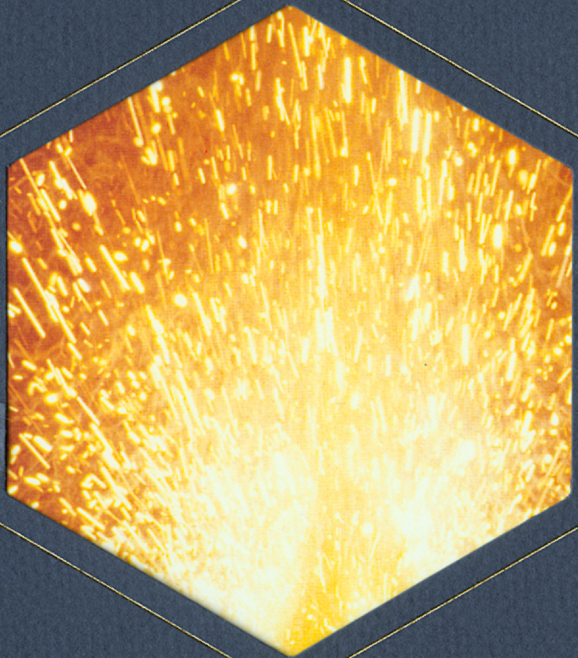
Georgia Tech
RESEARCH INSTITUTE



1991 ANNUAL REPORT

Georgia Institute of Technology

Thermite reactions are used at GTRI to synthesize a variety of valuable materials. Kathryn Logan (above) leads this effort.

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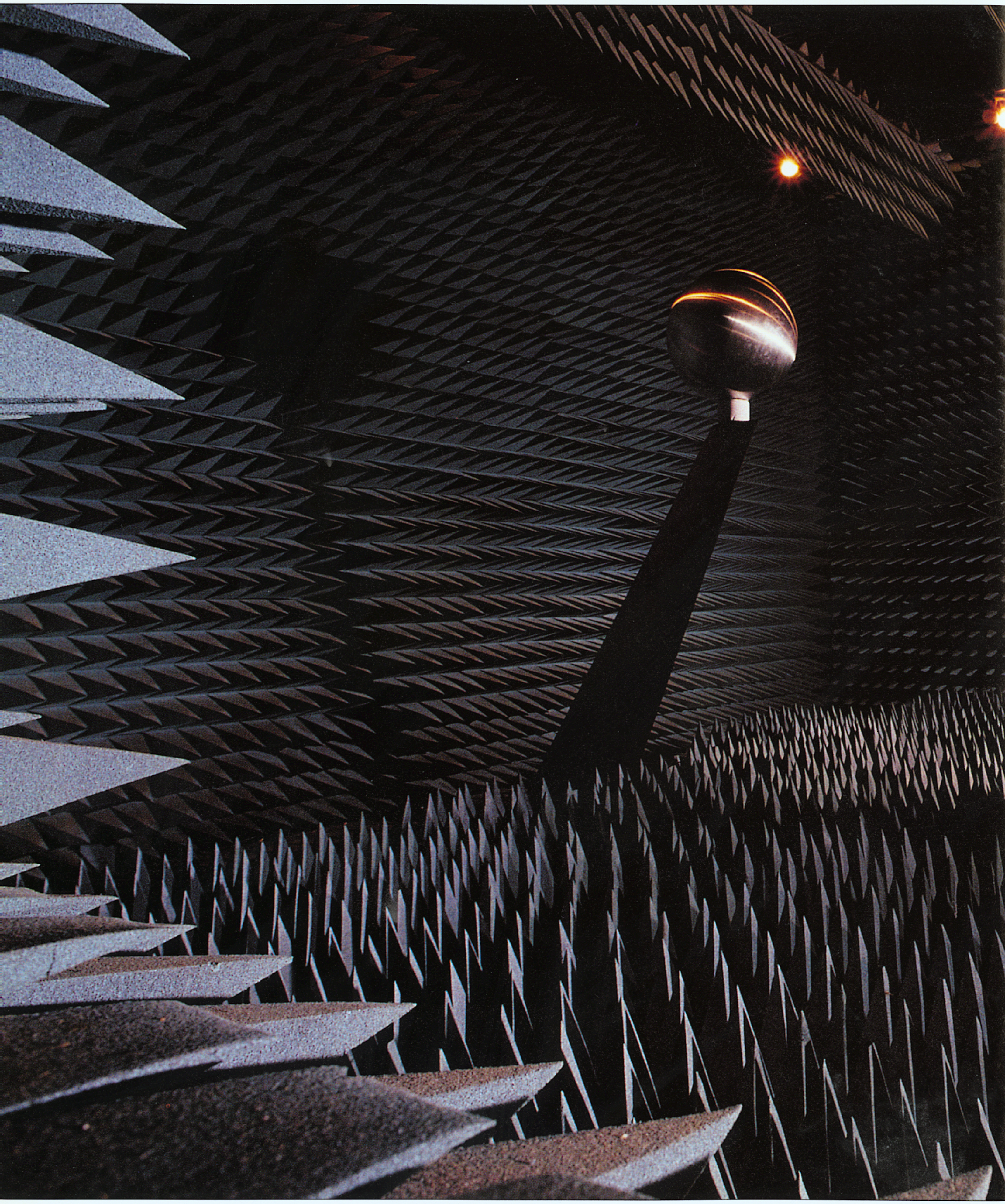

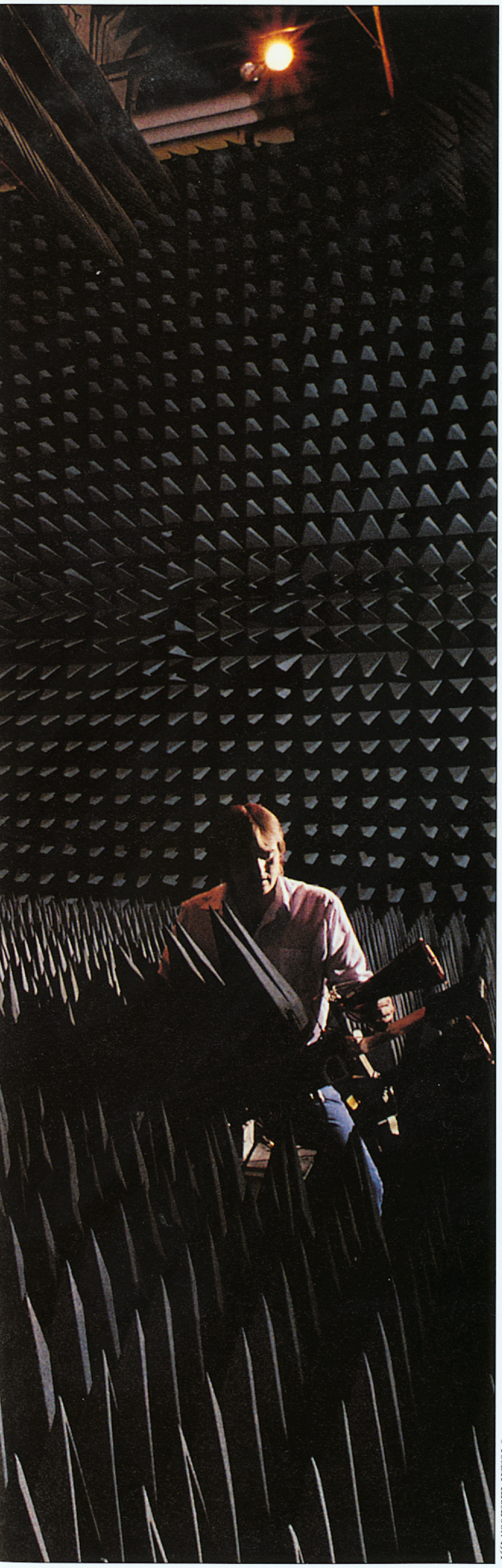

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The Year in Review

Fiscal 1991 was a year of notable successes at the Georgia Tech Research Institute (GTRI). Despite a highly restrictive research funding climate, GTRI was able to increase contract awards from external sponsors by approximately 11 percent. In all, GTRI research awards totaled nearly $100 million for FY 91. This accomplishment was particularly significant, coming as it did during the first year of GTRI's organizational restructuring.

During the year, research expenditures rose by approximately 5 percent to $100.5 million. There were no major changes in the distribution of externally sponsored funding. The U.S. Air Force remained GTRI's principal sponsor; however, its share of total organizational income fell from 33.4 to 29.4 percent. As was the case in the previous year, the Army and other Department of Defense (DoD) agencies accounted for the second and third largest amounts of research funding. The Army's share of the GTRI sponsorship profile rose from 21.5 to 23.8 percent, while other DoD agencies increased from 20.9 to 24.8 percent.

Research support from industry fell from 14 to 12.8 percent during FY 91. Minor decreases also were recorded in sponsorship from other federal agencies and the Navy, which finished the year at 4.2 and 4.1 percent, respectively. Funding from state and local government remained constant at slightly less than 1 percent.

GTRI maintains a compact range, which researchers use to perform a variety of measurements of antenna and radar cross section patterns.

Administrative Innovations ⬢ As previously noted, GTRI initiated a restructuring of its management and research operations. The new organization consists of 20 laboratories instead of the previous seven laboratories. Each of these new operating units has a relatively focused technical mission but maintains linkages to other labs through broad program initiatives.

The objective of this structure is to improve organizational flexibility, quicken responsiveness to client needs, and reduce costs. Such a move was essential for GTRI to remain competitive in the current funding environment, in which there are frequent changes in funding directions, technological focus, and procurement procedures.

After a year of work, we are pleased to report that this restructuring shows all signs of being a success. Though we have encountered the usual adjustments inherent in any process of change, GTRI laboratories are forming the interdisciplinary working groups necessary to compete effectively for a variety of national research programs.

Restructuring wasn't GTRI's only notable administrative innovation in FY 91. The internationally known program of Total Quality Management (TQM) was adopted for long-term use by our organization. In addition, GTRI established a mentoring program, through which junior and senior researchers are paired to work closely in developing new areas of R&D sponsorship.

External Research ● The value of GTRI's research was reinforced by Desert Storm, the recent military intervention in the Persian Gulf. One of the principal reasons for the success of this operation was the accuracy of highly sophisticated electronic defense systems. Over the years, research institutions such as GTRI have assisted the Department of Defense in the development of these systems and supporting technologies. Many of these R&D programs continue, so that U.S. military preparedness can remain at its present high level.

The value of GTRI's defense electronics research was reinforced by Operation Desert Storm.

In recent years, a growing focus of activity at GTRI has been the adaptation and use of defense technology for industrial purposes. For instance, many of our initiatives in manufacturing technology are based on knowledge gleaned from government-sponsored research in infrared/electro-optics. In addition, efforts are being made to apply expertise developed through Department of Defense-supported programs to problems in areas such as air safety, transportation, and civilian rotary-wing commuter systems.

One of the lessons re-emphasized by the Persian Gulf war was that America's national security interests can be enhanced by reducing the country's dependence on imported petroleum. At the same time, the nation has learned that unrestricted fossil fuel consumption poses severe environmental consequences, both locally and globally. For these reasons, interest in alternative energy sources has been rekindled. During the 1970s and 1980s, GTRI remained one of the nation's leading contributors to the development of biomass and solar energy systems and technology, and during FY 91 our organization took steps to rebuild work in these areas.

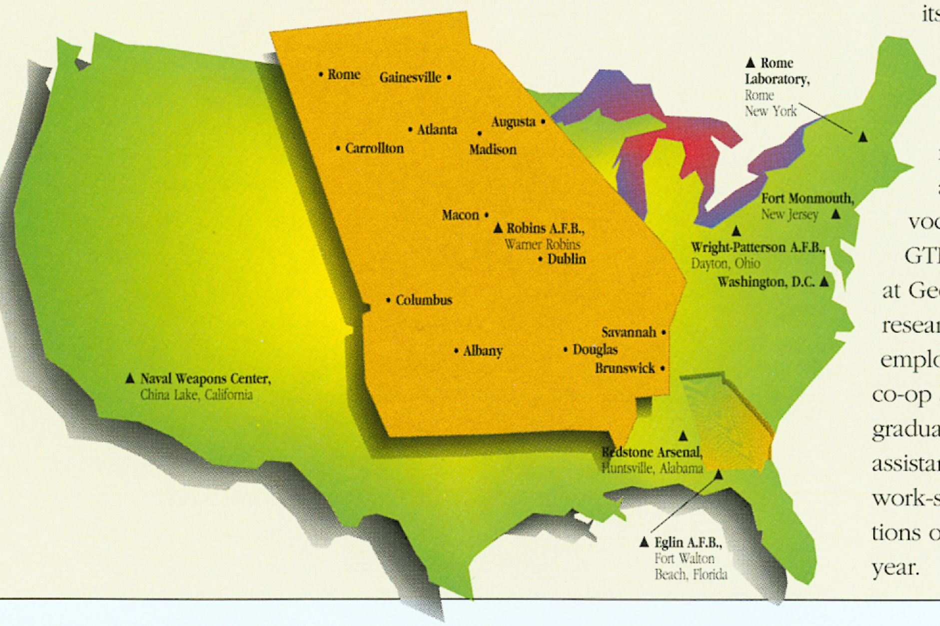
Environmental research has gained a high profile in its own right at GTRI, and these efforts continued to expand during the last fiscal year. In one major initiative, the U.S. Forest Service and major chemical companies supported an effort to make nontraditional measurements of occupational herbicide exposures. In another key environmental program, GTRI researchers developed methods to evaluate and measure health hazards associated with lead-based paint.

Another research initiative in which GTRI was an active participant last year was the campaign to create a Georgia Center for Advanced Telecommunications Technology (GCATT). This program seeks to make Georgia the hub of the growing telecommunications industry by building on an already strong infrastructure of industrial and research resources. GTRI researchers have assumed a leadership position on a committee investigating the potential for high-definition television systems. This quickly expanding activity promises to offer high yields for both Georgia's economy and Georgia Tech's research programs.

Internal Research ● GTRI's program for funding internal research continued to strengthen existing areas of expertise and develop new technologies. Areas of interest included radar systems, signal processing, electro-optics and sensing, environmental science and technology, materials science, and microelectronics. In FY 91, approximately $1.43 million was invested in the program, and 29 internally supported research projects were active. Academic faculty members at Georgia Tech participated in 20 of these projects. In addition, 33 graduate research assistants, one post-doctoral student, and one visiting faculty member were involved in the internal research program.

Contributions to Education ● One of the ways that GTRI upgrades its technical capabilities is its program for supporting continuing education of its employees. During the past fiscal year, 128 members of GTRI's research faculty received assistance to pursue advanced degrees, while 48 members of its support staff sought degrees in associate's, bachelor's, master's, doctoral, and vocational programs.

GTRI also offers extensive opportunities for students at Georgia Tech to work and participate in stimulating research programs. During FY 91, the Research Institute employed 124 graduate research assistants, 27 graduate co-op students, and 10 graduate assistants. At the undergraduate level, GTRI provided work for 172 student assistants, 196 undergraduate co-op students, and three work-study students. Forty-three students from institutions other than Georgia Tech also worked at GTRI last year.

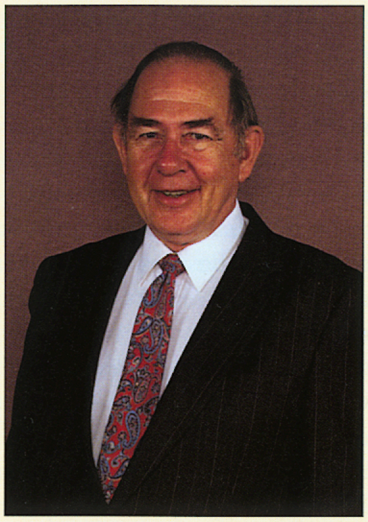


Service to Georgia ● The state derives economic benefits from GTRI in several important ways: first, through the federal and industrial research funds that it brings into the state; second, from the industrial companies that are attracted to Georgia, in part, by access to high-caliber technical support; and third, through programs of direct assistance. For every dollar of state revenue invested in GTRI programs, Georgia receives a benefit of approximately $2.34.

> Increasingly, GTRI's research programs are helping state government officials establish broad policy directions for Georgia.

In FY 91, GTRI continued to maintain research and technical assistance programs targeted to the needs of the state's key manufacturing sectors. For instance, the Apparel Manufacturing Technology Center began a major effort to develop machine vision technology for inspecting cut garment sections before assembly. In addition, the Agricultural Technology Research Program is assisting the poultry industry in developing high-speed machine vision systems for detecting defects in processed poultry.

Global competition is a concern of growing importance to the state's manufacturers. In FY 91, GTRI, together with several academic units, established a Center for International Standards and Quality to help companies in the state overcome the problems of exporting products to other countries. Initial emphasis will be on Europe, with its 1992 goal for unified standards.



Dr. Donald J. Grace

This initiative supplemented the continuing activities of the Southeastern Trade Adjustment Assistance Center, which helps firms in 11 industrial classifications to adjust to imports competition.

Increasingly, GTRI's research programs are assisting government officials in establishing broad policy directions for Georgia. In the economic development arena, the state is using an economic impact model created at GTRI to make cost-benefit analyses of proposed investments in economic development. In addition, a study identified technologies that have the best chance for commercialization in Georgia and outlined policy initiatives needed to stimulate this growth.

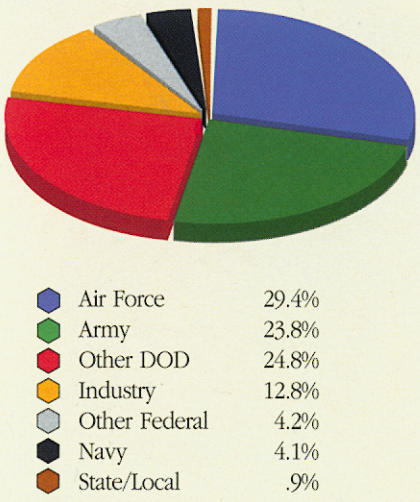
In closing, I would like to express my gratitude to the employees of GTRI. Faced with a year of organizational change and a threatening research climate, they responded with a renewed commitment to excellence and a year of positive growth. For these and other accomplishments, my deepest thanks go out to them.

Donald J. Grace

Donald J. Grace
Director

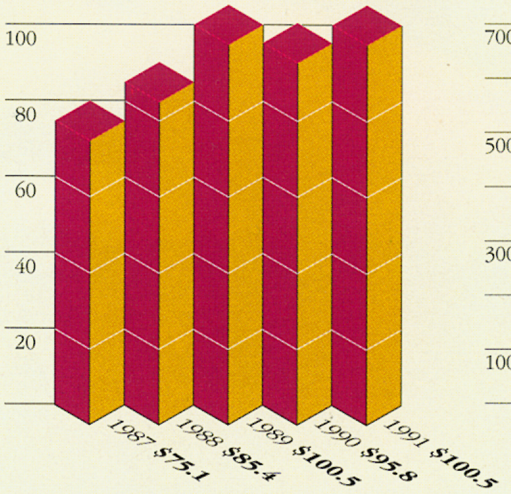
Major Sponsors

(Percent)

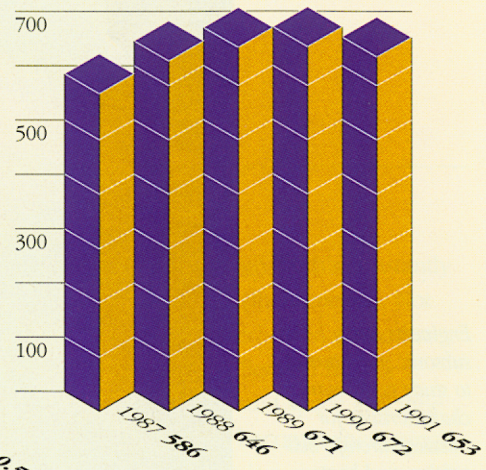


Research Expenditures

(Dollars in millions)



Number of Research Professionals



The successful design and evaluation of future aeronautical systems will rely increasingly upon the effective integration of a wide range of engineering disciplines. To meet this growing need, GTRI engineers have combined advanced computational and experimental testing methods from essential fields into a comprehensive development program. Recent efforts include projects in computational aerodynamics, avionics, aeroelasticity, guidance and control, and flight performance analysis.

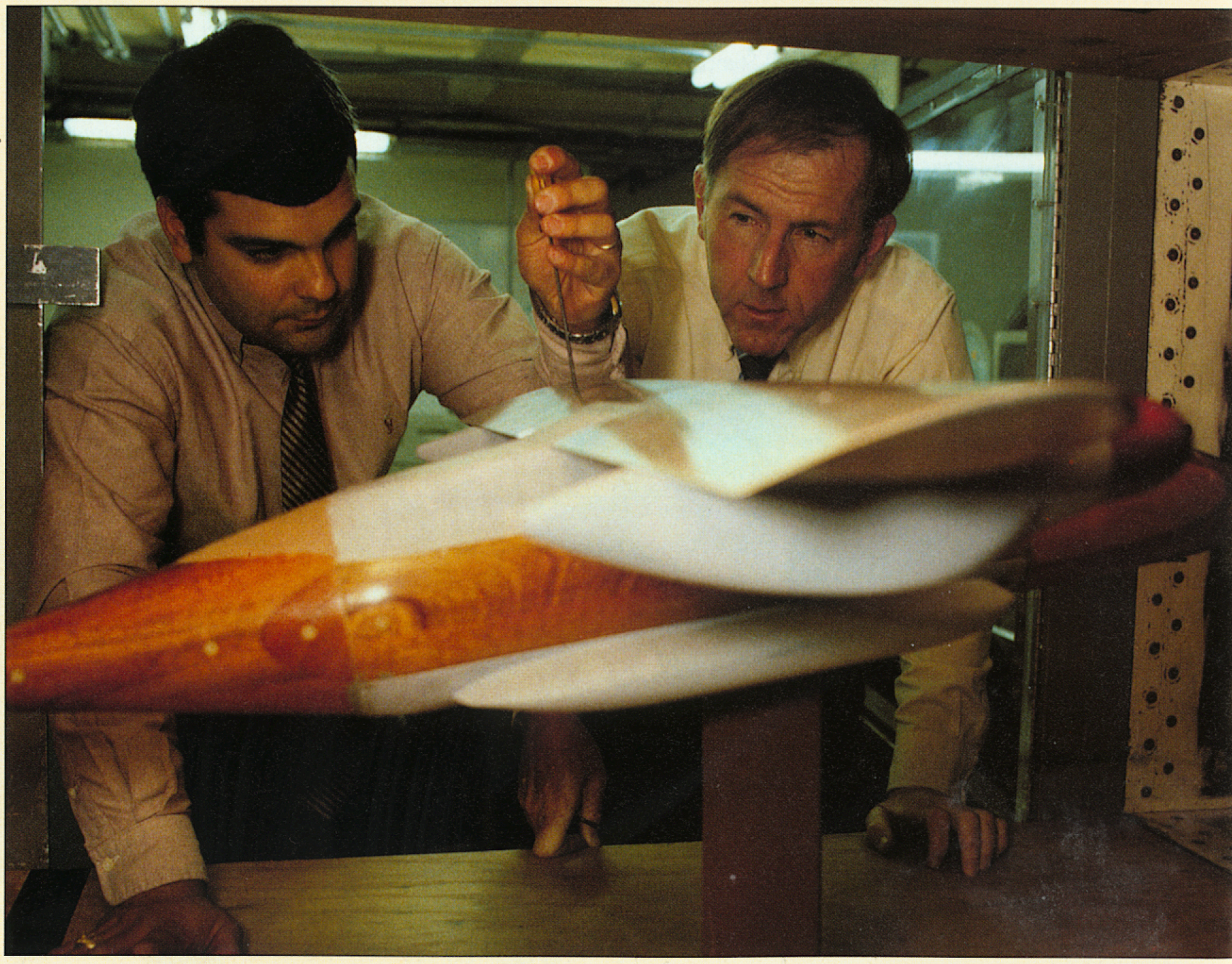
Researchers studied the aerodynamic performance and safety of racing boats.

AERODYNAMICS ● During the past fiscal year, engineers studied problems associated with airframe and propulsion integration, gas aerodynamics, and the transition from low-speed to hypersonic flight for a generic hypersonic vehicle. The main objective of this work was to assess the low-speed characteristics of the upswept, afterbody exhaust nozzles typically used on hypersonic vehicles. The program made use of computational fluid dynamics methodology and three-dimensional laser velocimeter testing techniques.

Using GTRI's subsonic wind tunnel, engineers analyzed the external aerodynamic characteristics of a low-speed missile. Surface pressures and aerodynamic forces measured in the wind tunnel were verified with data generated by computational fluid dynamics analysis. One of the project's main objectives was to investigate the feasibility of using surface static pressure as an effective altitude sensing device.

In a project for Douglas Ford Engineering, researchers investigated the aerodynamic performance and safety of modern hydroplane racing boats. These vehicles skim along the water's surface at speeds in excess of 200 miles per hour. The boats can become unstable when perturbed from optimal racing conditions, often resulting in dangerous "blow-overs" where the boats become airborne, then flip end over end before crashing back to the water.

Engineers performed computational and experimental simulations, and suggested aerodynamic design modifications which improved vehicle stability and reduced the likelihood of "blow-over" accidents.



JOE SCHWARTZ PHOTO

Engineers use a subsonic wind tunnel to study performance characteristics for missiles, aircraft, helicopters, and boats.

Structural Dynamics ● GTRI has been conducting research in high-temperature radome materials for nearly 20 years. During FY 91, engineers pursued the development of new high-temperature materials and structures to be used on the High-Endoatmospheric Interceptor. Because this ground-launched weapon reaches hypersonic velocities at relatively low altitudes, new radomes must be designed to withstand increased thermal and physical stress.

GTRI aerospace engineers also continued to work with the U.S. Special Operations Forces at Warner Robins Air Logistics Center in an effort to extend the capability of the MH-53J (PAVE LOW) helicopter to be operated at gross weights substantially higher than originally designed. Structural integrity analyses were performed using a detailed NASTRAN finite-element model to determine safety margins for fuselage elements over a wide variety of flight and ground conditions. Engineers also performed research related to the helicopter's damage tolerance and fatigue life determination, and supported development of an Air Force structural integrity program that will ultimately ensure a high confidence in the safe and reliable operation of the helicopter over the remainder of its useful life.

Computational Fluid Dynamics ● In the area of computational aerodynamics, GTRI engineers continued to apply computational fluid dynamics techniques to problems ranging from fundamental fluid dynamic research to the analysis of complete aircraft configurations.

In many cases, advanced modeling methods were integrated with other engineering disciplines to provide a fully coupled analysis capability. This approach reduces the need for constructing and testing expensive experimental models, and enables the analysis to extend beyond those conditions that can be simulated by experimental facilities.

A prime example of this type of interaction is an ongoing program to predict the complete infrared signature of the MH-53J helicopter. In this work, GTRI engineers are coupling computational aerodynamics codes with infrared signature analysis programs to determine the impact of the engine exhaust plume on the overall vehicle signature. This effort involves a full three-dimensional viscous analysis of the exhaust plume, including simulation of the actual vehicle geometry and the effect of main rotor downwash.

Researchers also coupled a three-dimensional equation analysis code with a linear structural model to produce aeroelastic analyses of fighter aircraft operating at extreme flight conditions. The program used a zonal grid approach to model complete aircraft configurations including wing, fuselage, horizontal tail, canard, and vertical tail. Researchers are extending this modeling capability to twin vertical fighter aircraft such as the F-15.

In similar work, a three-dimensional Euler/Navier-Stokes program was applied to the aerodynamic analysis of a novel air induction system for an advanced cruise missile. Wind tunnel studies evaluated the low-speed aerodynamics characteristics of the external geometry, including the effectiveness of various control configurations, and a number of fuselage geometries.

Other Research ● Other significant areas of research included:

- Designing more efficient computational techniques to better simulate helicopter rotor vortices and other flow-field phenomena;
- Exploring new methods for predicting flight loads and aeroelastic response of modern fighter aircraft;
- Applying two-dimensional Navier-Stokes equations to a number of high-lift airfoil concepts including circulation control airfoils; and
- Developing a multiple-component, mechanical high-lift airfoil grid generation code and an associated flow solver to enhance capabilities of GTRI's Model Test Facility.

Acoustics

Acoustics is increasingly important in target detection.

GTRI's acoustic research program spans a number of applications, from reducing noise in automobiles and aircraft to controlling jet exhaust plume deflections through use of sound waves. During the past fiscal year, work included the study of heated jets, development of noise prediction codes, examination of human and building response to low-frequency noise, and validation of theories on atmospheric propagation.

The propagation of sound through Earth's constantly changing atmosphere is a complex phenomenon. Not only are conditions in the atmosphere often unpredictable, but sound waves also may reflect off hills or ground cover, resulting in complicated space and time variations. As acoustic technology becomes increasingly important in target detection, there is a growing need for

JOE SCHWARTZ PHOTO

Methods for reducing automobile wind noise have been identified.

In a study for Ford Motor Company, researchers have sought to identify methods that will effectively reduce wind noise in automobiles.

an accurate and reliable acoustic propagation model.

Numerous models exist, but very little validation has been performed. As an initial step in the validation process, GTRI researchers are comparing existing models to determine which model is most appropriate under certain circumstances. Using common meteorological conditions and ground effects, differences in model outputs are being carefully analyzed.

Other work in the area of acoustic propagation modeling includes studying the effects of turbulence on propagation, incorporating those effects into existing propagation models, and developing timely prediction algorithms.

AUTOMOBILE WIND NOISE ● As automobiles become more luxurious and engines become quieter, passengers hear noises they did not hear in the past. One unwanted source is wind noise, produced by air rushing past projections such as antennas and roof racks. In a project for the Ford Motor Company, GTRI researchers ranked a number of antennas and roof racks in order of their acoustic generation characteristics at various speeds. Effective methods for reducing the wind noise generated by these devices were identified.

Researchers also investigated how wind noise is generated and transmitted into the passenger compartment. At high speeds, pressure differences can cause the side window glass to bulge outward, breaking the seal and allowing noise to enter the interior of the automobile. To determine the sound transmission properties of side window glass, researchers mounted part of an automobile in a specially designed anechoic test section of a closed-loop wind tunnel. Detailed acoustic measurements were made both inside and outside the automobile at speeds up to 75 miles per hour.

JET NOISE REDUCTION ● One of the main obstacles to developing an environmentally acceptable civilian supersonic transport is noise. In a project funded by NASA, engineers at GTRI are exploring a number of concepts for reducing noise generated by supersonic jet engines. To date, a variety of nozzle shapes — round, rectangular, elliptical, and triangular — have been tested for their acoustic performance, along with innovative designs involving the addition of mechanical tabs, notches, ejectors, and perforated walls. Several designs have shown promising preliminary results.

Unfortunately, a quieter exhaust nozzle can also mean reduced thrust and increased fuel consumption. To determine the impact of these noise-suppression concepts on engine performance, researchers built a special thrust measurement rig equipped with a six-component force measuring balance. The device allows measurement of nozzle movement in three directions. Researchers can now augment their acoustic and flow analyses with accurate thrust measurements.

In related work for Arnold Engineering Development Center, GTRI is investigating the physical mechanisms responsible for objectionable jet flow/acoustic interactions experienced at full-scale engine test facilities. Sound waves created by high-speed jets can cause test facilities to resonate, affecting data and subjecting test facilities to stress. An understanding of the physical mechanisms involved will help identify control methods and design practices to prevent such interactions.

SONIC BOOM ● Supersonic aircraft can create sonic booms and other noises that are unpleasant to humans and potentially damaging to property. As part of a NASA program to examine the building and human response to sonic boom, GTRI is constructing a low-frequency sonic boom noise simulator.

Unlike other sonic boom facilities, this portable unit will enable testing at frequencies as low as 2 Hz, and will simulate sonic booms of up to 1/2-second duration for realistic test conditions. The simulator will be used to investigate crack propagation and acoustic-fatigue failure in structures, to study the effect of sonic booms on animals and humans, and to validate existing theories of sound propagation through the atmosphere.

OTHER RESEARCH ● During 1991, GTRI has also been involved in:

- Developing noise prediction codes;
- Controlling plume deflection by acoustic excitation;
- Exploring acoustic levitation for applications in microgravity;
- Developing new adaptive filtering techniques for active noise control;
- Developing methods to visualize flows responsible for generating aerodynamic noise;
- Studying noise produced by rock-cutting, high-temperature burners;
- Examining acoustic holography as a potential aid in cancer detection; and
- Experimenting with acoustical methods to separate sulfur from coal slurry, a new concept that holds promise for alleviating acid rain.

MICROELECTRONICS AND APPLICATIONS

Researchers improved chemical vapor deposition techniques for growing II-VI materials.

During the past year, GTRI continued to develop chemical and molecular beam epitaxial growth techniques for advanced material structures such as atomically abrupt heterojunctions, multiple quantum well structures, and modulation-doped semiconductors. These material structures provide the basis for new and improved devices useful in a wide range of optoelectronic and electronic applications. Specific areas of specialization in GTRI include the development of new growth and fabrication technologies for infrared detectors, investigations of optoelectronic waveguide and switching devices for controlling phased-array radar, and improved microwave and millimeter-wave devices for radar and high-speed logic.

Conventional microwave lenses can provide valuable information on the direction of incoming radar signals, but their large size at low frequencies has hindered airborne applications, where size and weight are critical design parameters. In a project for the U.S. Air Force's Wright Laboratory, GTRI researchers utilized microelectronics technology and high dielectric substrates to reduce the lens size by a factor of 10. The result is a compact, lightweight, two-dimensional microwave lens that is suitable for military airborne applications.

INFRARED DETECTOR MATERIALS ● In several areas, GTRI researchers improved chemical vapor deposition techniques for growing II-VI materials, particularly mercury cadmium telluride (HgCdTe), cadmium telluride (CdTe), and zinc telluride (ZnTe). In FY 91, they grew extremely thin HgCdTe epitaxial layers with very low carrier concentrations and high mobilities that are useful for infrared detector applications in the 2-5 and 10-14 micron spectral regions. New techniques for gas-source extrinsic doping of CdTe and HgCdTe were developed to allow halogen n-type doping of these materials and also monomer or dimer arsenic p-type doping. These techniques are expected to result in greater control and increased flexibility in the growth of complex heterojunction and superlattice device structures.

In addition, the successful n-type iodine doping of CdTe was demonstrated, p-type arsenic doped CdTe was grown, and low-temperature procedures for the

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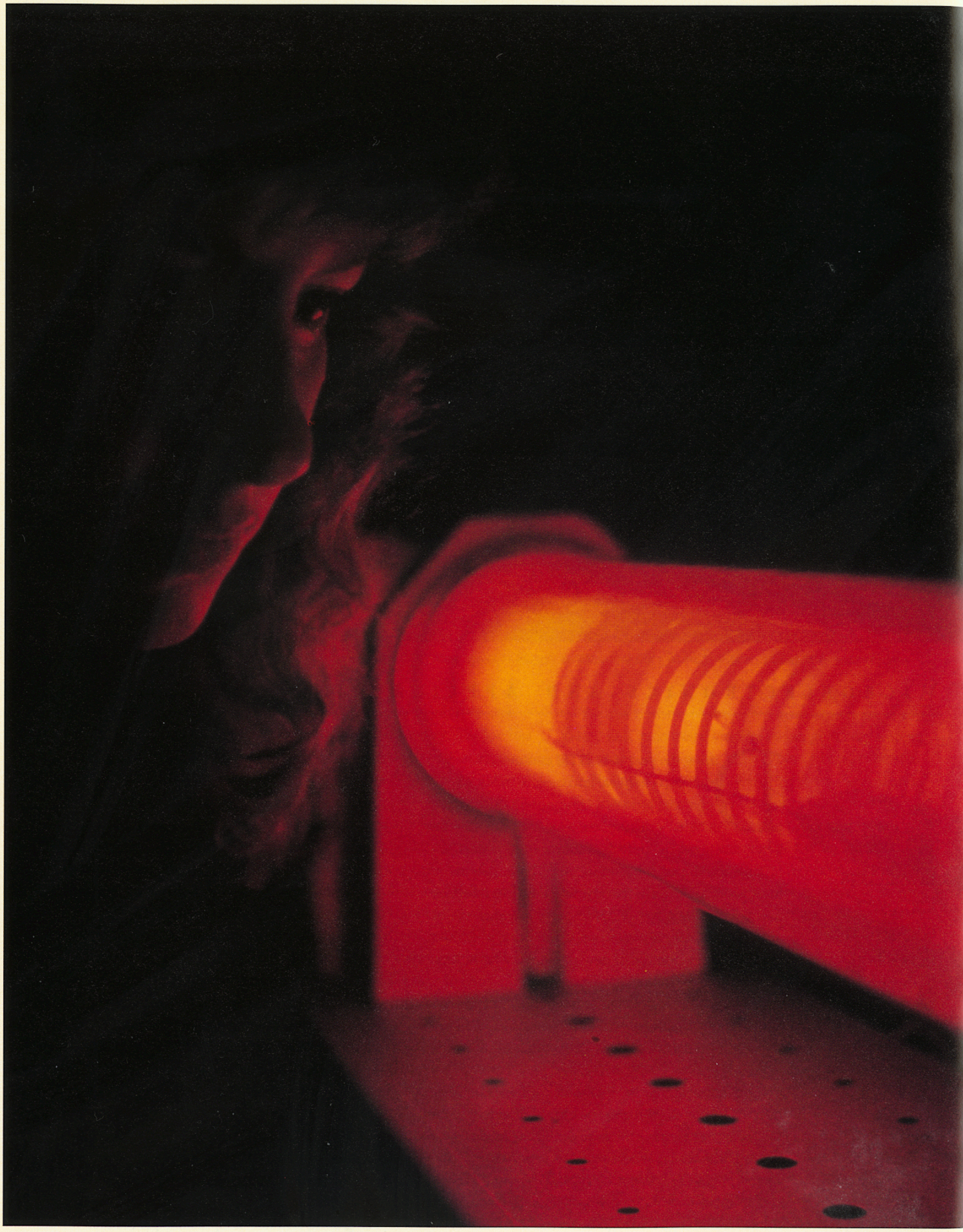


fabrication of CdTe and HgCdTe detector structures were developed.

OPTOELECTRONICS ● Optoelectronics programs were directed toward both the application of these techniques for steering phased-array radars and research into specific devices. In the former area, an integrated optoelectronic approach to a basic time-delay network was developed. By using a folded optical waveguide structure, delays in the nanosecond range can be achieved in a compact package.

Optoelectronics techniques were used for steering phased-array radars and research into specific devices.

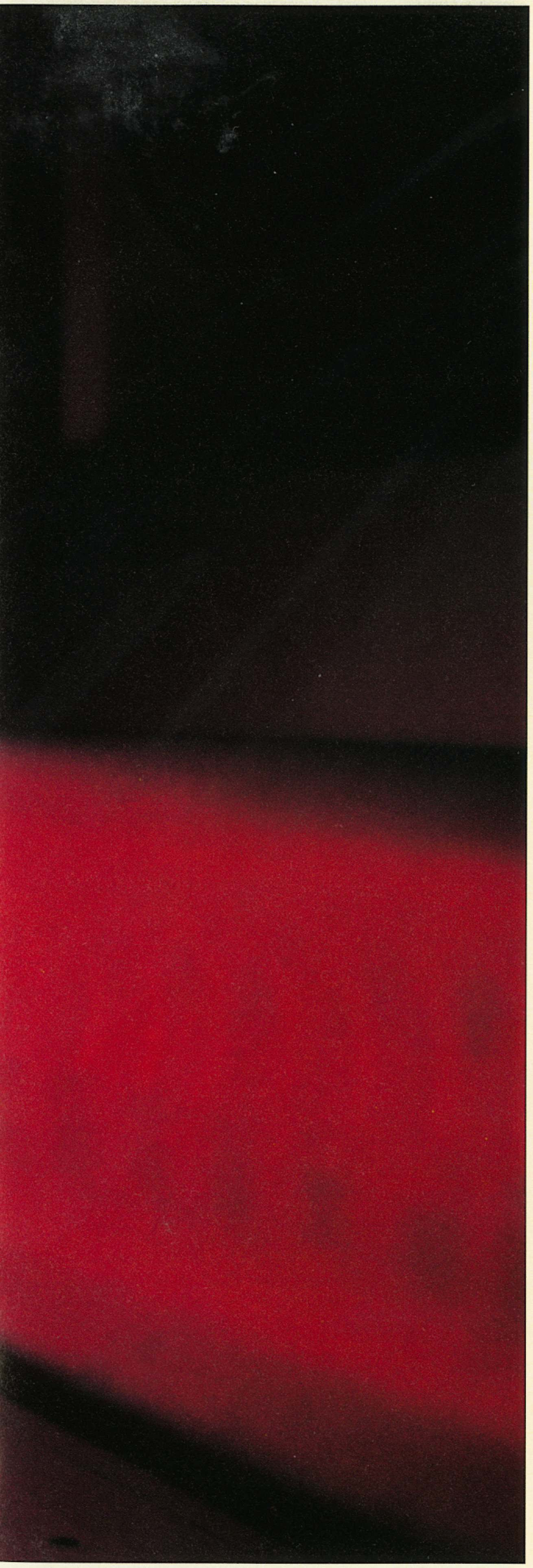
To demonstrate the feasibility of the integrated optical delay line concept, researchers constructed a folded-path structure over a path length of 16 centimeters, corresponding to 0.84 nanosecond of delay. An extension of this work is predicted to produce time delays greater than 10 nanoseconds in a 25 x 75 millimeter package, with even longer delays being produced by switching into single-mode fibers.

During FY 91, gallium arsenide and aluminum gallium arsenide-based optical devices also were investigated extensively for potential application in optical switching, optical computing, and monolithic optical and electrical circuit integration. This research involved the development of models for optical waveguide switches, such as nonlinear directional couplers and grating waveguide devices.

As a result of these investigations, GTRI scientists developed a new nondestructive technique to accurately measure the effective refractive indices of single-mode gallium arsenide and aluminum gallium arsenide semiconductor slab waveguides. The new technique, which utilizes the different focusing positions for guided and unguided light traveling through a planar waveguide, is expected to be very useful in designing waveguide structures and as a tool for wafer selection in distributed feedback laser processing, diffraction grating processing, and the fabrication of optical waveguide devices.

GTRI researchers also continued to extend their capabilities in the area of millimeter-wave testing by the acquisition and setup of a microstrip transistor test fixture. This assembly permits S-parameter measurements to 50 GHz and, when coupled with circuit modeling programs, allows the de-embedded S-parameters of the actual device to be determined. New planar barrier doped diodes were also grown, fabricated, and tested at frequencies up to 94 GHz. In support of this program, researchers worked to develop multilayer photoresist structures for electron beam patterning of sub-quarter micron line widths.

In other work, researchers investigated the use of microelectronic optical test point arrays and optical test port windows for their effectiveness in testing complex microelectronic devices and circuit assemblies.



GTRI research scientists continue to work with academic colleagues at Tech's Microelectronics Research Center, where technologies such as a process for gallium arsenide deposition are being studied.

Researchers demonstrated a direct correlation between dislocation processes and electromigration damage in aluminum.

INTERCONNECTION TECHNOLOGY ⬢ As increasingly small microcircuits have been designed and manufactured, product reliability issues have come to the fore. In FY 91, GTRI researchers made an important breakthrough, demonstrating a direct correlation between dislocation processes and electromigration damage in aluminum. Electromigration is caused by very-high-current density pulses — "electron winds" that produce creeping voids, hillocks, and whiskers in microcircuit materials. Over time, electromigration damage can lead to declining performance or sudden, catastrophic failure in microelectronic devices. In the past, these defects often were blamed on diffusion along grain boundaries in metallic circuit materials. However, experimental measurements by GTRI researchers have provided strong evidence that plastic deformation, a significant dislocation process, also contributes to electromigration. The design prescriptions most likely to inhibit electromigration appear to be those measures that would increase mechanical strength in circuit materials. Thus far, these reliability studies have focused on aluminum conductors, but during the last year, researchers also turned their attention to the causes of electromigration in microcircuit solder joints.

Precise knowledge concerning the mechanical performance of the small material structures employed in microelectronic circuits is becoming more important as circuit technologies progress to greater complexity, higher density, and smaller component dimensions. The reductions in scale are introducing circumstances where metallurgical microstructures and interface geometries are becoming dominant factors in determining ultimate performance.

During the past year, GTRI researchers continued to investigate the micromechanical stress-strain, creep, and fatigue behavior of metals and alloys with low melting points. Critically important correlations between mechanical performance and microstructure-interface characteristics were also pursued through high-resolution imaging microstructural studies. This work included the growth and analysis of intermetallic compounds using electron microscopy and optical metallography. Intermetallic compound growth kinetics, fine precipitates, and interface characteristics were investigated in specially prepared solder interface specimens and in commercially manufactured solder joints.

Researchers also developed experimental techniques for producing thin unsupported solder specimens using methods well suited for controlling microstructures. These new specimen configurations are ideal for controlling growth of both metal and intermetallic compound layers in detailed investigations of the important interface mechanics processes involved during the stressing of such structures.

JOE SCHWARTZ PHOTO

INFRARED/ELECTRO-OPTICS

Researchers are collecting remotely sensed data on environmental and socio-economic conditions in Georgia and the Southeast.

In FY 91, Georgia Tech established a focused research center for analysis in spatial technologies. The center combines GTRI's system design, image processing, mapping, and spatial modeling capabilities with activities occurring elsewhere on campus to pursue research problems requiring interdisciplinary skills.

One of the center's early projects was developing a high-resolution, three-dimensional model of the Georgia Tech campus, using digital color aerial photography, high-resolution elevation data, and individual building photographs. An advanced version of the GTVISIT simulation software, employing multiple-resolution databases, photo texture, and interactive scene modeling, will be used in conjunction with Georgia Tech's new 20-year campus master plan.

Researchers also began forming a data repository containing both environmental and socio-economic data for Georgia and the Southeast. This spatial information will permit research into a diverse set of problem domains, including assessment of the technologies available for efficient handling of large spatial databases. A variety of commercial and developmental geographic information systems (GIS) will be implemented for data management support and for developing new spatial analysis methodologies.

Center personnel have actively supported the expansion of the Georgia Tech GIS curriculum to include expanded course offerings in spatial analysis. Course development included short courses with Education Extension Services as well as formal academic programs.

ASTRONOMY ● During the past fiscal year, scientists designed and built a high-speed, low-noise CCD (charge-coupled device) camera system to detect and continuously record extremely faint images. Researchers will use the camera for speckle imaging of extended astronomical objects of interest to planetary scientists and astrophysicists and for laboratory measurements of faint optical phenomena such as spectra of scattered light from optical fiber.

Last summer, GTRI secured the donation of a 72-inch diameter active mirror from the Itek Optical Corporation, the company producing the 10-meter mirror for the Keck telescope. The 72-inch mirror is thin and lightweight; its spherical surface figure is controlled by 40 actuators. Researchers plan to construct a telescope at GTRI's recently acquired AT&T satellite relay station in Woodbury, Georgia. The optical telescope will complement two 100-foot radio telescopes already at the site, and will be used in projects to measure stellar luminosities, to study mass loss

GTRI received the donation of a 72-inch diameter active mirror from the Itek Optical Corporation, the firm that produced the 10-meter mirror for the Keck telescope.

by supergiant stars, and to probe the earth's atmosphere.

In other work, GTRI researchers analyzed the effects of photon noise on reconstruction of blurred images taken with the flawed optics of the Hubble Space Telescope. They also developed a low-light-level, high-definition, solid-state camera for the B-52 bomber, and initiated the design, fabrication, and testing of binary optics on the Georgia Tech campus.

SIGNATURE EVALUATION ● In projects for the U.S. Air Force's Warner Robins Air Logistics Center and the U.S. Army's Aviation Systems Command, GTRI researchers studied the susceptibility of helicopters to infrared-tracking missile threats. Researchers created models for the PAVE LOW, APACHE, and BLACK HAWK helicopters to predict their infrared signatures and permit the evaluation of countermeasures in combat scenarios such as Operation Desert Storm. Several computer codes were employed in this effort, including GTVISIT (used for three-dimensional rendering of visual and infrared images), GTSIG (for thermal modeling of hardbody, plume, and background scenes), and DISAMS (which simulates the infrared seeker and missile flyout).

GTRI's field measurement capabilities were considerably augmented.

GTRI researchers have developed an interactive visualization tool for use in campus planning at Georgia Tech.

An important aspect of signature calculation is the determination of the fluid flow field near the engine exhaust. The exhaust plume temperature, fluid density, and chemical species concentrations all contribute to the production and absorption of radiant energy perceived by an infrared seeker that tracks the target helicopter. In order to simulate the flow conditions produced during forward flight or hovering, computational fluid dynamics modeling is performed. This modeling permits rapid generation of approximate flow field solutions that could otherwise be obtained only through time-consuming and expensive field-test measurements.

GTRI fluid dynamicists employ potential flow, Parabolized Navier-Stokes (PNS), and full Navier-Stokes algorithms to depict different types of flow fields, depending on the degree of accuracy, solution speed, and class of problem examined. A combination of potential flow solutions with PNS calculations has been developed by GTRI to create a methodology whose flow fields are in good agreement with those produced by more expensive and time-consuming full Navier-Stokes codes. Calculations conducted with this methodology yield reductions in solution time of nearly two orders of magnitude over standard Navier-Stokes solvers. This allows additional configurations to be examined in the same time period, or alternately permits enhanced resolution of flow field characteristics.

FIELD MEASUREMENTS ● GTRI's field measurement capabilities were greatly augmented this year by the acquisition of an imaging system based on an indium antimonide focal plane array sensitive in the 1 to 5.5 micron region.

The system provides 12-bit image data directly to a computer through a digital interface, and is used primarily for aircraft signature measurements in support of modeling and threat assessment programs. The new imager can be used with other systems to cover the wavelength range from the ultraviolet (0.2 to 0.4 microns) through the long-wave infrared (8 to 12 micron).

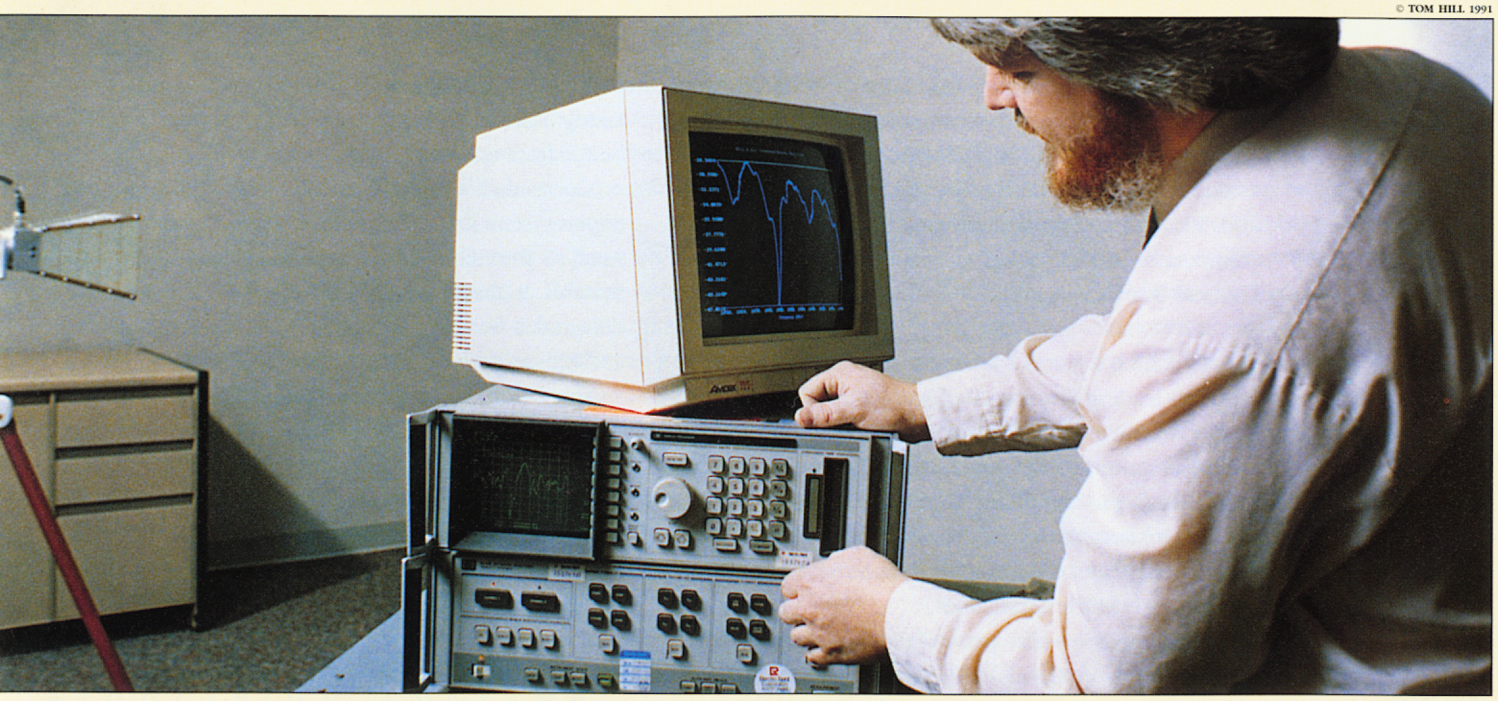
Field measurements during the past year focused on infrared signatures of aircraft. This work included a study of a prototype engine for the P-3 aircraft, in which the new engine was compared to the standard T56-A-10 engine, and detailed signature measurements on the PAVE HAWK and PAVE LOW helicopters in various flight conditions.

COMMUNICATIONS AND INFORMATION PROCESSING

Advanced studies were made of new threat capabilities.

Communications and information processing have long been major research thrusts within GTRI. These technologies embody classical communications pursuits such as the development and enhancement of wire and radio message transmission techniques; establishment of communications networks over wide geographical areas; and communications and propagation metrology. They also involve the innovative processing of data of varied types from diverse sources to support command and control and the applications of computer-based signal processing techniques to the analysis and interpretation of results provided by sensors and manufacturing processes. The varied research efforts from multiple laboratories synergistically provide a sound foundation for research in high-definition systems, neural nets, and interactive graphics along with other applications involving high-rate signal and data processing.

COMMUNICATIONS NETWORKS ● In FY 91, GTRI researchers performed systems engineering for the U.S. Army to interconnect Department of Defense test ranges with a multiplexed high-speed network. Studies, site surveys, facilities planning, and design services were undertaken on internal communications, telemetry, computers, and range control facilities. This task is in its



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GTRI provided BellSouth with technical support in its efforts to develop a commercial Personal Communications Network (PCN).

second year and is part of a five-year, $10-million project for the Army. The end result will be a network linking 13 major Department of Defense test ranges with real-time, wide-bandwidth fiber and satellite links. The network is multimedia-compatible, carrying data, voice, telemetry, and high-resolution video. Data rates of computers and equipment connected to the network range from 1.2 kilobytes per second to more than 44 megabytes per second. State-of-the-art features will minimize operational costs while maximizing performance. Automatic failure recovery and efficient multiplexing provide cost-effective performance suitable for real-time multi-range test operations.

In another project, GTRI provided BellSouth with technical support in its efforts to develop a commercial Personal Communications Network (PCN). PCN technology represents the third generation in cellular telephony beyond the original analog mobile cellular and digital mobile cellular systems. GTRI engineers are helping BellSouth design PCN terminals and characterize the indoor propagation channel for several frequency bands within and around an office building. They also are characterizing the trade-offs between several potential multiple access strategies, including time- and frequency-division multiple access. Another phase of the program involves an examination of potential modulation formats with regard to their performance in data transmission, frequency re-use considerations, security, privacy, and performance in the presence of propagation anomalies such as reflective multipath. This effort also contains a significant test and evaluation component, including the definition of test methodologies, procedures, and data analysis techniques to characterize the indoor propagation channel, execute test procedures, and collect and assess data.

Under the sponsorship of the U.S. Air Force's Wright Laboratory, engineers are designing and developing new techniques for low-probability-of-intercept communications. Featureless waveforms have been developed and subjected to extensive analysis and measurements of communications performance in complex electromagnetic environments. Two transceivers are being designed and constructed to demonstrate airborne communications. Extensive use is being made of high-speed adaptive digital signal processing to achieve performance levels previously unachievable.

Communications, Test, and Evaluation ● In a program for the Pacific Missile Test Center, engineers analyzed the need for and feasibility of a higher frequency telemetry band that allows large increases in telemetry information rates for Navy test and evaluation programs. GTRI examined the need for new frequency allocations based on projected information rate requirements for voice, data, and video. Researchers also studied more efficient methods of utilizing existing telemetry frequency assignments, such as high-order modulation and coding. Engineers assisted the Navy in its transition to newer systems by determining the impact of new frequency assignments on antenna systems and other equipment. They documented the procedures for pursuing new assignments by application to the appropriate agencies.

GTRI conducted a detailed evaluation of test requirements for satellite communications and subsystems for strategic defense applications. In addition, engineers worked on the design of a testbed, to be established at Rome Laboratory, that will test all critical aspects of the communications technology elements of the strategic defense system. This project, conducted under a multi-year tasking agreement with the Air Force, encompasses space and ground satellite communications subsystems that utilize optical and RF links. This effort includes a study to determine design specifications for space qualification and ground terminal testing under high temperatures, solar radiation, cosmic dust, and war-time nuclear threats in space.

INTELLIGENT SYSTEMS ● GTRI is one of the nation's leading developers of knowledge-based autonomous vehicle systems. Programs in progress include the Heuristic Autonomous Route-Planning Oracle, a system that uses five independent knowledge sources in a blackboard architecture to produce adaptive routes. Decisions take into account conditions such as terrain, tactical needs, and vehicle capabilities.

GTRI is a leader in low-cost decision-aiding and planning systems.

GTRI engineers also are working on expert systems to operate unmanned aerial vehicles. In a program for the U.S. Army Missile Command, they developed a Multiple Aerial Vehicle Expert (MAVE) system that lets a ground operator oversee as many as six unmanned aircraft in a given mission. The MAVE system's architectural core is GTRI's Generic Expert System Tool, and the Heuristic Autonomous Route Planning Oracle gives MAVE operators the capability to cast new plans as mission conditions change.

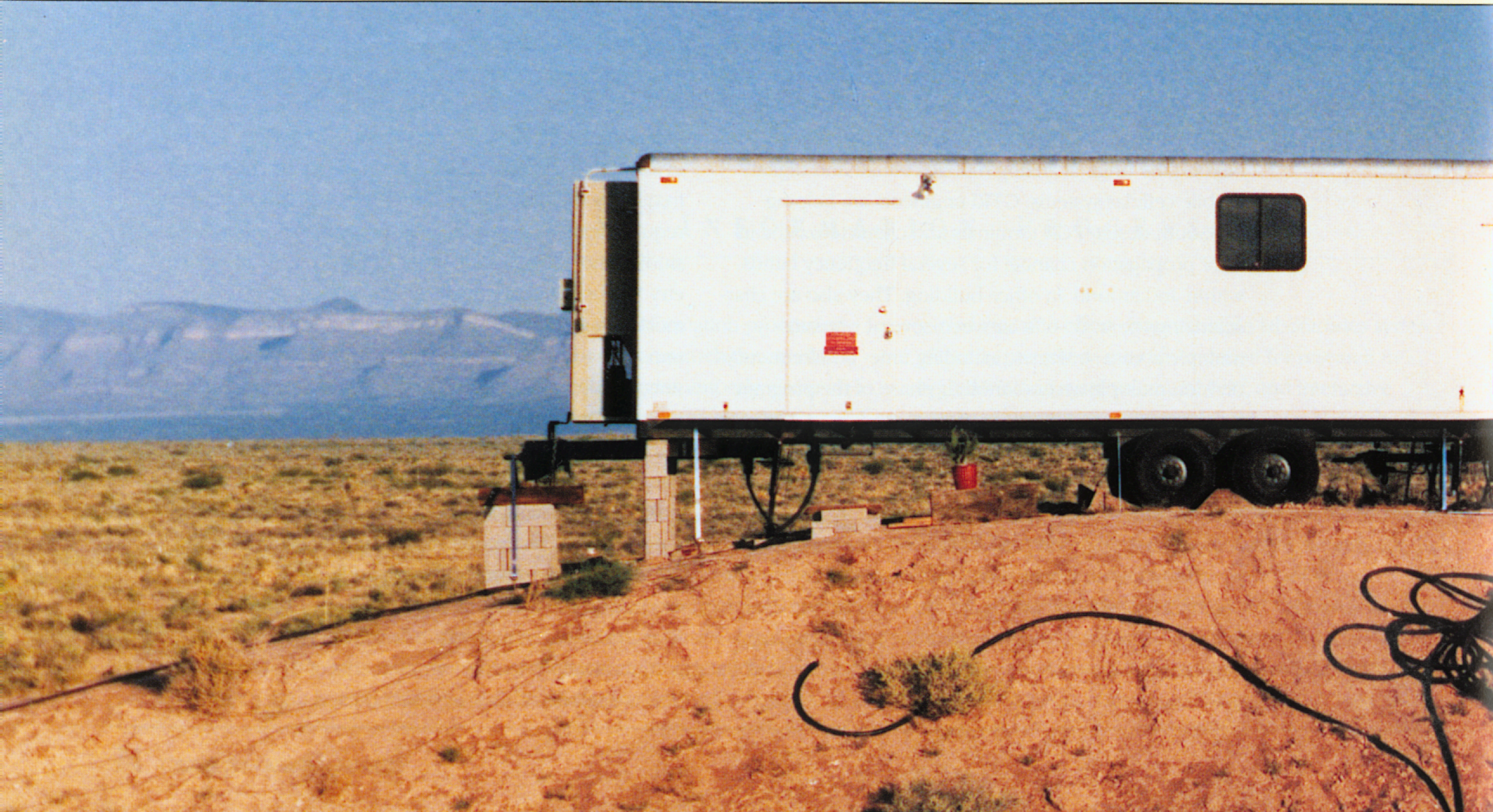
Another project has resulted in an expert system that can evaluate images and decide the algorithms that are best suited for different jobs. The system, called Blackbox, seeks out cues in the surrounding environment that make image recognition easier and less computationally taxing. Blackbox could be adapted with varying needs to be the front end of existing vision systems.

Contextual cues are significant in a GTRI-developed expert system known as TANKS, which stands for Target Analysis through Non-deterministic Knowledge-based Systems. In this system, motion is shown as images are detected, a feature that enhances target recognition. TANKS can parcel out the tasks of image enhancement, segmentation, and other recognition algorithms to different processors.

DECISION SUPPORT SYSTEMS ● GTRI is a leader in low-cost decision-aiding and planning systems for a variety of user applications. Innovative research for the Tactical Air Forces Mission Support System II, a peacetime and wartime aircrew mission planning system, has resulted in dramatic increases in the performance of processing operations.

To solve the problem with storage of large digital geographic data sets on small computers, a lossless data compression algorithm was developed by GTRI researchers that allows storage of data in up to one third of its original space with no reduction in processing speed due to decompression.

Software coding and style standards for the C language were derived, allowing code to be portable among UNIX, PC, and RISC computers. Portability has been enhanced, maintenance costs lowered, and reusability of software modules across programs increased.



GTRI engineers built this mobile van capable of emitting a host of signal formats.

GEORGE EWELL PHOTO

Finally, to solve a problem in providing access to large national intelligence data bases, GTRI researchers have successfully combined multiple communications protocols for on-line availability of the information.

Computer-Aided Engineering ● GTRI researchers continued to develop concepts, methodologies, techniques, and tools in computer-aided engineering (CAE), including computer-aided software engineering (CASE). These programs benefit electronic design and test engineers, environmental engineers, software engineers, and researchers in artificial intelligence.

The Automatic Test Equipment Software Support Environment (ATESSE) combines research in circuit design and software engineering to aid test engineers in creating software programs that automatically test analog and mixed analog/digital circuit cards. Early applications of ATESSE focused on the avionics systems of military aircraft; however, in FY 91, researchers worked to develop new models and to retarget the simulator to support research and development in environmental engineering. For example, ATESSE can help to improve understanding of the complex biological processes in sewage treatment systems so that more cost-effective treatment plants can be built.

Research also continued during the last fiscal year on the Analog Circuit Analysis and Partitioning System (ACAPS). When integrated into ATESSE, this tool will apply artificial intelligence techniques for automatic analysis of the structure and behavior of analog circuit designs.

Simulation Systems

GTRI sought to resolve ambiguities in data from noncooperative targets.

GTRI researchers continue to contribute to America's understanding of foreign weapons systems, the threats they pose, and this nation's ability to overcome them. FY 91 accomplishments included advanced studies of new threat capabilities, prototyping of advanced test beds, upgrades to previously developed threat simulators, and ongoing development of new simulators.

Advanced studies were conducted to resolve questions and ambiguities in observed data from noncooperative targets. Such investigations led to identification of system operational modes and major parameters. Work in this area was supported by the Air Force Foreign Technology Division and the Army Missile and Space Intelligence Center.

With sponsorship from MIT Lincoln Laboratory, researchers developed and supported in the field a mobile testbed capable of emitting a host of signal formats asso-

ciated with one advanced radar system. The resulting system is highly flexible and can be relocated easily to various locations for specialized test exercises.

Significant capability upgrades were made to an Air Force C-Band radar simulator. The ability for automatic tracking of a high-speed maneuvering aircraft was added. This upgrade required extensive design/development efforts in the areas of antenna, transmitter, receiver, pedestal, and data acquisition subsystems.

Researchers also modified another Air Force simulator to present a more realistic target for training purposes. Specific modifications included angle controls, transmitter/modulator, and receiver automatic gain control. Planned future efforts include upgrades to the analytical missile fly-out model that measures the effectiveness of the threat system in hitting an aircraft.

A quick reaction program was performed for the Air Force in support of Operation Desert Storm. A non-Soviet "gray threat" was instrumented to gauge the effectiveness of Allied airborne electronic countermeasures.

The most recent simulator development award was received from the Army. The objective of this program is to simulate the appearance, radiated signal format, and fire control for a threat system capable of firing anti-aircraft munitions. The preliminary system specification has been completed, and system design has been started.

In FY 91, researchers continued to develop a missile simulation capability that includes software-only and hardware-in-the-loop systems. These simulations serve to evaluate the effectiveness of missile guidance, kill probabilities, and electronic counter-countermeasures capabilities. They include both batch and real-time applications.

The software-only simulations developed at GTRI are useful in exploring many missile flights for statistical results and in examining many scenarios. The hardware-in-the-loop simulators achieve the highest degree of realism short of an actual missile flight. These systems are used in the proof-of-principle tests necessary before actual flight tests can be undertaken.

Large quantities of data are produced in both types of simulation. GTRI's new high-end personal computers allow researchers to make the kinds of sophisticated analyses that are normally available only with large and costly mainframe computers.

RADAR

Radar techniques were studied for detecting windshear during aircraft takeoff and landing.

Inclement weather may be responsible for as many as one half of all aircraft fatalities. One particularly dangerous weather phenomenon is the microburst, a strong localized downflow which results in sudden, hazardous changes in wind speed and direction known as windshear. NASA and the Federal Aviation Administration are working closely to determine the applicability of airborne, coherent Doppler radar techniques for detecting windshear during aircraft takeoff and landing.

In the past year, GTRI researchers participated in multi-contractor teams reviewing NASA test plans and evaluating proposed signal processor designs. They also developed an architecture suitable for in-flight use on NASA test aircraft.

In addition to the radar signal processor development, GTRI has proposed construction of a novel millimeter-wave radiometer for windshear detection. The radiometer would make temperature measurements at three frequencies in the 50 to 60 GHz region to detect thermal changes associated with microbursts and to estimate the range to the windshear.

In support of the U.S. Army Strategic Defense Command, GTRI provided technical analysis and evaluation of the prime contractor's performance in the Lightweight Exoatmospheric Projectile (LEAP) program in the areas of guidance and control, fire control, electronics, and seekers. GTRI researchers analyzed error sources in inertial sensors and their impact on interceptor performance, analyzed seeker performance as a function of wavelength, and provided critical analysis of the LEAP autopilot design.

In another program for the U.S. Army, GTRI organized a "Blue Team" of industry experts to evaluate the contractor's full-scale development (FSD) design for the Wide Area Mine. The team's primary goals were to uncover any major problem areas early in the FSD effort in order to prevent costly problems from occurring near the end of the development phase. The Blue Team prepared a detailed report summarizing the contractor's strengths and weaknesses. The Army will use the report to correct design and program deficiencies with the contractor.

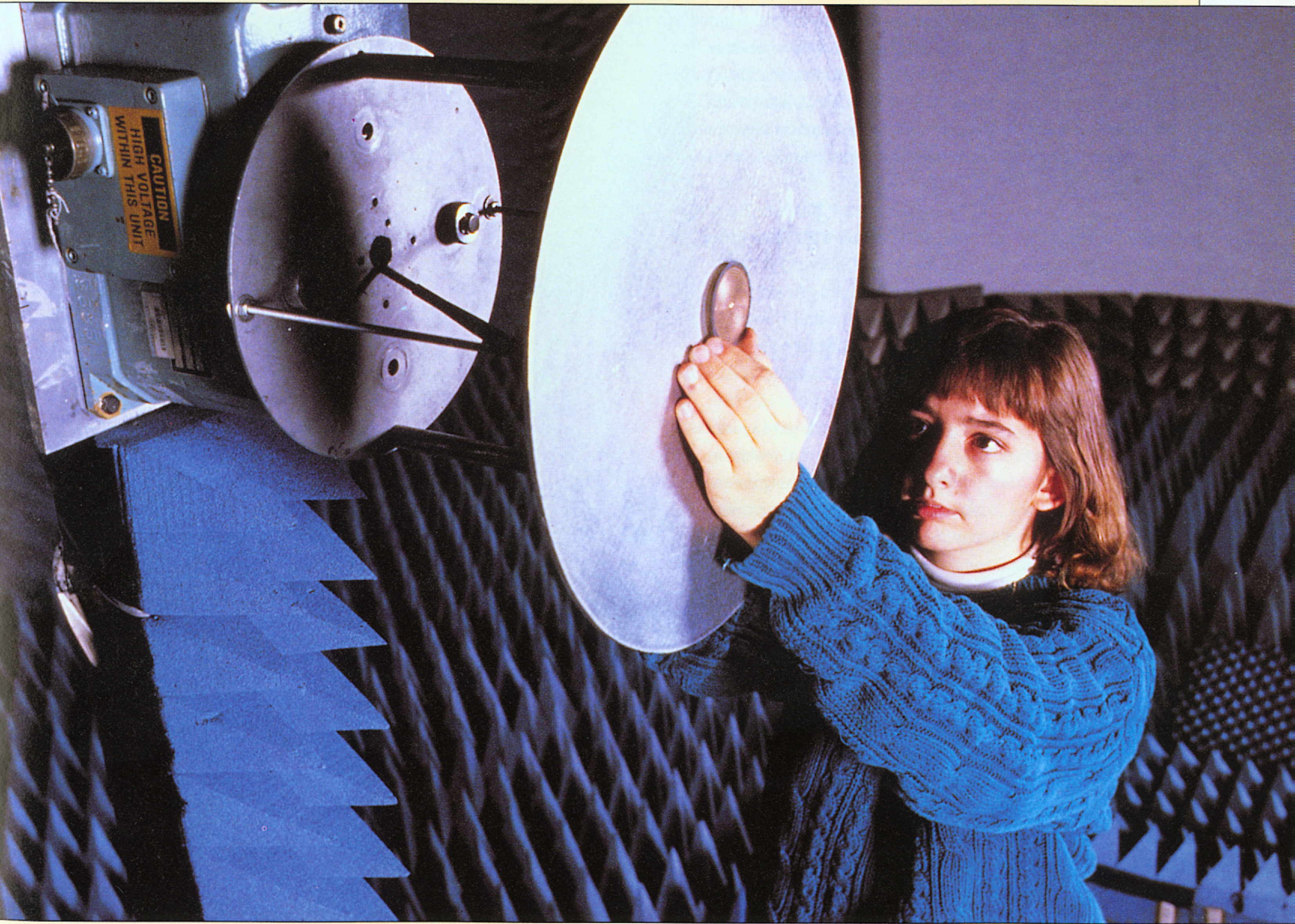
RADAR SYSTEMS ● Bistatic radar has been proposed as an effective means of detecting low observable targets, but achieving the required coherency and dynamic range remain key technological issues. To better address these issues, GTRI researchers are using internal funds to build a bistatic/digital beam-forming testbed array. The array consists of 16 microstrip antennas and one horn antenna. Sample data will be processed using range correlation and beam-forming algorithms developed by GTRI to bistatically detect and locate targets of interest.

For the past several years, GTRI has maintained an ongoing program to investigate polarization characteristics of phased-array radars. Sponsored by Crossbow and internal funds, researchers are studying advanced threat radars and U.S. simulations of those radars. Array polarization computer models have been developed, array polarization predictions have been completed for two specific radars, and the relative susceptibilities of these radars to cross-polarization countermeasures have been determined.

During FY 91, GTRI continued to provide technical assistance to the Naval Ocean Systems Center for the development of a special waterside security system. When deployed, the system will contain multiple radars, sonars, and imaging sensors combined into a single highly automated system for detecting potential terrorist threats to Navy assets.

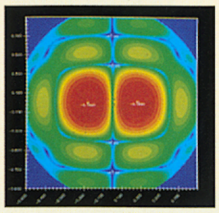
TARGET IDENTIFICATION ⬢ GTRI has been actively involved in noncooperative target recognition (NCTR) research for over 10 years, conducting major programs in radar-based stationary target identification and moving target classification and identification. Recently, GTRI researchers have undertaken a major effort in support of multi-spectral identification of fixed-wing aircraft under the ongoing Multi-Attribute Identification and Analysis (MAIDA) program with the U.S. Air Force. In the past fiscal year, GTRI personnel had active NCTR contracts with all three Department of Defense services as well as industrial sponsors, published two invited magazine articles, prepared a chapter for the upcoming

Below: *Engineers at GTRI have developed a new class of microstrip antenna that offers bandwidths as high as 500 to 600 percent. Here, an experimental antenna is placed onto a positioner in Georgia Tech's compact range for testing.*



JOE SCHWARTZ PHOTO

Fractal geometry was applied to stationary target identification.



Above: *Antenna researchers can display three-dimensional data about phased-array patterns.* Photo right: *GTRI developed and installed one of the world's largest compact ranges at Fort Huachuca, Arizona.*

Airborne Early Warning Systems text, and published four symposium papers.

During FY 91, researchers applied a new technique involving fractal geometry to the problem of stationary target identification. In this technique, target and clutter radar signatures are forced to become fractal images through an interpolation technique. The fractal dimension, a measure of the amount of space a fractal occupies, is then computed for the fractal image. As a single-feature discriminator, the fractal dimension performs very well, achieving a high probability of detection with a low false alarm rate. This project was sponsored by MIT Lincoln Laboratory.

In other work, researchers are modifying GTRI-owned instrumentation systems to provide for full polarization matrix, coherent, radar cross section data collection with an equivalent bandwidth of 2 GHz (0.25-foot range resolution). Researchers are also developing an automated data acquisition system with high data rates and the ability to perform a wide variety of analyses, including polarization distortion matrix corrections, Fourier transforms, and high-resolution Inverse Synthetic Aperture Radar plots of target images. The combined radar and data acquisition system will be utilized to obtain high-quality radar cross section signature data of special foreign and domestic targets of military interest.

MILLIMETER-WAVE TECHNOLOGY ● Under subcontract with Electromagnetic Sciences in Atlanta, Georgia, GTRI is supporting NASA in the design, development, and deployment of a special microwave instrumentation radar. The system will be used to characterize the plasma boundary layer which forms around reentering spacecraft. The instrumentation radar will operate at frequencies of 20, 44, 95, and 140 GHz with sufficient bandwidth to allow range measurement accuracies of better than one centimeter.

For the Army, GTRI is building a combined 35/95 GHz instrumentation radar. This dual-band radar will provide full polarization matrix radar cross section measurements with a bandwidth of 800 MHz (0.75-foot resolution) at a peak power of 5 W. The system will be used by the Army to validate radar cross section signatures of full-scale target models of foreign and domestic military vehicles.

In related work, GTRI is assisting Eglin Air Force Base with the development of an airborne 95 GHz instrumentation radar. This system will be used to collect high-resolution radar cross section signature data of selected tactical targets.

OTHER RESEARCH ● In other FY 91 programs, GTRI researchers:

- Developed specifications for an upgrade to the F-15 radar system;
- Created a comprehensive training course on smart munitions for the U.S. Army; and
- Assessed the vulnerability of weapons and communications systems to hostile electronic warfare.

ELECTRONIC DEFENSE

In FY 91, GTRI engineers conducted a study of threat air defense weapons systems for the Air Force.

Air Force pilots require immediate recognition and identification of threatening signals detected by their radar warning receivers, but ambiguities may arise when many radars are operating simultaneously. To resolve such ambiguities, GTRI engineers are exploring the feasibility of recognizing subtle differences in multiple radar signals.

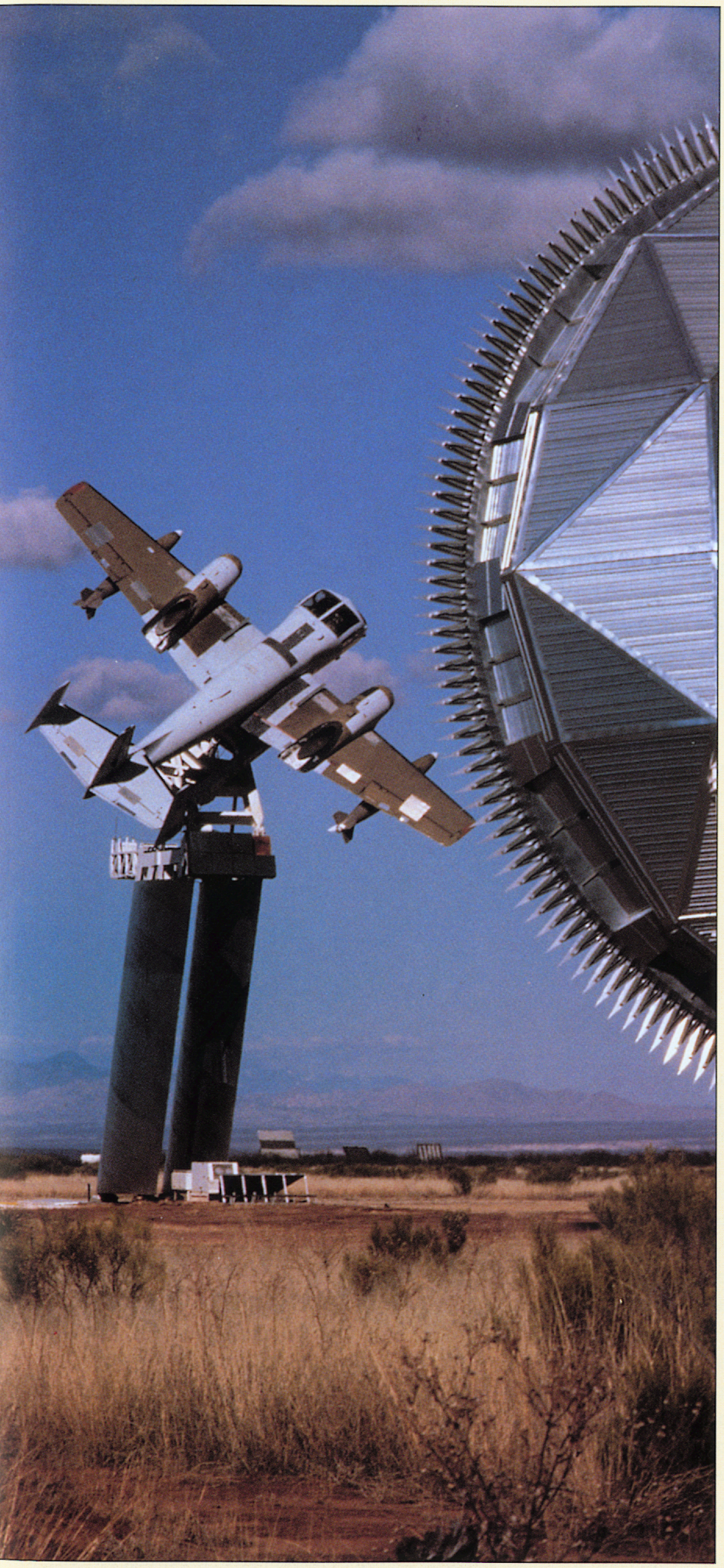
Under the sponsorship of the U.S. Air Force's Wright Laboratory, engineers added to the signal characteristics library by collecting data simultaneously, using separate receiver and data acquisition systems on the ground and in one of GTRI's research aircraft. These data are being analyzed to determine the effects of multipath amplitude and phase differences on the reliability of various radar identification signal processing algorithms. Under a separate Wright Laboratory program, GTRI is studying the application of neural network concepts for adaptive signal recognition techniques.

For the U.S. Air Force, GTRI conducted an extensive study of threat air defense weapon systems. The interactions of existing and proposed techniques with weapon system modes were analyzed, potential vulnerabilities to electronic countermeasures techniques were investigated, and new techniques were conceived. Results from this study are expected to set the standard in this field for the next several years.

In other work, GTRI engineers developed an improved methodology to analyze the performance of digital radio frequency memory (DRFM) jammers operating against coherent radars. This task included developing a description of the output of a DRFM when excited by conventional pulsed-Doppler radars, discrete phase-coded radars, and chirp radars. The performance of two ground-based radars against anti-detection jamming was also evaluated.

TECHNOLOGY UPGRADES ● The performance, reliability, and maintainability of fielded military elec-

SPECIAL PHOTO



tronic systems often can be greatly enhanced through the use of more advanced technology than was available when the systems were developed. Maintenance-free digital components can replace troublesome analog functions, and specialized, highly miniaturized digital circuits can replace older digital technology, reducing both size and power requirements. Through such technological upgrades, GTRI has made significant improvements to a number of Air Force radar warning receivers.

During FY 91, new circuit boards for the AN/ALR-69 radar warning receiver were developed, tested, and environmentally qualified. New assembly language software was written and tested, and the currently fielded operational flight program software was translated for a more powerful microprocessor. Flight testing of these improved systems is under way.

Improved mission readiness for the B-1B bomber's AN/ALQ-161A defensive avionics suite is the planned result of a redesign of the electronic countermeasures waveform generator. New circuit boards have successfully completed burn-in and environmental qualification tests, and are scheduled for upcoming flight tests. GTRI's Reprogramming Software Support Tool, developed as part of this project, will enable the parameters of electronic countermeasure techniques to be modified, and new control data to be generated and stored in the waveform generator.

AVIONICS SUPPORT ● The U.S. Special Operations Forces rely heavily on helicopter-based systems for carrying out many of their missions. In a program for the Warner Robins Air Logistics Center, GTRI is integrating various electronic warfare systems used on the PAVE LOW MH-53J helicopter. Engineers are coordinating the work of several companies that manufacture the associated electronic warfare, avionics, navigation, communications, and display subsystems. They also are designing a new remote control unit to coordinate operation of dual AN/ALQ-136 electronic countermeasure systems, and developing improved software to manage message traffic more effectively and perform the sensor fusion necessary to assess and correlate information and make intelligent decisions.

GTRI engineers also assisted the 3246th Test Wing at Eglin Air Force Base, Florida, with the implementation of a disciplined electronic combat testing procedure for avionics systems used by the Special Operations Forces. This work included development of scientific test methodologies, standardized measurement systems, and test facilities to support system integration and flight testing.

In related work, GTRI engineers are analyzing the survivability of the Light Helicopter (LH) platform in certain operational environments. The analysis includes predicting radio frequency and infrared helicopter signatures, predicting the ability of enemy threat systems to engage the LH, and the ability of LH survivability equipment to successfully counter these threats.

ELECTRONIC COUNTERMEASURES ● If current electronic countermeasures (ECM) systems are used, significant numbers of aircraft will be lost in the early stages of a major war. These ECM systems are unable to identify and counter threats whose parameters change in war. Generally, they also are incapable of applying the proper ECM techniques to given threats within the allowed time constraints, even when the parameters of these threats have been identified. In addition, these systems are normally unable to optimize a coordinated response to a variety of simultaneously emerging threats, even when ECM techniques for each threat are known.

Engineers are analyzing the survivability of the Light Helicopter in different settings.

Researchers at GTRI are helping the Air Force to develop an all-software testbed for the ECM Resource Manager, an intelligent system capable of continuous resource planning, real-time resource allocation, and real-time effectiveness monitoring. The ECM Resource Manager is being designed to achieve more time-optimized, threat-adaptive countermeasures against an aggregate threat population than is possible with current hardware and software technologies. An important requirement for developing such a system is the capability to fuse data from a variety of electronic defense and avionics sensors on aircraft as well as any data from sensors not on aircraft. This research is being performed for Wright Laboratory at Wright-Patterson Air Force Base, Ohio.

ELECTRONIC INTELLIGENCE ● In support of the Army's Common Module ELINT subsystem, GTRI engineers developed software for a user-friendly, menu-driven program that assisted in defining system requirements. Engineers also helped to design specifications for a new threat simulator. This system will include acquisition and track radars, and will simulate firing anti-aircraft munitions.

A new class of microstrip antenna that combines the broadband performance typical of spiral and sinuous antennas with the surface mount capability, efficiency, and low cost of microstrip antennas was developed for the U.S. Air Force's Wright Laboratory — Electronics Warfare Division.

OTHER RESEARCH ● Significant areas included:

- Analyzing the performance of broadband canceller systems to time-varying periodic interference;
- Devising an effective methodology for reducing the cost and complexity of testing terminally guided smart munitions; and
- Preparing an expanded introductory guide and test planning handbook for radio-frequency electronic combat receiver systems.

ELECTROMAGNETIC ENVIRONMENTAL EFFECTS

Electromagnetic interference in integrated circuit devices was explored.

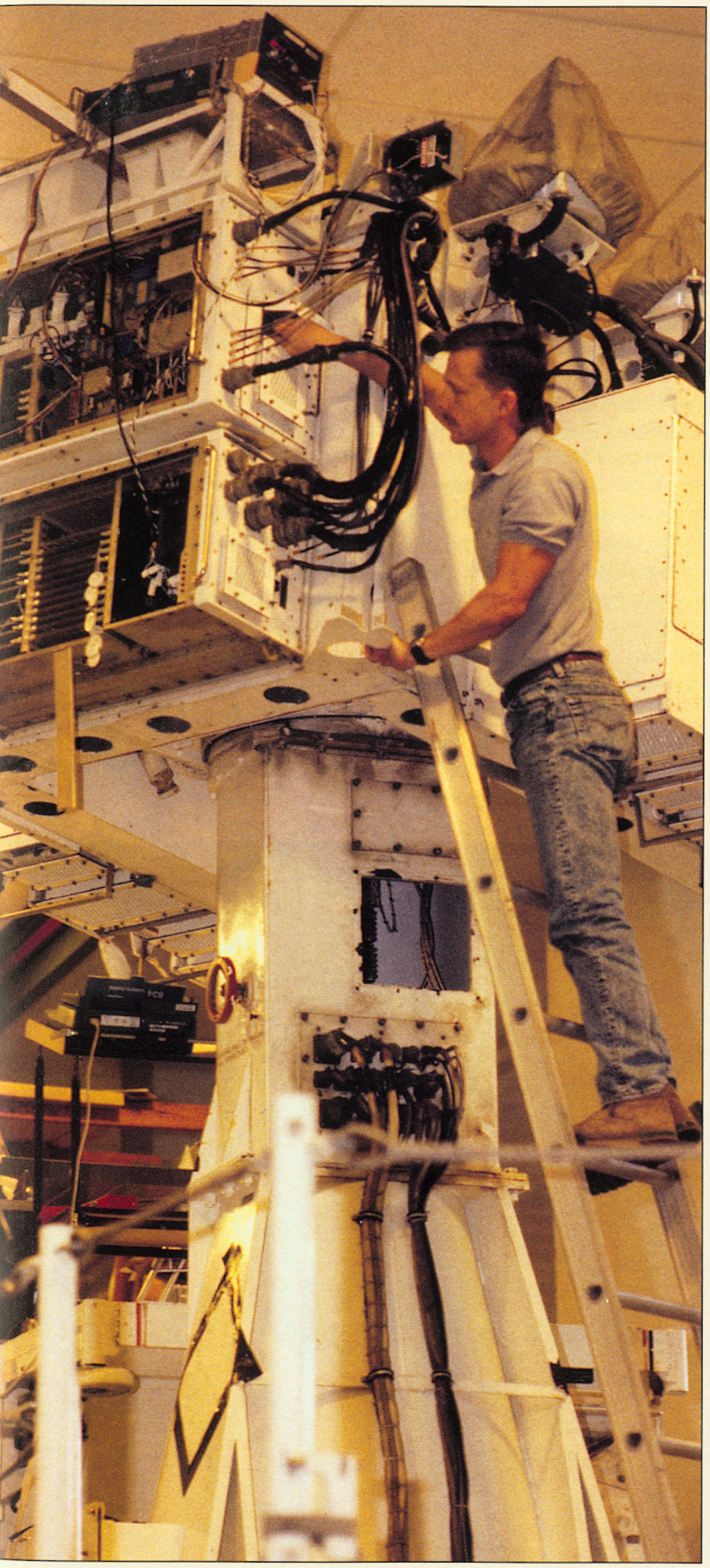
Over the past three decades, there has been dramatic growth in the number and variety of electronic devices for medical diagnostic and therapeutic purposes. Because many of these devices are essential to the care and treatment of critically ill patients, their potential susceptibility to extraneous electromagnetic radiation is of prime concern.

For the past 20 years, GTRI engineers have examined the susceptibility of implantable cardiac pacemakers and defibrillators to such electromagnetic environments as microwave ovens, airport security systems, and anti-theft devices. To date, approximately 100 programs involving over 1,500 individual units have been conducted for many domestic and foreign manufacturers. The test methods and exposure environments developed by GTRI have been adopted by the medical and regulatory communities into worldwide standards. Through these programs, GTRI engineers have helped to significantly improve the designs of implantable devices for protection against upset in an increasingly cluttered electromagnetic environment.

In a program for the U.S. Air Force's Rome Laboratory, engineers evaluated the feasibility of developing a miniature broadband electromagnetic field sensing system. This electromagnetic performance monitor (EMPM) is designed to detect the electromagnetic field exposure of aircraft from 300 MHz to 18 GHz both in flight and during ground tests. The EMPM consists of multiple field probe elements and a central data signal processing module. Each probe element consists of a three-axis resistive dipole antenna with built-in detector, along with a summing preamp, fiber optic data transmitter, and an optically powered receiver. The data processing module is capable of receiving, preprocessing, and storing information from four probes.

To identify design techniques for enhancing the reli-

Right: *GTRI engineers upgraded a prototype system of the AN/MLQ-T4 ground jammer system, improving its reliability, maintainability and jamming capabilities.*



JOE SCHWARTZ PHOTO

ability of personal computers operating under poor power quality conditions, engineers recently completed a study of various power quality problems. The study delineated design and test methods for "hardening" computer power supplies against power sags and surges, brownouts, spikes, and transients.

ELECTROMAGNETIC COMPATIBILITY ● In an ongoing four-year program, GTRI continued to develop the Electromagnetic Environment Generating System for the Naval Air Test Center. This system is an integral part of the center's test facilities for susceptibility testing of aircraft communication, navigation, electronic warfare, computer, and flight control systems to high-level electromagnetic environments. GTRI engineers are providing program management, system design engineering, software development, and integration.

During the past fiscal year, engineers continued their implementation of a rigorous Electromagnetic Environmental Effects (E3) program for the Warner Robins Air Logistics Center by incorporating electromagnetic compatibility (EMC) into the upgrading of existing aircraft into Special Operations Forces platforms. GTRI is providing E3 program management and engineering support, developing an operational environment for electromagnetic vulnerability testing, performing E3 modeling of existing platforms and emerging technologies, and conducting interplatform electromagnetic interference testing on specific aircraft.

GTRI engineers wrote an EMC Program Guide and developed an E3 Operating Instruction for Air Force personnel to use when conducting platform modifications. They also developed an Electromagnetic Compatibility Advisory Board Charter for Air Force program engineers to use in managing and integrating contractor's EMC efforts. Specific platforms addressed to date include the MH-53J PAVE LOW helicopter, the MH-60G PAVE HAWK helicopter, and the AC-130H SPECTRE gunship. Through this program, an E3 baseline has been defined for the two helicopter platforms, several specific equipment and subsystem interference problems have been corrected, and a long-term process for preventing unacceptable electromagnetic interactions between critical systems has been put in place.

OTHER RESEARCH ● Other significant research activities included:

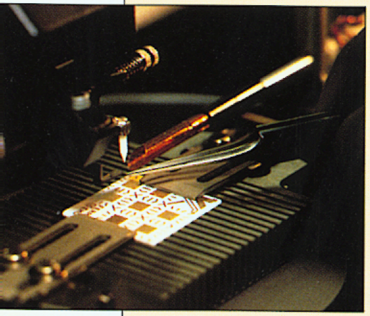
- Developing lightning and transient protection techniques for traffic control equipment;
- Recommending wiring practices for the electronic home of the future;
- Developing conductive sealants for aircraft; and
- Characterizing RF susceptibility properties of solid-state circuit breakers.

For a number of years, GTRI has maintained one of the nation's leading university-based research activities in molecular sieve zeolites. In fiscal 1991, the Zeolites Research Program announced development of H1(GTRI), a very-large-pore molecular sieve that can be produced without costly organic substances. Molecular sieves are necessary in a variety of industrial processes, including the catalytic "cracking" of hydrocarbons in the refinement of petroleum. H1(GTRI) is an organic-free, synthetic version of another large-pore sieve known as VPI-5. When exposed to mild heat, the new molecular sieve's pores shrink, transforming it into a related sieve known as $AlPO_4$-8. Because the transformation isn't smooth, the crystal structure of the new $AlPO_4$-8 is disordered and its pores blocked. For this reason, researchers must make further advances before H1(GTRI) can be used to crack large hydrocarbon molecules. However, GTRI scientists believe that future versions of H1(GTRI) will remedy this deficiency and that it can be used to replace a number of expensive-to-produce large-pore sieves.

A GTRI-developed molecular sieve does not need costly organic substances.

During the past year, zeolites researchers continued to look for molecular sieves to improve the efficiency of catalysts for converting alternative sources of energy to gasoline. They examined the prospects for a modified iron silicate molecular sieve, a patent-pending material first developed at Georgia Tech, as a catalyst for converting coal-derived gases to gasoline.

CHEMICAL VAPOR DEPOSITION ● In another long-term program, development activities progressed on chemical vapor deposition techniques for fabricating existing superconducting materials into useful shapes. In FY 91, researchers continued work in an effort to coat flexible fiber with superconducting material in a continuous fiber-coating furnace. The wire produced through such a process would be valuable as magnet or motor windings. In a related, internally funded project, researchers sought to develop metallorganic chemical vapor deposition (MOCVD) techniques for lining the inside surfaces of hollow objects with thin films of superconducting material. The resulting superconducting cavities and other geometries could prove useful in stripline resonators, antennas, low-noise oscillators, microwave filters, accelerators, magnetic shields, and infrared detectors. A demonstration cavity will be made by coating the inside of a hollow silver cavity with yttrium barium copper oxide.



Above and right: *Researchers are developing the precise parameters for implementing ultra-high purity copper as a substitute material for bonding wires that now use gold or aluminum alloys.*

JOE SCHWARTZ PHOTOS

A model has been created that predicts the uniformity of oxidation protection coatings on carbon/carbon composite panels.

Another internally funded project is aimed at processing advanced ceramic fibers through chemical vapor deposition. GTRI researchers are creating these fibers by depositing coatings of materials such as titanium diboride and silicon carbide on commercially available carbon fiber substrates. These advanced ceramic fibers enhance strength, stiffness, and creep resistance in ceramic and metal matrix structural composites that must function in high-temperature environments. Titanium diboride and silicon carbide were selected for this application because of their light weight, high strength and stiffness, and chemical compatibility with several potential matrices. Researchers are characterizing the microstructure and strength of these fibers so that processing conditions can be optimized.

TITANIUM DIBORIDE PRODUCTION ● In FY 91, researchers at GTRI continued scaling up a process for producing titanium diboride powder and made submicron-sized samples of the material for ballistic testing. This process uses a thermite reaction that self-propagates through completion while simultaneously generating large amounts of heat. Oxide raw materials such as titanium oxide and boron oxide are mixed with various reducing agents, synthesizing a final product from which the oxides can be separated to produce a pure compound or retained to form a composite material. The GTRI process is advantageous because it employs low-cost oxide raw materials, initiates a reaction at relatively low temperatures (600° C to 1000° C), and generates high enough temperatures (more than 3000° C) that no external energy source is needed. In addition, many refractory compounds can be made with this reaction. Titanium diboride is useful in a wide range of industrial, space, and defense applications.

COMPOSITE MATERIALS ● Supporting General Dynamics Corporation's proposed design for the National Aerospace Plane (NASP), GTRI researchers have developed a model that predicts the uniformity of oxidation protection coatings applied to carbon/carbon composite panels. The model simulates temperature gradients and gas flow patterns within a chemical vapor deposition furnace and combines this with diffusion and kinetic parameters to calculate a steady-state coating rate. In FY 91, the model was validated by comparing model predictions to experimental coatings results for a subscale NASP body panel. The successful model will be used to determine optimum processing conditions and furnace configuration for full-scale panels.

A multi-year program on modeling of the chemical vapor infiltration (CVI) process for ceramic composites progressed in two different directions during FY 91. On one hand, the model has been applied to a manufacturing-scale problem: fabrication of a large rotor with a complex geometry. In this application, the model is used to identify optimum infiltration conditions and process monitoring techniques, and can be used in sophisticated feed-forward process control schemes. Researchers at GTRI also have initiated a fundamental study of the microstructure of woven fiber preforms and how this microstructure influences the densification process. In collaboration with researchers from the School of Materials Engineering and Lawrence Livermore National Laboratory, they are using high-resolution X-ray computed tomography to watch the pore-closing process and relate local densification to large-scale connectivity in the porous structure.

In a new program, GTRI researchers evaluated a number of ceramic fibers with potential for electromagnetic window applications. Providing an independent data base of both physical and dielectric properties for these fibers, this program is allowing evaluation of manufacturer claims and comparison of the fibers.

METALS PROCESSING ● In the area of metal processing, engineers continued to conduct research to evaluate the drawability, ball formability, ball bondability, and reliability of copper wire for microelectronic interconnections. GTRI also made progress in metals processing studies, principally in continuous casting, hot rolling, and drawing of aluminum alloys and copper. Process improvement studies focused on aluminum alloys for mechanical applications, with the objective of upgrading the cast structure to eliminate surface defects from the hot-worked metal. For a multi-client group, researchers studied the effect on drawability of surface conditions of continuously cast and rolled copper rod manufactured by different systems. Ferrous metal studies were aimed at improvements in the anti-corrosion properties of nodular cast iron in a steam environment and improvements in the surface quality of bare steel wire to replace galvanizing in bailing applications.

MATERIALS CHARACTERIZATION ● During FY 91, materials specialists continued to supply one-of-a-kind analyses and characterization to industry throughout the Southeast and to provide analytical support to a variety of Georgia Tech research programs. Using sophisticated analytical equipment and broad practical experience, these researchers conducted wear studies on innovative fuel injector parts, studied the movement and propagation of flaws in injector parts, studied the movement and propagation of flaws in microcircuits as a function of current and time, analyzed asbestos contamination in mineral deposits, characterized recyclable plastic containers for soft drinks, identified corrosion products and mechanisms in circuit boards, and carried out failure analyses of turbine blades. Results of these and other analyses give critical information necessary to a fairly large number of research programs external and internal to Georgia Tech.

Polymers and Coatings ● Polymers and coatings research focused on the development of electrically conductive polymeric sealants to protect aircraft from electromagnetic interference and corrosion. These materials have been field-tested on Air Force aircraft such as the E-3 AWACS. In another area, lead paint abatement has become an important concern in residential structures such as Army base housing. Fallen lead paint chips can be eaten by children and also can pollute living spaces. Research projects sponsored by the U.S. Army Construction Engineering Research Laboratory have made progress in finding a method to remove lead paint without contaminating the work area or residences. Special vacuum abrasive cleaning of surfaces is being evaluated through these studies.

Manufacturing Technology

GTRI is mounting a major initiative to develop gray-scale machine vision for a variety of industrial uses.

Machine Vision ● GTRI engineers have begun a major initiative to evaluate and develop gray-scale machine vision technology for specific industrial applications. In particular, they are working in conjunction with the Apparel Manufacturing Technology Center to develop a material inspection system for the Defense Logistics Agency. The major goal is to build a prototype work cell for inspecting cut garment sections before assembly to identify and remove material bearing one or more of 15 defects. The engineers have completed the specification and design stages, and they are beginning construction.

A major area of study for the Agricultural Technology Research Program (ATRP) is the development of high-speed machine-vision systems for detecting defects in processed poultry. Recent emphasis has been on improving system speed. To accomplish this, researchers are developing a transputer-based system that employs complex algorithms, allowing true parallel processing. The system has the potential to be four times as fast as conventional sequential processing systems.

Another ATRP advance has been the development of color vision imaging. Gray-scale systems, analyzing light intensity alone, have not always provided enough data for accurate image interpretation. Shadows caused by inconsistent lighting frequently interfered with defect analysis. Color vision systems, analyzing hue and saturation in addition to intensity, have shown promise for providing much more specific and accurate data for quality control operations. To further enhance accuracy, engineers have developed a computer-aided-design model to test lighting arrangements for the imaging system.

Technology for Poultry Industry ● GTRI engineers also are continuing their efforts to evaluate and develop robotics technology for the poultry industry. Their goal is to speed the implementation of robots in poultry processing plants. The initial focus has been on evaluating the capability of commercial robots in conventional poultry processing tasks. This research has resulted in a first-generation machine-feeding robot prototype, complete with a specialized gripper to handle irregularly shaped poultry products.

Having determined some of the more serious limitations of existing systems, researchers are investigating the development of a customized research robot, which they will use to further evaluate the requirements on robots in the processing environment. ATRP engineers are beginning to investigate improving the guidance systems for robots, using specialized sensors and machine-vision technology. They hope to determine whether robots can keep pace with realistic processing line speeds, and whether costs will be low enough for the industry to accept. Also as part of this study, the researchers are developing a tray-pack robot to load this popular form of poultry packaging into freezer baskets.

Preventing job-related cumulative trauma disorders in the poultry industry has been another area of focus for the ATRP. As is the case with many labor-intensive industries, the poultry industry is eager to improve employee protection.

In a pioneering study, Georgia Tech researchers are equipping knives used in various processing plant jobs and the personnel using them with sensors that measure the force output and the exertion of the arm muscles. The research team will videotape the processing plant workers as they use the tools in their regular jobs.

Engineers will analyze the collected data to determine any possible relationship to known risk factors. Ultimately, the researchers hope this information will help processors better identify and correct potential high-risk tasks.

ATRP engineers have continued to develop the Poultry Environmental Computer System (PECS). This computerized broiler house monitoring and control system gathers environmental information from a variety of

Uses for an integrated-optics chemical sensor include detection of toxic or hazardous chemicals, biomedical or biochemical sensing, and process control.

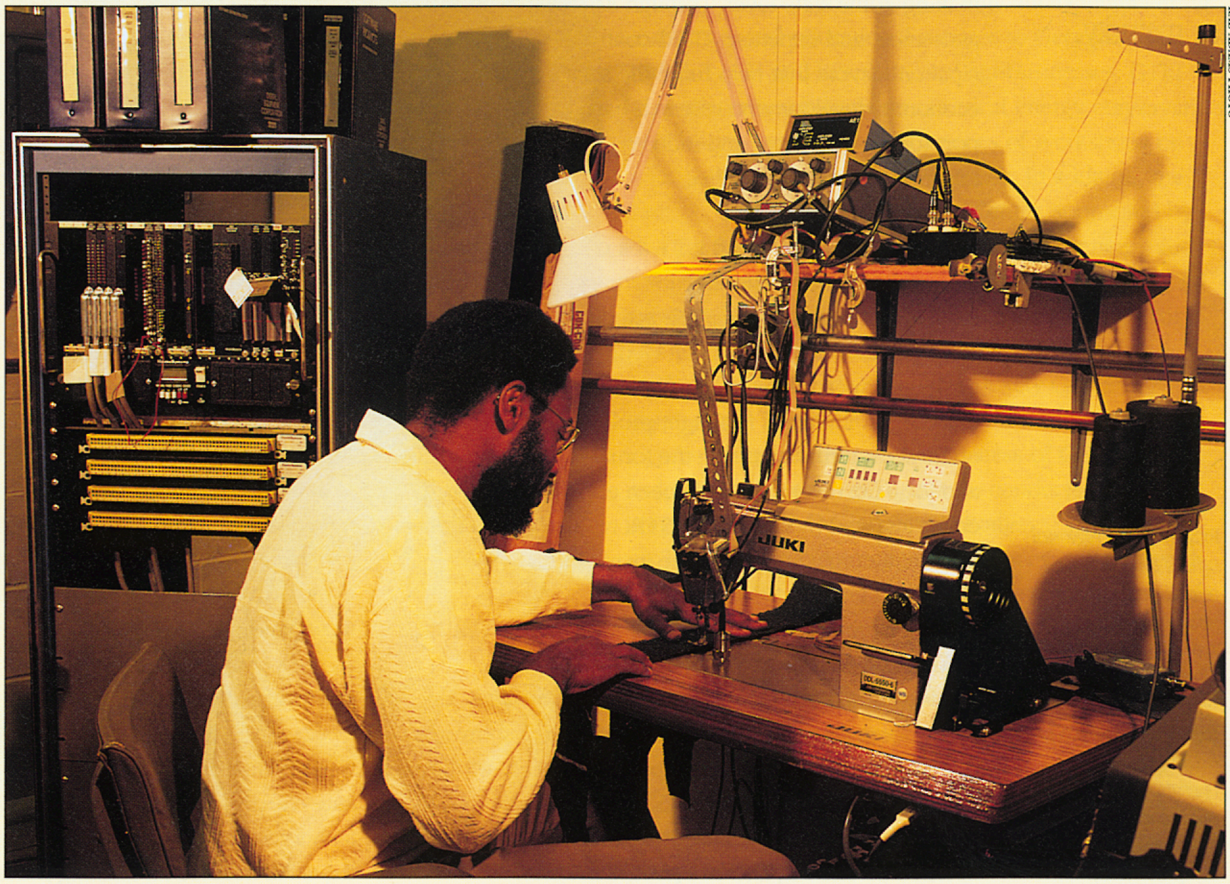
indoor and outdoor sensors and uses the data to maintain a highly consistent growout environment. A working prototype of this system is installed at the GoldKist research farm in Talmo, Georgia.

Engineers have gradually increased the system's level of intelligent control over the house environment. PECS currently mimics traditional growout practices, controlling the house on a temperature-and-time basis. This year, researchers expanded the algorithms, allowing the PECS computer to control the environment based on changes in humidity and ammonia levels in addition to temperature. The researchers are developing an addition to PECS that will measure bird weights, prepare average weight calculations, and project future average bird weights. This new module could help the industry to better schedule pickups and estimate feed requirements.

INDUSTRIAL CHEMICAL SENSORS ● Integrated optics has made possible a new and more sophisticated chemical sensor for industrial use. Devices of this kind offer very-high-detection sensitivity, active or passive measurement capability, and freedom from electromagnetic interference. In an internally funded initiative, GTRI researchers continued to develop an interferometric integrated-optics chemical sensor that is capable of sensing refractive index changes in surrounding fluid or in a chemical selective film applied to the surface of the device. Applications of the device are numerous and include detection of toxic or hazardous chemicals, biomedical or biochemical sensing, and process control.

INNOVATION FOR APPAREL INDUSTRY ● Few industries have been hurt as much by foreign competition in the last decade as America's apparel makers, and GTRI's Apparel Manufacturing Technology Center (AMTC) has sought to help this industry strengthen itself through infusions of innovative technology. In FY 91, the AMTC continued to perform research and demonstrate technology for the apparel industry. In its first three years, the center specialized in trouser-making; however, with a renewal of its contract from the Defense Logistics Agency, it began to broaden its program to other apparel processes and increase its focus on manufacturers in the southeastern United States.

GTRI researchers working through the AMTC evaluated computer-aiding for marking fabric to be cut into apparel components. Through this technology, it may be possible to reduce fabric waste substantially. Another continuing program dealt with ergonomic problems in apparel plants—the physical and psychological conditions that cause stress to workers. Researchers have surveyed several plants, looking for health and comfort problems caused by workstation design, layout of materi-



RAE ADAMS PHOTO

Right: *GTRI engineers are developing and demonstrating a variety of advanced technologies for the apparel industry through the Apparel Manufacturing Technology Center.*

als, and environmental factors such as lighting, noise, and factory temperature.

Through this study, they evaluated an ergonomically improved chair in three trouser-assembly plants. Another product of this program has been the development of a manual to help apparel plant supervisors become more sensitive to ergonomic factors.

COMPUTER-AIDED ENGINEERING ● Increasing complexity in circuits and systems has forced the computer-aided engineering community to focus more heavily on development of tools that handle both analog and digital circuits, and that extend to board-level, behavioral-level, and even multidisciplinary domains.

In FY 91, GTRI engineers extended the capabilities of the SPICE 3CI simulator developed at the University of California at Berkeley. This research has concentrated on board-level and behavioral-level modeling of analog and mixed-mode circuits through introduction of new models at the simulator's source code level. These new models have been simplified so that users can operate the simulator without understanding its underlying code and algorithms.

ECONOMIC DEVELOPMENT AND TECHNICAL ASSISTANCE

GTRI spurs business development by working with firms from start-up to maturity.

In recent years, states have shifted their approach to economic development. They no longer simply try to attract new industry but instead place greater emphasis on developing industry, within their borders. They increasingly see technological innovation and technology transfer as keys to economic growth.

A major asset in this process is GTRI, which attracts federal funding, nurtures technology-driven industry in diverse ways, and provides information for decision making at the state level. Through its research, technical assistance, and expertise, GTRI contributes to four principal endeavors that help fulfill the state's mission in economic development: research base expansion, support for new business and industry, transfer of research advances, and policy studies.

EXPANDING THE RESEARCH BASE ● GTRI is a major magnet in the state for attracting federal and industrial research dollars. This activity has long-term strategic value in ensuring that Georgia is well-positioned to share in technological developments by attracting additional research and top-flight professionals. It also offers short-term benefits in the form of increases to state and local tax revenues. It has been estimated that each dollar invested by Georgia in GTRI research has returned $2.34 to Georgia in tax revenue increases.

BOOSTING NEW ENTERPRISES ● GTRI staff who obtain patents and copyrights often spawn new product lines, even new companies. Such activities expand Georgia's economic base. Latest figures show that since GTRI's founding, it has spawned 19 spin-off firms, with 4,096 employees and $635.7 million in sales. GTRI intellectual property includes 187 records of invention, 2 licensed inventions, and 11 software licenses.

Another way in which GTRI spurs new business development is by working with firms from start-up to maturity. For instance, in 1991, its regional office staff in south Georgia helped a plastics products company get under way by providing facilities planning and material handling assistance. Subsequently, GTRI field engineers responded to the firm's request for assistance with methods improvement, and the company employment has risen from 7 to 45.

The state-funded Economic Development Research Program entered its sixth year of exploring ways to better use the state's natural resources and foster economic development across Georgia. Projects completed during the year include a handbook for determining the potential for retail development in communities, an assessment of Georgia's potential for retiree developments, and a study to define and evaluate Georgia's public and private R&D facilities.

TRANSFERRING RESEARCH ADVANCES ● Recognizing that manufacturers must operate increasingly in a global economy, GTRI provided leadership to establish a Center for International Standards and Quality to assist industry with exporting to the European Community, Pacific Rim, and elsewhere. The new center will provide information on standards, regulations, and directives; assist in accessing and interpreting technical information; assess a firm's readiness to meet quality assurance compliance and certification; and offer seminars and workshops on standards-related topics.

Also in FY 91, GTRI received a $65,000 grant from the National Institute of Standards and Technology to investigate effective means of transferring federally developed technology to industry. Through its EDA University Center, GTRI initiated an Existing Industry Program to help

RIGHT: *GTRI's regional offices help new and established companies with technical and managerial problems. The Rome regional office has provided start-up assistance to a Canton plating operation. Here, staff engineers examine the plating on a computer terminal.*

GARY MEEK PHOTO

chambers of commerce and local development groups throughout the state work more effectively to retain their industries.

Yet another promising development is the Faculty Liaison Program, in which Tech's academic faculty members receive nonsalary-related discretionary funds for teaching and research needs in exchange for their time on technical assistance projects undertaken by the regional offices. In FY 91, there were 20 such projects with an average funding of $1,500 per project. The program, which started with the College of Engineering, now includes all of the Georgia Tech colleges.

In terms of technical assistance and technology transfer statewide, GTRI's FY 91 level of activity is represented by totals in various categories. Technical assists to industry numbered 4,945. Economic development assists totaled 555. Requests for information amounted to 7,609. There were 509 workshops, seminars, and short courses presented and 227 in-plant training classes conducted.

GTRI's statewide network of 12 regional offices forms the primary conduit for transferring knowledge and techniques. In FY 91, assistance ranged from a materials failure reduction study for a steel company and a quality study for a carpet manufacturer to a survey on women's issues for the Rome Chamber of Commerce.

The transfer of research advances occurred in several arenas. In energy conservation, GTRI continued to operate programs sponsored by the Governor's Office of Energy Resources to provide energy audits, engineering assistance, and educational services to Georgia industries, schools and hospitals, and agribusinesses. GTRI also offered workshops on electrical energy conservation and load management, and a series of workshops on utility cost reduction at state facilities. In addition, the Energy Analysis and Diagnostics Center, sponsored by the U.S. Department of Energy, performed energy audits for plants in Georgia, Alabama, and South Carolina and recommended conservation measures that would cut energy consumption by 205 billion Btu.

The Georgia Productivity and Quality Center in FY 91 emphasized Total Quality Management (TQM) as a strategy to strengthen the competitiveness of Georgia's industries. Seminars on TQM were conducted in Atlanta, Augusta, Macon, LaGrange, and Rome.

The Georgia Procurement Assistance Center entered its sixth year of helping Georgia firms market their goods and services to the federal government. Since 1985, the center has assisted more than 700 companies, resulting in $35 million in contracts awarded and approximately $10 million in pending contracts.

Since its inception in 1978, the Southeastern Trade Adjustment Assistance Center (SETAAC) has worked with more than 180 regional firms faced with severe imports competition. At the end of FY 91, the center's case load

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was distributed over 11 industrial classifications, ranging from textiles to electrical manufacturing.

Continuing education and in-plant training contribute to economic development by enhancing productivity through improvement of employee skills and the creation of healthier workplaces. GTRI's industrial education professionals conducted TQM and Statistical Process Control courses at firms across the state in FY 91. GTRI also presented the American Economic Development Council-accredited Basic Economic Development short course for the 24th consecutive year.

UNDERTAKING POLICY STUDIES ● GTRI research has an impact on state policymaking. In FY 91, researchers studied the numbers and types of Georgia firms that export and why they do so, information that will help determine what services would promote further exporting by firms across the state. An updated economic impact model devised by GTRI will assist the state in evaluating the cost-benefit ratio of investments it might make to foster economic development opportunities. A third example involved a study of the economic effect of siting a hazardous waste treatment facility. Also, a study entitled "Science and Technology Opportunities for Georgia in the 1990s" investigated various technologies where Georgia has a competitive advantage and outlined possible state policy initiatives to promote growth.

ENVIRONMENTAL SCIENCES AND TECHNOLOGY

Scientists at GTRI have created a risk assessment program to measure lead sources.

Many of society's most compelling problems are caused by environmental pollution. GTRI has a growing program of basic and applied research, technical assistance, information dissemination, and training to help individuals, businesses, and government organizations deal successfully with their environmental hazards.

HAZARDOUS MATERIALS/SAFETY ● In FY 91, GTRI scientists continued to develop methods to evaluate and measure health hazards associated with lead-based paint. In addition to providing detection and occupational health surveillance for public housing authorities in several Georgia locales, scientists developed a risk assessment program to measure sources of lead. They also designed risk reduction techniques other than full abatement to help reduce exposures immediately and participated in an effort to develop a statewide child lead poisoning prevention program.

This chemical dye laser is one tool used by GTRI scientists in fundamental studies of the earth's atmospheric chemistry.

In FY 91, GTRI offered 120 environmental science and technology courses to approximately 4,000 students.

Researchers are concluding a major initiative to measure occupational herbicide exposures. Funded by the U.S. Forest Service and major chemical companies, this research provides an innovative approach, combining biological monitoring techniques with traditional environmental exposure monitoring. Scientists used patch tests, air sampling devices, and hand rinses to determine routes of exposure, and they used urinalysis to estimate doses. Having refined these procedures, the researchers now are developing a joint project with the University of Georgia's Agricultural Experiment Station to examine exposures to herbicides and pesticides used in turf grass maintenance.

As Georgia industries have become more concerned about environmentally responsible hazardous waste management, the need for consultation has increased. GTRI answers that need with the Hazardous Waste Technical Assistance Program, which helps public and private industries properly identify, handle, store, and dispose of hazardous wastes. Because many companies that call for assistance have similar waste problems, researchers developed *Tech Tips*, general-purpose information sheets on managing common hazardous wastes such as solvents, used oil, and paints.

GTRI also has a strong ongoing program in training safety professionals to handle hazardous materials spills and accidents. Last year, approximately 180 people attended the Hazardous Materials Control and Emergency Response course, an intensive 40-hour certification program. This year, researchers are adding an eight-hour refresher course and a 24-hour course to provide advanced training and certification in hazardous materials control.

During the past year, GTRI offered 120 courses for approximately 4,000 students in subjects concerning environmental science and technology. Of these, seven were new for 1991. The remaining courses were repeat offerings of Georgia Tech's highly popular programs in subjects such as asbestos abatement, hazard communication, and industrial hygiene topics.

INDUSTRIAL ENVIRONMENTAL ASSISTANCE ● GTRI has a strong program in industrial pollution prevention. Researchers recently completed a project with the Georgia Environmental Protection Division to train pollution inspectors. They have begun a project funded by the Environmental Protection Agency to reduce or eliminate the incidence of 17 targeted pollutants in 10 selected industries. This project includes the development of a pollution profile matrix that will give a picture of industrial chemical releases and indicate the best strategies for reduction efforts. In addition, researchers will conduct workshops in pollution prevention and provide specialized technical assistance to 10 newly targeted industries.

RAE ADAMS PHOTO

In 1991, GTRI had an active health sciences technical assistance program. A major thrust in this area was the State Chemical Hazard Communications Program. This effort helped public sector employees in Georgia identify and manage chemical hazards on the job in accordance with a new state law dealing with employees' "right to know" about workplace hazards. Another assistance effort was the Occupational Safety and Health Consultation Program, a federally funded project through which Georgia Tech scientists performed on-site audits and provided recommendations to help companies comply with OSHA occupational safety and health regulations.

ATMOSPHERIC CHEMISTRY ● The chemistry of the earth's atmosphere is a long-term research interest at GTRI, as scientists seek to improve basic understanding of such environmental concerns as acid rain, greenhouse gases, and the depletion of the stratospheric ozone layer. In FY 91, researchers continued studies to assess the action and influence of tropospheric sulfur chemistry, stratospheric halogen chemistry, and free radical chemistry in cloud water. In another project, they used tunable diode laser spectroscopy to study the kinetics and mechanisms of several chemical reactions of note in the atmosphere's sulfur cycle. This cycle has a critical influence on the earth's radiation balance and acid precipitation. One important finding during FY 91 concerned the rate of reaction of iodine monoxide (IO) radicals with dimethyl sulfide. GTRI researchers demon-

In GTRI's Hazardous Materials and Emergency Response course, firefighters and other emergency response personnel get practical experience in coping with environmental accidents.

strated that this reaction is several hundred times slower than previously thought, a finding suggesting that its role in marine chemistry is negligible. The IO/dimethyl sulfide reaction had been thought to play a major part in the transformation chemistry of both sulfur and iodine in marine air.

In another phase of GTRI's atmospheric science program, researchers continued to refine a mass spectrometric technique for measuring the hydroxyl (OH) radical, the trace chemical species that is the atmosphere's most important cleansing agent. Because OH is present at very low concentrations, it has proved difficult to measure. GTRI scientists have developed an apparatus with a detection limit of 1×10^5 molecules of OH per cubic centimeter, a sensitivity that is substantially better than any other known measurement technique. In the past fiscal year, the apparatus has been used in field measurements at Cheeka Peak Research Station in Washington State and near Boulder, Colorado. At the latter location, its performance was compared with that of another instrument used for hydroxyl measurements by the National Oceanic and Atmospheric Administration.

In FY 91, chemical ionization mass spectrometry also was employed in the continuation of a long-term program to measure ions in the lower atmosphere. In this study, researchers have moved from the detection of single core ions to that of ion clusters. They also are attempting to identify clustering agents that may be responsible for the poorly understood process of gas-to-particle conversion in the atmosphere. The measurement of ion and neutral clusters is important because these species are believed to play a key role in the formation of aerosols.

In another area, Georgia Tech filed a patent application for a GTRI-invented interface device that measures neutral species in the atmosphere. This device has been taken into the field to measure dimethyl sulfide, dimethyl sulfoxide, and methane sulfonic acid, a major sulfur species emitted by the ocean and two of its oxidation products.

AGRICULTURAL TECHNOLOGY ● Georgia Tech researchers in the Agricultural Technology Research Program are applying innovative technologies to areas of environmental concern. For example, they are evaluating anaerobic packed-bed reactor (APBR) technology for the treatment and selected pretreatment of poultry processing wastewater. This biological treatment method produces a minimum of waste sludge and also converts organic material to usable biogas. The goal of this long-term research effort is to reduce the capital and operating costs of APBR technology, providing processors with a cost-competitive, low-sludge alternative to traditional wastewater treatment methods. Researchers have conducted continuous laboratory tests with 13 reactors, analyzing changes in various operating conditions. Among their more significant efforts has been the substitution of waste tires for the more expensive plastic packing media used in field tests. In addition, they have tested waste streams from other poultry operations, such as broken eggs and rendering waste, generating a data base of treatment characteristics.

Researchers are also studying ways to improve the operation of dissolved-air-flotation (DAF) treatment systems that are commonly used in the poultry industry. Wastewater discharge regulations and restricted skimmings disposal have fueled the demand for immediate progress in this area. Researchers are investigating system design modifications (such as the addition of plate packs and the use of highly soluble gases) to increase the units' efficiency. An important step has been the construction of a pilot-scale DAF unit. Designed to allow ready changes in major operating parameters, this unit will provide valuable data in field testing.

Finally, researchers are evaluating the feasibility of burning DAF skimmings. Processors are generating greater volumes of skimmings every year, but recycling and disposal options are becoming more limited. Researchers have discovered that partially dewatered skimmings have a significant fuel value and are capable of supporting self combustion. Tests have proven that incinerated skimmings have a very low ash content. Properly applied, this research could greatly reduce the volume of skimmings for disposal.

Development of advanced sensors for energy and environmental applications has been ongoing for the last few years.

The Persian Gulf war reminded America of its overemphasis on foreign petroleum sources and underlined the nation's need to examine its energy use and production patterns. The National Energy Strategy recently announced by the Bush Administration displayed a renewed recognition by the federal government that innovation is necessary to reduce energy costs and offset insecure foreign oil sources.

Since the 1970s, GTRI researchers have maintained research programs aimed at the development of new and environmentally acceptable energy sources, conservation approaches, and utilization systems. These initiatives have focused on biomass thermochemical conversion, solar thermal energy technology, photovoltaics, high-temperature materials research, hydrogen storage, alcohol fuels, methane technology, and heating and cooling technology. In addition, GTRI continues to operate one of the most effective industrial energy conservation programs in the United States.

ENTRAINED-FLOW PYROLYSIS ● In FY 91, GTRI undertook national and international marketing efforts to commercialize Georgia Tech's entrained-flow pyrolysis process, which can utilize a wide variety of waste residues to produce bio-oils. Independent studies have identified this process as the world's benchmark in terms of production efficiency. In sustained trials with Tech's process demonstration units at a daily feed rate of 1.5 dry tons, product yields were obtained in excess of 60 percent on a dry weight basis. Discussions were under way during the year with several potential licensees or joint venture partners for a commercial size scale-up of the process. Work continued to advance the technology conversion of the bio-oil to gasoline-quality products for transportation.

RAE ADAMS PHOTO

Through Georgia Tech's Microelectronics Research Center, GTRI researchers are participating in a program to develop new semiconductor materials for photovoltaics devices and to design innovative new solar cells.

SOLAR THERMAL TECHNOLOGY ● After nearly 15 years of continuous operation, the U.S. Department of Energy's (DOE) Advanced Components Test Facility at Georgia Tech was dismantled as a result of the national attrition in government funding for solar thermal technology and the accompanying disincentives for industrial investment. GTRI, however, continued to operate the Georgia Tech Solar Furnace, a facility capable of concentrating solar energy to a level of more than 10,000 "suns." Engineers here concluded advanced materials processing programs for DOE that processed carbon fiber in the solar furnace. In related work, researchers laid the groundwork for a collaborative research effort in solar thermal technology with a major Israeli solar energy research center.

ADVANCED SENSORS ● The development of advanced sensors for energy and environmental applications has been an ongoing R&D program for the last few years. This effort has resulted in a patented integrated optics technology based on the phase shift between the lower and higher order modes of light caused by the interaction of the higher order modes with a chemically selective coating applied to a planar waveguide. As the chemically selective coating reacts with a specific chemical, the phase angle between modes changes, producing a detectable output. The reaction between the chemically selective coating and the specific chemical being sensed must be reversible so that the device output changes with fluctuations in the concentration.

DOE is funding an application of this integrated optics technology to measure gaseous ammonia. Nitrogen-based fertilizer is one of the largest consumers of energy in agriculture. More than 50 percent of the fertilizer is anhydrous ammonia that can be lost during application, due to improper equipment settings or application rates. A real-time integrated-optics sensor attached to the application equipment could be used to adjust settings and reduce losses. The sensor also could monitor emissions of ammonia from solid fertilizer to determine the need for another application due to nitrogen loss from the soil.

Other uses of the technology under investigation include real-time monitoring of food processing for features such as moisture and sensing of soil gas emissions from hazardous waste sites contaminated with chlorinated hydrocarbons.

JOE SCHWARTZ PHOTO

GTRI EXECUTIVE COUNCIL

Seated from left: *Donald J. Grace and Robert G. Shackelford.* Standing from left: *Edward K. Reedy, Devon G. Crowe, Gerald J. Carey, and Patrick J. O'Hare.*

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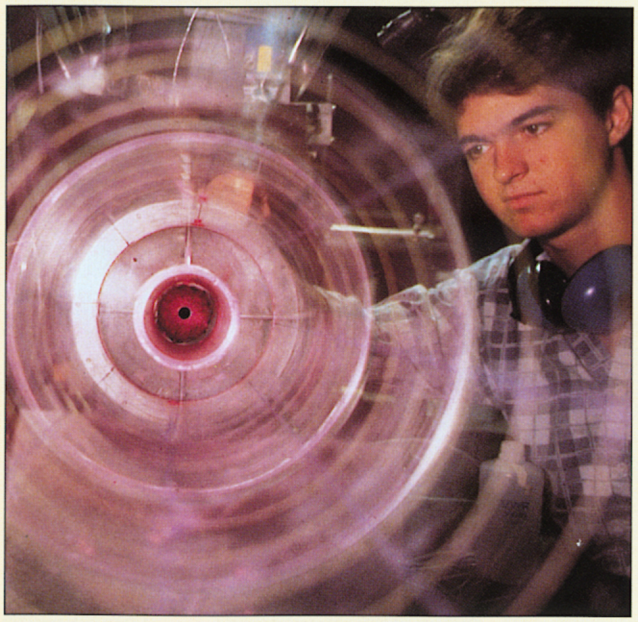

GTRI researchers conducted sub-scale experiments to replicate the aeroengine noise study undertaken at full-scale facilities.

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