining the throughput that modern communications applications demand.

Major emphasis was placed on the development of signaling techniques which adapt to changes in the environment to constantly assure maximum performance in a rapidly changing situation. These adaptive signaling techniques have application



■ ■ ■ Above, prototypes are assembled and tested to verify communications principles and hardware performance.



■ ■ ■ GTRI engineers have designed signal collection systems to cover wide frequency bands.

in both military and commercial roles. For military use, the goal is to ensure data integrity and rapid message delivery. For commercial application, adaptive signaling techniques allow operation of large networks at minimum cost and delay.

To determine the performance of signal formats used in command, control and communications systems, GTRI researchers have analyzed the performance of several military systems operating in the presence of intentional interference, or jamming. Unintentional interference due to the operation of multiple communications systems in a single location is also becoming an increasingly vital research area. GTRI communications engineers have developed methods for dealing with "co-site

interference" to allow the simultaneous operation of multiple radio systems. The effects of electromagnetic propagation are key aspects of this research area.

FY 89 also saw the expansion of a major research effort with the Army to study communications technology and its implementation in systems for use worldwide. The identification of levels of technology insertion and common design practices are of key interest.

GTRI continues to serve as the prime contractor on an Air Force program which also involves more than a dozen industrial subcontractors. Research topics include optical communication, network control and design, and computer-aided design tools as applied to command, control, communications, and intelligence networks.

Other significant efforts included:

- Developing a computer model to characterize dense signal environments;
- Evaluating test results for a tri-service data distribution system; and
- Designing subsystems to aid in the characterization of the electromagnetic environment for use in adaptive communications systems.

Today's advanced aircraft are loaded with electronic equipment. In FY 89, GTRI engineers conducted a major study to evaluate the potential for electromagnetic interference between various items of this equipment. In this study, researchers evaluated the energy coupled from one piece of equipment to another, designed both laboratory and field tests to determine the emissions and susceptibility of hardware equipment, and provided advice and guidance on steps to control such interference. They also began developing a computer expert system to aid aircraft designers in determining the optimum locations for electronic equipment to minimize electromagnetic interference.

In the "smart house" of the future, household utilities and appliances will plug into a unified system controlled by a central computer. In FY 89, GTRI engineers performed evaluations of signal transport properties of new wiring concepts, including their electromagnetic interference implications, and assessed how well they might operate in the home of the future.

GTRI researchers continued their major study of the effects of external radio frequency sources on high-speed, high-density integrated circuits. They completed assessment of currently available computer analysis models to evaluate the nonlinear behavior of monolithic microwave integrated circuits, and continued laboratory measurements of the effects of electromagnetic interference on these circuits.

Engineers prepared for national distribution a video training tape and manual to teach traffic engineers and maintenance personnel how to choose and apply appropriate measures to protect electronic traffic control equipment from lightning and other fleeting overvoltages.

In other activities, GTRI researchers:

- Continued developing an automated testing facility for examining the effects of electromagnetic energy on aircraft;



- *GTRI engineers prepared a video training tape that demonstrates appropriate measures for protecting electronic traffic control equipment from lightning and other fleeting overvoltages.*

- Continued investigating conductive caulks and their effectiveness in sealing aircraft from environmental and electromagnetic effects;
- Worked with the developer of a fiber-optic guided missile to assess the effects of the radio frequency environment on its control electronics;
- Continued testing cardiac pacemakers for various manufacturers; and
- Served on the Electromagnetic Compatibility Advisory Board for the U.S. Navy's Standard Missile Program.

Researchers studied the problem of electronic interference in the "smart house" of the future. ■

Development of millimeter wave systems normally requires a lengthy and costly process. To reduce both lead time and expense, GTRI engineers are designing a Millimeter Wave Technology Class System that will replicate a variety of systems over the full range of millimeter wave frequencies. This unique, versatile system is capable of simulating radars, communications systems, and countermeasures. Consisting of numerous rack-mounted modules such as modulators, timers, converters, processors and drivers, the system can be easily reconfigured to attain desired test-bed signal characteristics. This multi-functioned system is being built around a central core of currently existing equipment.

GTRI researchers are also investigating the reception characteristics of a new type of millimeter wave substrate-mounted antenna. These miniature

Researchers are investigating reception characteristics of a new substrate-mounted antenna. ■

antennas are being produced by the same photolithographic techniques used in standard integrated-circuit electronics. Investigators are examining how antenna properties change with substrate thickness, and exploring the use of the substrate to focus energy onto the antenna. Applications of this new technology include free-space power transmission, millimeter wavelength imaging, and submillimeter/infrared radiation detection.



■ ■ Above, researchers use this Fabry-Perot interferometer to characterize materials at high millimeter wave frequencies.

Software and Analysis

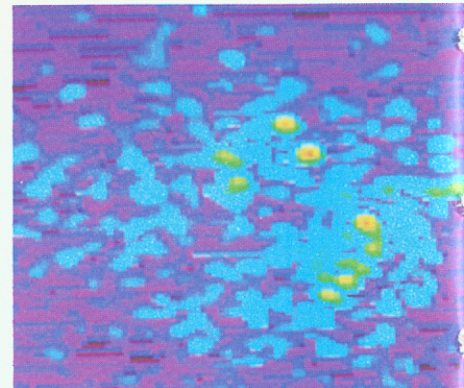
In a project for the U.S. Army Missile Command (MICOM) in Huntsville, Alabama, GTRI engineers developed special software to process complex radar cross section data on a small personal computer. The new data-handling package can calibrate and process data from standard nine-track magnetic tapes and produce high-resolution color images—functions normally requiring the use of a much larger computer.

GTRI researchers are also investigating the modeling and signal-processing

issues involved in fusing a passive infrared sensor and a millimeter wave radar into a dual-mode sensor. This multi-spectral signal-processing study is focusing on infrared and millimeter wave scene registration and fusion algorithms for detection and discrimination by the sensor. The capability for analytically modeling dual-mode sensor data is being developed from existing radar and infrared signature research at GTRI.

Other major areas of interest included:

- Assisting the U.S. Army Missile Command with developing specifications for a new millimeter wave/infrared test tower;
- Developing theoretical models for temperature dependence of dielectric/magnetic mixtures; and
- Investigating superconducting ceramic properties at centimeter and millimeter wave frequencies.



■ ■ GTRI engineers used a polarimetric millimeter wave radar to produce this inverse synthetic aperture radar (ISAR) image of an automobile.

In FY 89, GTRI completed its fifteenth year of cooperation with the Georgia Poultry Federation, seeking technological solutions to problems facing the state's leading agribusiness.

Engineers finished developmental work on the design of a Poultry Environmental Computer System and began field tests on a Gold Kist Research Farm. The system employs state-of-the-art technology to monitor such factors as temperature, humidity, ammonia level, weight of birds, and feed and water consumption. It uses the data to control environmental conditions in poultry growout houses. Expert system software helps to interpret data and set new control points based on real-time information, which has never before been available.

Machine Vision

GTRI also began field testing its machine vision system for grading and sizing birds in poultry processing plants. The tests are helping researchers evaluate and refine the performance of their design under actual plant conditions. Development work continued on a vision system to identify cut-up parts, and exploratory work began on the use of low-intensity X-rays in conjunction with machine vision to detect bone chips in the finished product.

GTRI's thermally enhanced process to speed the dewatering of skimmings from poultry processing wastewater treatment facilities was modified for continuous, rather than batch, operation. Field studies on a pilot-scale system indicate this is a cost-effective solution to a serious waste disposal problem in the industry. The system can be installed for one half the capital cost and 75 percent of the operating costs of more conventional dewatering systems. Commercialization of the design appears likely.

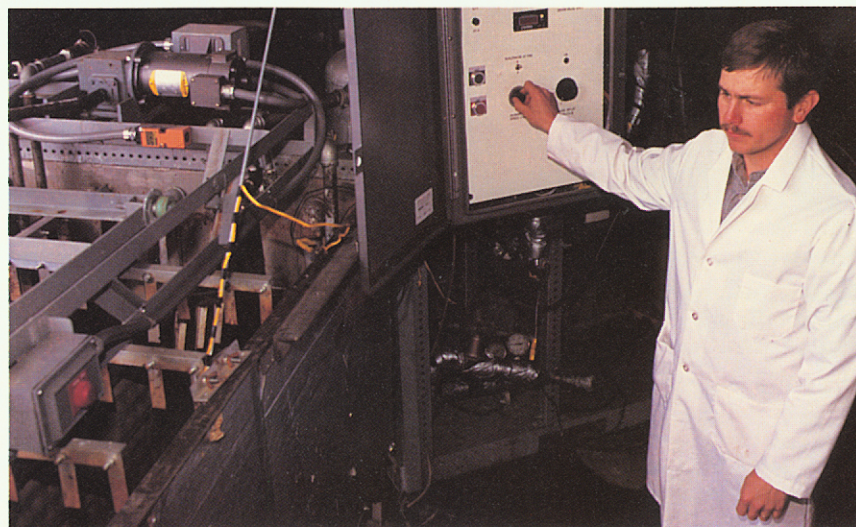
A new area of investigation in FY 89 was cold weather removal of nitrogen from treated wastewater. Winter temperatures typically impact the efficiency of commonly used biological treatment systems to remove nitrogen. Researchers

looked at two techniques—ammonia stripping and breakpoint chlorination—both of which convert nitrates into nitrogen gas that can escape harmlessly into the air. GTRI engineers built pilot-scale treatment plants and tested them at a poultry processing facility.

Other research activities included:

- Field-testing an anaerobic packed-bed reactor for treating poultry processing wastewater;
- Evaluating methods of on-line reprocessing of contaminated birds;
- Transferring technology through workshops, publications and trade show exhibits; and
- Providing technical assistance in response to industry requests.

■ ■ GTRI's Thermally Enhanced Dewatering System economically recycles nutrients in poultry processing plant wastewater.



Researchers developed a pilot-scale treatment plant to convert wastewater nitrates into nitrogen gas. ■

Under the Economic Development Research Program funded by the state legislature, economists began in FY 89 a "match marketing" survey of all manufacturers in Georgia to develop a computer database of the specific products they buy and sell, and who their suppliers and customers are. The results will reveal opportunities for Georgia industry and be useful for industrial recruiting as well. The

Economic development specialists completed a study of the tourism potential of a seven-county area in north Georgia. ■

initial pilot program concentrated on 500 wood products firms.

GTRI continued its target industry studies, in which the resources of an area are computer-matched with requirements of specific industries, and updated the methodology to make the studies more effective. An analysis of the kaolin belt pinpointed the strengths and weaknesses of industries in the area to help development leaders determine the potential for diversification into alternate products. Researchers also completed a study of the tourism potential of a seven-county area in north Georgia. Directories compiled with governmental cosponsorship included one on plastics industries in Georgia and another on services for Georgia businesses.

In the last year, the volume of marketing research for private industrial sponsors doubled. For a Georgia chemical products firm that wanted to expand into new product lines, marketing experts performed a product feasibility and preliminary market assessment; for a major utility company, they investigated nationwide markets

for several reconstituted wood panelboard products and evaluated plant location factors for these products. Other market studies helped an aluminum extruder and a seafood wholesaler to expand.

Researchers surveyed both commercial and residential customers of another utility firm to collect information to drive an energy demand forecasting model. The residential study included an attitude survey to determine what consumer incentive programs would be effective in managing energy loads.

Under one of six federal grants awarded to state correctional agencies, researchers set up a marketing and production feasibility framework to assist Georgia Correctional Industries in selecting new products, based on special manufacturing conditions in prisons.

Another federally funded project was started to assess the level of technology in selected industries in the Appalachian region of north Georgia, to identify those that could benefit most from technology improvements, and to transfer new technology to individual companies.



■ ■ Computer-based management and technical training, a new focus in GTRI's industrial education department, can be more cost-effective than traditional instructor-led training.

Assistance to Development Groups and Industry

In FY 89, GTRI's statewide network of 12 regional offices and technology centers completed some 1,400 technical assistance projects for industries, assisted nearly 500 community and area development groups, and answered over 1,850 information requests. Assistance ranged from helping a chamber of commerce design a community brochure to conducting a quality audit for a peanut processing plant, and from providing layout assistance for plant expansions to assessing electromagnetic noise sources in a printed circuit board and recommending corrective actions.

Building on cooperative efforts initiated with the University of Georgia last year, GTRI's industrial extension service began exploring a more formalized relationship with the University's small business development centers, looking at areas where they could act as resources for each other. A joint seminar for a 13-county area in east-central Georgia highlighted the critical role of banks in the economic development of rural Georgia.

The Energy Analysis and Diagnostic Center, operating under contract to University City Science Center, has been helping small and medium-size manufacturers in Georgia, Alabama and South Carolina conserve energy since 1976. During this period, engineers and students performed energy audits for 367 plants in 18 industrial classifications and recommended 2.2 billion Btu of energy savings amounting to \$22 million, of which some \$16 million were implemented.

The Industrial Energy Extension Service, funded by the Governor's Office of Energy Resources, continued to provide educational services, energy audits, and engineering assistance to Georgia industries, schools and hospitals, and agricultural processors. Over the past 12 years, more than 850 establishments have followed their recommendations and saved 110 trillion Btu of energy, resulting in cost savings of \$350 million. A boiler tune-up program is a new service added in FY 89.



The Georgia Productivity Center continued to help Georgia business and industry increase their competitiveness by focusing on strategies to improve quality, participative management, and technology utilization. In FY 89, the center developed and tested a new productivity audit procedure and conducted projects with more than a dozen companies. A seminar on linking employee rewards to productivity and quality, co-sponsored with Georgia State University, drew nearly 100 attendees from 10 states.

The Procurement Counseling Center started its fourth year of helping Georgia businesses bid on government contracts. Since its inception, the center has worked with some 500 firms, of which 59 received procurement awards totaling \$12 million, with another \$6 million pending at mid-FY 89. The computer service to match government bid requests with subscriber company capabilities continued to

grow, and a new database was added to help firms make realistic bids on parts for the Department of Defense. Procurement seminars also were offered around the state.

Other specialized technical assistance programs continued. They included hazardous waste management, workplace safety and health, help to manufacturers in coping with import competition, technology transfer to apparel manufacturers, and business development assistance through the Economic Development Administration University Center.

Education and Training

Industrial education courses continued to focus on quality improvement through statistical process control. These courses, along with a results-oriented follow-up

■ ■ *GTRI industrial extension specialists helped a manufacturer of plastic cups increase productivity and improve plant safety.*

program, were taught to first-line supervisors at a dozen industries throughout the state. Other courses included applied principles of industrial engineering for the textile industry and numerous development courses for managers and supervisors. GTRI staff also delivered a video-based tap and die course and began research on providing computer-based instruction.

In FY 89, GTRI continued a strong, nationally recognized program in radar research. In addition to ongoing work in target identification and modeling, integration and performance of airborne radar systems, and source technology, GTRI researchers are developing signal processing algorithms for new types of tactical radars employing digital beam-forming and bistatic technology. These radars of the future will combat emerging threats of anti-radiation missiles, electronic countermeasures, and dense target environments. Unlike conventional phased arrays, digital beam-forming radars will be phased in the data processor, allowing greater target resolution while controlling sidelobe inter-

ferences. GTRI researchers are developing digital data processing algorithms that enhance digital beam-forming and bistatic processing functions.

GTRI has conducted research over the past decade culminating in a fully developed, sophisticated radar target modeling program called TRACK. This generic missile-tracking simulator predicts radar cross section as well as seeker track errors due to radar glint from complex targets. In FY 89, GTRI researchers enhanced the simulator to include models for ship-launched chaff and a split-gate range tracker.

In a related project for the Applied Physics Laboratory at Johns Hopkins University, GTRI engineers tailored the TRACK soft-

ware to a specific radar seeker and calculated track errors against ship targets. Researchers also constructed geometric databases for selected ship targets and exercised the missile flyout simulator to predict missile hit points.

In FY 89, GTRI researchers also continued vulnerability and survivability studies on the Army's synergistic radar system known as FIREFINDER. Researchers are integrating off-line parametric studies into a computer simulation model that will simultaneously evaluate FIREFINDER's ability to detect, acquire and track mortar and artillery projectiles in a realistic electronic countermeasures threat environment.

Stable Signal Sources

Recent advances in radar and communications technologies have generated requirements for extremely stable signal sources. GTRI researchers are improving signal stability by closely coupling conventional sources to a superconducting resonant cavity. Initially, conventional superconductors operating at liquid helium temperatures are being used, but high-temperature superconducting technology is also being monitored for possible applications.

In FY 89, GTRI continued to support technology evaluations of promising target identification techniques for the TAAWS (Target Acquisition for Army Weapons Systems) Program Office. Through this project, researchers are comparing existing non-cooperative identification systems (including sensors operating in various bands of the electromagnetic spectrum) under realistic field conditions.

In a project for the Special Operations Forces at Warner Robins Air Logistics Center, GTRI researchers are providing engineering support for the modification of airborne platforms. Containing radars, infrared detectors, navigational equipment, and other avionics systems, each platform must be carefully configured to prevent sensor interference. GTRI engineers are conducting electromagnetic compatibility tests and studying the integration and performance of various avionics systems.

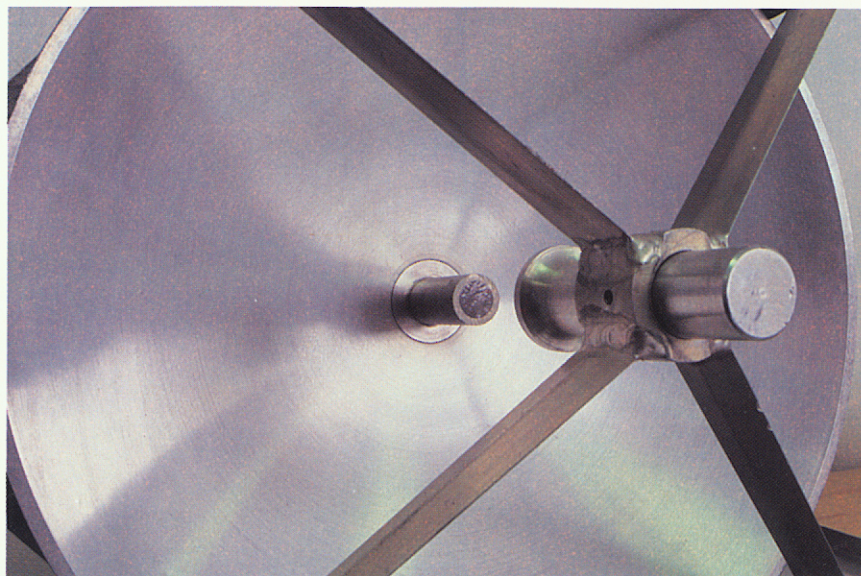


■ ■ GTRI engineers built a computer-based system that automatically monitors radar returns, alerting the human operator only when a potential target is detected.

In another project for the Warner Robins Air Logistics Center, GTRI researchers are investigating shelf-life reliability problems associated with traveling wave tubes and backward wave oscillators. These high-power transmitter tubes, integral components in radars and jammer systems, are exhibiting high failure rates when removed from storage and placed in operation. GTRI is examining potential causes, and seeking ways to extend tube shelf life through improved manufacturing processes and storage procedures.

Special Systems

To reduce manpower needs and improve security, GTRI engineers implemented a



■ ■ This 95 GHz dish antenna is used for radar reflectivity measurements.



■ ■ Researchers monitor the performance of a new active array in GTRI's rooftop laboratory.

computer-based automatic target detection and alerting system for a remote Army facility located in the Pacific Ocean. GTRI scientists designed a novel radar interface with special processing algorithms to suppress clutter and recognize and track multiple aircraft and marine targets.

In a program for the U.S. Army Strategic Defense Command, GTRI is supporting development of the GBR-X (Ground-Based Radar—Experimental), a key element in the Strategic Defense Initiative. GTRI engineers are analyzing major radar compo-

nents, including the antenna, transmitter, receiver, and signal processor.

GTRI engineers are also assembling an in-house pulsed Doppler radar laboratory. The new facility will be used for prototype testing of proposed electronic counter-countermeasures techniques.

Two New Publications

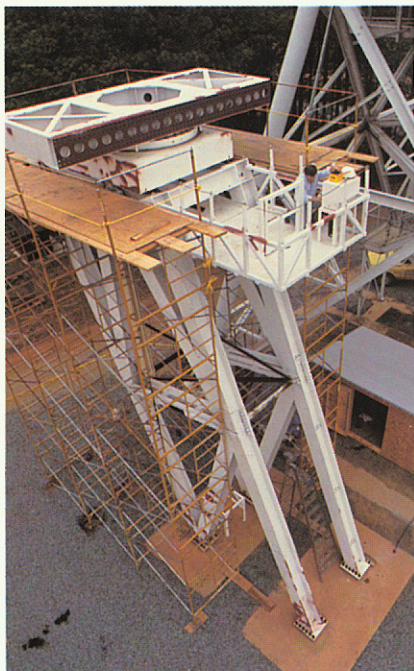
In FY 89, GTRI researchers made a substantial contribution to the radar field with the publication of two new books. *Airborne Pulsed Doppler Radar*, edited by Guy Morris, treats medium pulse repetition frequency, a topic missing in other radar textbooks. This 416-page book also contains discussions on detection performance prediction and clutter rejection by signal processing.

Class notes from GTRI's popular Modern Radar short course (now marking its 20th anniversary) led to the creation of *Principles of Modern Radar*. Edited by Jerry Eaves and Edward Reedy, this 712-page book covers new developments in radar technology. Of the book's 22 chapters, all but three were written by GTRI researchers.

Other significant areas of research included:

- Developing theoretical models to define values of key parameters in stable, coherent radar systems;
- Developing unique radar discrimination algorithms for use in terminally guided smart munitions; and
- Devising a methodology for testing airborne intercept radars in an electronic countermeasures environment.

GTRI engineers implemented a computer-based automatic target detection and alerting system for a remote Army facility in the Pacific Ocean. ■



To receive information simultaneously from multiple stationary and moving objects, GTRI engineers are developing a novel broadband lens antenna. Resembling a giant eyeball, the spherical lens is composed of a dielectrically loaded foam material that focuses incoming beams of radiation. Several robotic arms, each equipped with a different frequency feed, independently ride across the lens surface to track different objects. This design approach offers a unique solution for a multipurpose lightweight antenna suitable for both satellite communications and battlefield surveillance.

Flight testing began on one of the largest airborne phased-array antennas ever built. ■

In a project for Hanscom AFB, GTRI researchers are developing an innovative technique for producing magnetic hybrid feed horns for parabolic antennas. The new process, in which a uniform layer of magnetic material is deposited onto a horn's smooth inner surface, offers significant cost and weight savings over conventional machining methods.

Phased Arrays

To accurately align the thousands of elements and phase shifters required in a phased-array antenna, GTRI engineers assembled a new in-house near-field range. This state-of-the-art facility incorporates modern laser technology to precisely position the measurement probe automatically. The new range is operational up to 40 GHz.

One promising approach for reducing the cost of complex phased arrays involves the use of monolithic microstrip patches which combine a large number of elements into one package, complete with phase shifters and control circuitry. GTRI researchers are developing a mathematical

■ ■ Far left, this novel positioner, designed by GTRI for the U.S. Army, is capable of supporting tanks or light aircraft at various attitudes above the ground. Above, this large phased-array antenna mounted on the side of an airplane can simultaneously track five targets at speeds up to Mach 5.

model to describe the electrical performance characteristics of a microstrip patch element in an infinite array environment. The array will initially have a triangular lattice, but the model will be general enough to allow other configurations.

GTRI engineers have performed extensive research to define the polarization characteristics of reflector type antennas for applications in electronic countermeasures and target identification. Extending this capability to phased-array antennas, researchers are attempting to understand, model and predict the mechanisms of cross-polarization. Users can then determine the susceptibility of various phased arrays to different types of jamming and evaluate whether they are appropriate for use in polarimetric radars.

Also in FY 89, flight-testing began on one of the largest airborne phased-array antennas ever built: a 1,728-element system designed to simultaneously track five targets

traveling at speeds up to Mach 5. Built by GTRI for the Sierra Research Division of LTV Missiles and Electronics Group, the phased array is 30 feet long and weighs about 2,800 pounds. The antenna will be used by the U.S. Air Force Systems Command to obtain telemetry data for missile testing.

Compact Range Technology

In FY 89, GTRI engineers continued work on an outdoor compact range for the U.S. Army Electronic Proving Ground at Fort Huachuca, Arizona. One of the world's largest compact ranges, the system includes a 75-foot diameter reflector and novel positioner capable of supporting tanks, helicopters, or light aircraft at various attitudes above the ground. GTRI researchers developed special wide-band feeds for the range, as well as a unique edge treatment that reduces unwanted scattering from the reflector's edge.

Using an in-house compact range, GTRI scientists continued to obtain high-resolution radar cross section data for a variety of targets. Researchers are also using the range to develop a set of procurement specifications for a new state-of-the-art antenna for the U.S. Air Force.

Modulated Scattering Technique

During FY 89, GTRI engineers continued to develop a modulated scattering technique for quickly measuring the near-field characteristics of microwave antennas. This program, a joint effort with the Ecole

Supérieure d'Electricité (SUPELEC) in Paris, France, has demonstrated the feasibility of the new technique under controlled laboratory conditions. Researchers are now developing a portable unit to assess the feasibility of the modulated scattering technique for on-site antenna testing.

GTRI scientists are also exploring the use of photosensitive materials whose microwave and millimeter wave properties might be switched rapidly by a modulated light signal. Applications include optically switched modulated scattering arrays and control of radar cross section.

Other major areas of research included:

- Developing a large near-field range at the

Johnson Space Center to characterize space-deployable antennas up to 30 feet in diameter;

- Developing conformal array antennas for airborne measurements of intrapulse characteristics;

- Experimentally evaluating dispersion characteristics of switched-beam arrays;

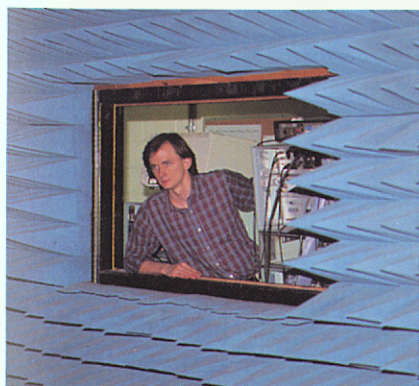
- Developing a user-friendly, on-aircraft antenna analysis code; and

- Designing high-gain, high-performance airborne antennas for sensing military signals of the future.

■ ■ GTRI engineers are developing a spherical lens antenna suitable for both satellite communications and battlefield surveillance.



■ ■ Left, using an in-house compact range, GTRI scientists continued to obtain high-resolution radar cross section data for a variety of targets.



Keeping pace with hostile weapons systems requires that scientists develop more effective, efficient and affordable electronic defense equipment for the United States. During the past year, GTRI researchers continued to help the Department of Defense create more capable radar signal receivers and to adapt artificial intelligence techniques to the management of electronic countermeasures resources on-board aircraft. Other programs increased the

Scientists are studying sound cues as a potential supplement to sight by humans in operating complex systems. ■

effectiveness and reliability of electronic test and evaluation activities. Researchers also focused on improving the performance of human operators doing complex tasks, upgrading military modeling and simulation capabilities, and developing methods for replacing components and subassemblies no longer available to repair military electronic systems that are still in use.

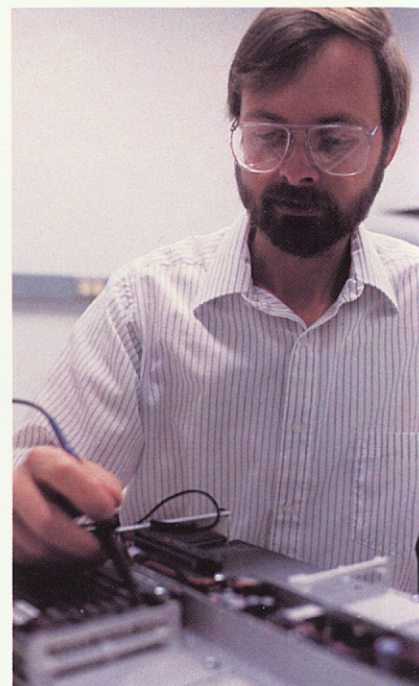
Aircraft Survivability

In a project to improve receiver technology, GTRI engineers completed development of a prototype receiver system for measuring radar polarization. This multi-octave super-heterodyne system is used to determine whether radars can be identified and sorted by measurements of polarization. The system incorporates digital filtering and control, and can be modified easily to measure multiple radars in the microwave and millimeter wave bands. It was successfully tested for signal recovery and discrimination, polarization tracking, and data collection. With improved knowledge of

potentially hostile radars, aircraft can better survive combat.

Survivability also can be enhanced if an aircraft's crew is able to detect the presence of threatening radar-directed weapon systems at greater ranges than possible with current radar warning receivers. This capability would allow pilots to take evasive action in time to remain undetected by the threat radar. GTRI researchers have developed an improved preamplifier and demonstrated its capability to provide current radar warning receivers with greater detection range.

With the increasing complexity and density of enemy weapon systems, there is a need for more sophisticated and efficient means of defending aircraft through integrated electronic countermeasures. Toward this end, GTRI researchers began development of a software test bed in which



■ ■ Above, a GTRI engineer tests an interface board used in a software development/software maintenance station.



■ ■ GTRI is developing an integrated support system for the F-15 Tactical Electronic Warfare System.

researchers can apply artificial intelligence techniques to the management of electronic countermeasures resources. In such a software test bed, relevant aspects of aircraft engagement are simulated abstractly, allowing the researcher to concentrate on the development of time-optimized, adaptive algorithms for integrated electronic countermeasures management.

Electronic Countermeasures

In conjunction with these advances to enhance the survivability of friendly aircraft, researchers made advances in techniques of electronic countermeasures testing.

One problem plaguing testers is the measurement of jamming effects on several radars simultaneously. To solve this problem, GTRI engineers developed the Jamming Analysis Measurement System (JAMS) for use by Department of Defense test agencies in evaluating electronic combat equipment. The system is a real-time data acquisition software package that provides detailed data on multiple radar targets and jammer signals. JAMS provides the first quantitative assessments possible of the effects of countermeasure techniques in degrading the effectiveness of multiple radars. The instrumentation system has been installed at Eglin Air Force Base's Electromagnetic Test Environment.

In the past year, GTRI engineers also investigated the vulnerability of semi-active air-to-air and surface-to-air missiles to a particular class of interference signals. Using data collected at the U.S. Army Advanced Simulation Center, analytical expressions useful in modeling the effects of electronic countermeasures on missile performance were developed and refined. The application of these findings is helping researchers to better understand how the electronic countermeasures would actually work.

Environmental Symphony

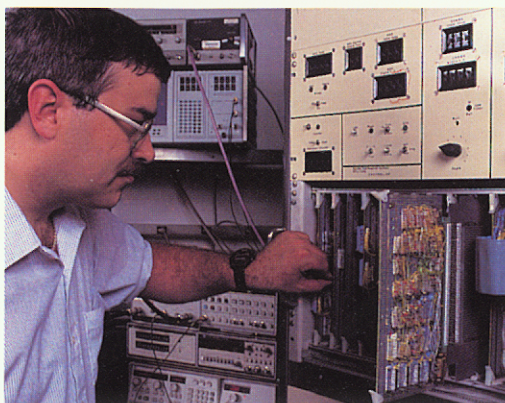
Humans ordinarily work and live in environments filled with information-rich sounds such as the hum of an automobile engine or the rhythm of an industrial machine. These sounds may give information on the position and relative motion of the sound source or may alert operators to potential mechanical problems. Last year, GTRI scientists investigated ways in which the ability of the human to isolate and inter-

pret individual sounds within the continuous environmental "symphony" can be exploited to provide more effective information displays for pilots, battle managers, and remote equipment operators. In this program for the U.S. Army Defense Supply Services, researchers found that operators working on a complex task performed significantly better when the visual displays they monitored were enhanced with auditory information. They also discovered that, as a task becomes more difficult, the advantage provided by the auditory displays becomes even greater.

Researchers developed and delivered an automated database on radar systems for the Ft. Monmouth Electronic Warfare/Reconnaissance, Surveillance, and Target Acquisition Center. This VAX-compatible, on-line system provides a way to easily access radar system data in magnetic media. The user-friendly interface allows an operator who is not familiar with the intricate structure of the Department of Defense's magnetic database to retrieve highly useful subsets of the data through a series of software driver menus. This database is the first building block of a Modeling and Simulation Support Facility at Ft. Monmouth that will contain various databases to drive a variety of software models for evaluating Army electronic defense equipment.

In other FY 89 programs, GTRI researchers:

- Analyzed parameters important in the selection, design and development of applications for digital RF memory technology;
- Established a field office in Dayton, Ohio, to strengthen its sponsor base in this area. The Dayton office joins similar operations for the Air Force that are active in Warner Robins, Georgia, and in Ft. Walton Beach, Florida;



■ ■ GTRI engineers developed and field-tested a prototype receiver system for measuring radar polarization.

- Used sophisticated software to model and design microwave integrated circuit and monolithic microwave integrated circuit devices. These software tools help engineers increase the functionality and reliability of electronic defense systems by reducing weight and power consumption;
- Completed development of an engineering support station for the Warner Robins Air Logistics Center. This station contains all the software testing, analysis and updating functions of an integrated support station; and
- Began planning for a collaborative program with the Georgia Tech School of Physics to investigate the use of high-temperature superconductors in passive receiver applications.



■ ■ Seated: Donald J. Grace
 Standing from left: Patrick J. O'Hare, Hans
 O. Spauschus, James C. Wiltse, Robert G.
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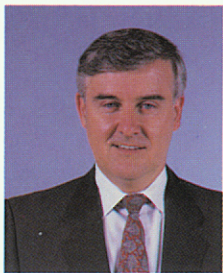
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■ ■ GTRI's laboratory directors are: (top row from left) David S. Clifton, Devon G. Crowe, Robert P. Zimmer, Daniel J. O'Neil; (bottom row) Edward K. Reedy, Fred L. Cain, Charles K. Watt.



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