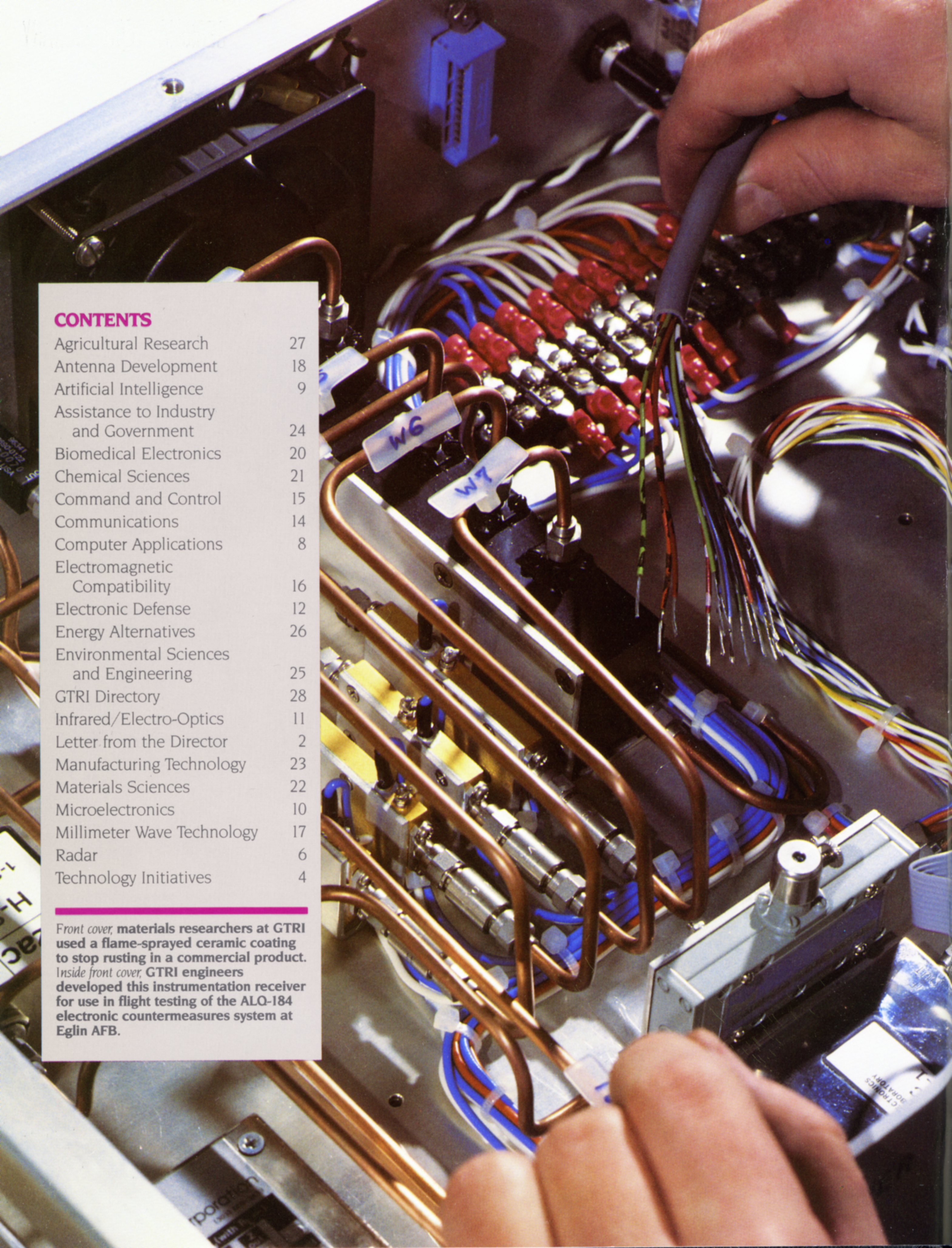

1987
ANNUAL
REPORT
GEORGIA TECH
RESEARCH
INSTITUTE
GEORGIA
INSTITUTE OF
TECHNOLOGY



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Front cover, **materials researchers at GTRI used a flame-sprayed ceramic coating to stop rusting in a commercial product.** *Inside front cover,* **GTRI engineers developed this instrumentation receiver for use in flight testing of the ALQ-184 electronic countermeasures system at Eglin AFB.**

A TIME OF TRANSITION

Fiscal 1987 was a year of marked transition for all research organizations at the Georgia Institute of Technology. With the passing of President Joseph Mayo Pettit, Georgia Tech found itself ending an era of great accomplishment.

Dr. Pettit left a deep imprint on every phase of this university's life, but one of his most impressive accomplishments was the nurturing of research at Georgia Tech. During his fourteen-year tenure, Tech grew from a university primarily devoted to undergraduate-level studies to an institution with one of the country's leading engineering research programs.

Georgia Tech's research community benefited from Dr. Pettit's leadership in many ways. Not only did he encourage faculty to become more active researchers, but he also kept the Georgia Tech Research Institute as an integral part of the university at a time when some similar academic R&D organizations were breaking away from their mother institutions.

This decision has allowed the Georgia Tech research community to grow with more vigor and diversity than might otherwise have been possible. Increasingly, engineers and scientists from GTRI have become involved in productive collaborations with other faculty in Georgia Tech academic departments. With the growing need for interdisciplinary research, these partnerships should become increasingly frequent.

Despite his belief that GTRI should remain close to Tech, President Pettit wanted the organization to be anything but inward-looking. For this reason, the Research Institute has continued to maintain one of the country's leading university-based programs in electronic defense. It also has been a pacesetter in developing alternative energy sources, protecting the environment, and making computers more useful to society.

Another key mission at GTRI has been economic development — for Georgia, the United States and the world's underdeveloped nations. In this state, Georgia Tech has played a key role in the expansion of high-technology industry. Pettit was well acquainted with what a university could do in this area. At Stanford University, he was influential in the founding of Silicon Valley, and he saw Tech playing a similar role in Georgia.

Ever the realist, Dr. Pettit's reaction to his own impending death was to encourage his colleagues at Tech to prepare for the future then "get on with it." Georgia Tech has dutifully done just that: selecting Henry C. Bourne as acting president and appointing a search committee for a new permanent president. When this report reaches some readers, Dr. Pettit's successor will be in office, and the next era in the university's life will have begun.

Despite the many changes to come, Dr. Pettit's legacy will continue. We dedicate this year's annual report to the memory of this outstanding man.

LETTER FROM THE DIRECTOR

Dr. Donald J. Grace

As we proceed into Georgia Tech's second century, GTRI continues to broaden its capabilities in areas ranging from artificial intelligence to communications to manufacturing technology. And with additional senior research investigators, GTRI has further strengthened its position at the leading edge of research in the fields of biosafety and metallurgical development and processing.

To retain its viability and competitiveness as an organization, GTRI moved to a sounder financial base through the creation of an overhead rate separate from that of Tech's academic research community. The new rate more accurately reflects GTRI's own research costs. In achieving fuller recovery of its expenses, GTRI will have additional resources for internal discretionary research and capital equipment purchases, as well as for covering essential operating costs.

In tandem with the new, somewhat higher rates, GTRI formed a series of task groups to intensively study the administrative and support functions of GTRI and to search for more cost-effective ways of accomplishing our work. Containing costs is vital to maintaining GTRI's ability to compete economically with other research organizations.

GTRI also began to explore new ways to meet the challenges of a changing federal procurement system. Specifically, the Competition in Contracting Act is impacting our applied research and development work, which is primarily contract-derived, rather than flowing through university-type grants. While we enthusiastically support the act's goal of cost-effectiveness, we will work to influence the system to recognize and take advantage of the unique qualities that make university-based research a national resource.

In response to changes in the structure of federal funding, GTRI is continuing to increase its industrial sponsorship. A $7.3 million subcontract to develop and build one of the largest phased-array antennas ever to fly on an aircraft exemplifies GTRI's growing partnership with industry. During FY87, industry accounted for 24.6 percent of GTRI research dollars, compared with 21.9 percent in FY86.

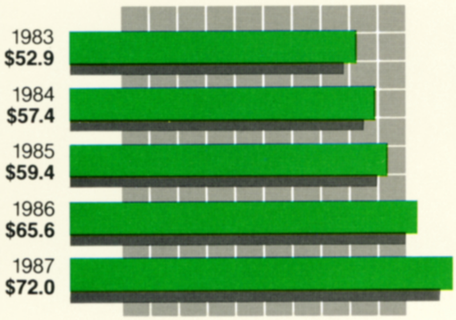
A factor in the growing amount of industrial sponsorship will be the Basic Research Credit, a part of the 1986 Tax Reform Act. Companies will now be able to reduce their costs in conducting basic research by claiming a 20 percent credit on research grants, contributions, and contracts at qualifying universities and other non-profit institutions. Designed to encourage U.S. competitiveness through technological innovation, the credit serves as an incentive for companies to support basic research in science, engineering, and mathematics at research facilities.

GTRI also continued to organize large, interlaboratory research programs as many of our sponsors moved toward larger projects that require multidisciplinary efforts. For example, our researchers are continuing their work on a $16.9 million contract from the U.S. Air Force to develop an advanced threat simulator — the single largest contract in GTRI's history.

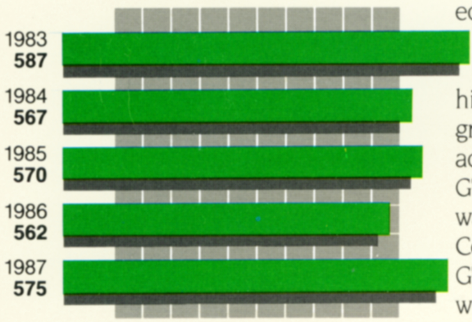
Beyond increasing the interaction of our own laboratories, we are moving to meet the multidisciplinary needs of our clients by arranging joint efforts between GTRI and our academic colleagues at Georgia Tech.

FY87 also saw a number of achievements and milestones that epitomize GTRI's commitment to excellence:

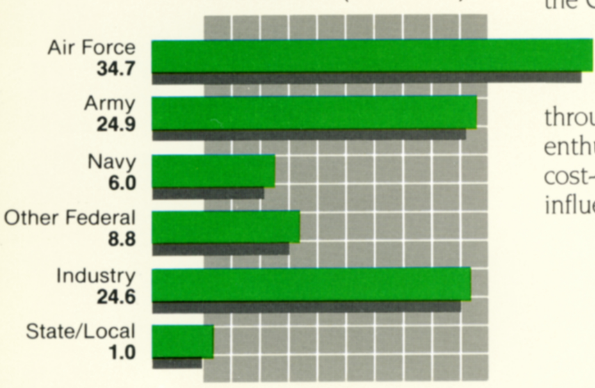
RESEARCH EXPENDITURES (Millions of Dollars)



NUMBER OF RESEARCH PROFESSIONALS



MAJOR SPONSORS (In Percent)



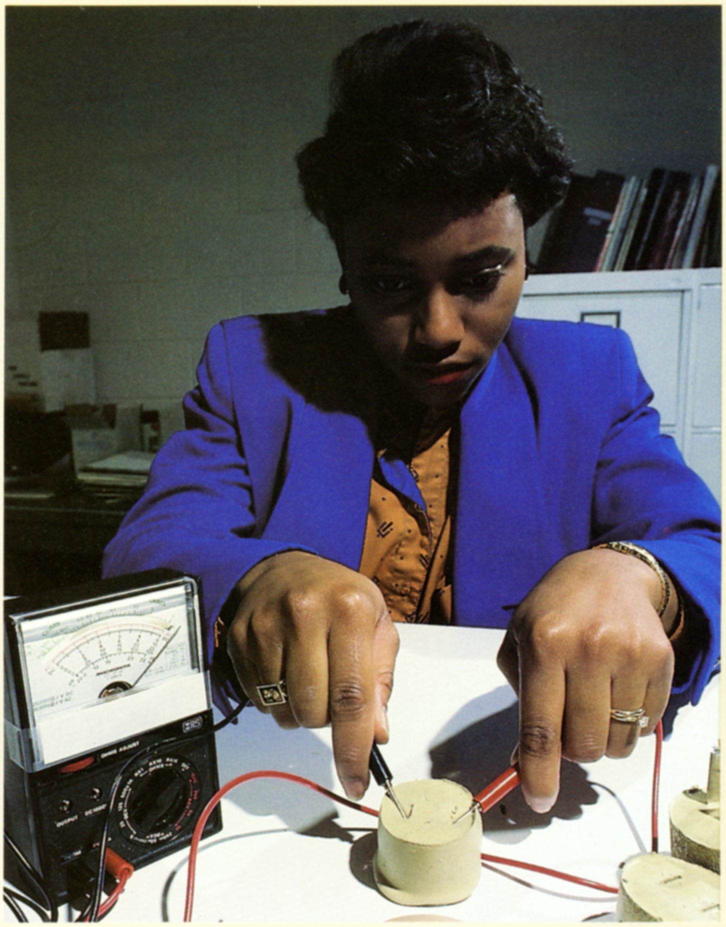
— Celebrating its 25th anniversary, the Industrial Extension Service completed the upgrading of five regional offices into Georgia Technology Centers. Located in Albany, Augusta, Gainesville, Macon and Savannah, the Centers help businesses adopt new technologies, improve productivity and gain access to GTRI's computerized technology and productivity information retrieval service. The Centers grew out of the Georgia Tech Industrial Extension Service, which provides technical and management assistance to more than 1,500 Georgia industries every year.

— GTRI began its role as a partner in the Biomedical Technology Research Center, created in FY87 by Georgia Tech and Emory University to facilitate joint medical/engineering research efforts. Examples of current research include a laser technique for removing fatty deposits from arteries without damaging normal arterial tissue; a high-strength plastic for synthetic replacements of ailing bones and joints; the mapping of the human body's "electrical blueprint" to improve medical radiation therapy; and a new kind of intrauterine device (IUD) with a design that may avoid infection problems associated with conventional IUDs.

— The antenna and reflectivity range at our Cobb County site became operational. This unique research facility, made possible by an internal investment of over $2 million, is available for industrial and government users as well as our own researchers.

GTRI also continued to serve as a training ground for the scientists of tomorrow, employing more than 100 graduate research assistants during FY87. And as part of our ongoing effort to strengthen the ability of GTRI to meet the growing — and changing — demands of research, nearly 130 full-time professional staff continued their advanced education through GTRI's tuition reimbursement program.

FY87 was indeed a year of transition. But it was also a year of great achievement made possible by the dedication, creativity and teamwork of GTRI personnel.



GTRI researchers developed a polysilicone elastomer as a material for finger pads in industrial robots. This flesh-like material should greatly improve the sense of touch in robots of the future.

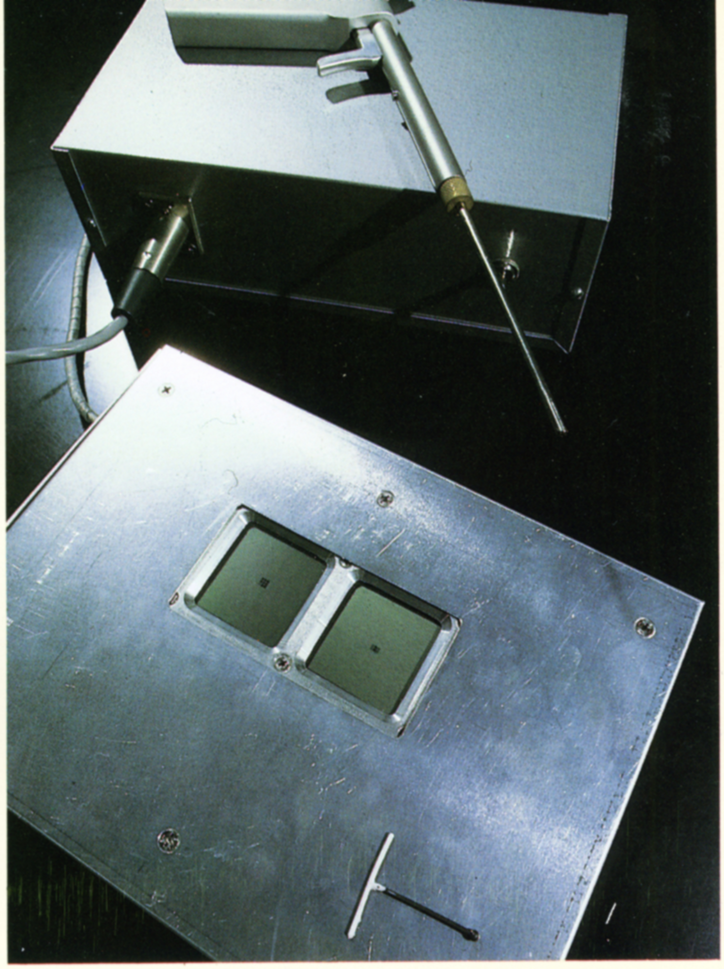
Although the future holds many challenges, I believe it holds much promise as well.

For their efforts and for their successes, I extend my deepest gratitude to every member of the GTRI community. What follows is a summary of their achievements during the last year.

Donald J. Grace

Donald J. Grace
Director
Georgia Tech Research Institute

TECHNOLOGY INITIATIVES



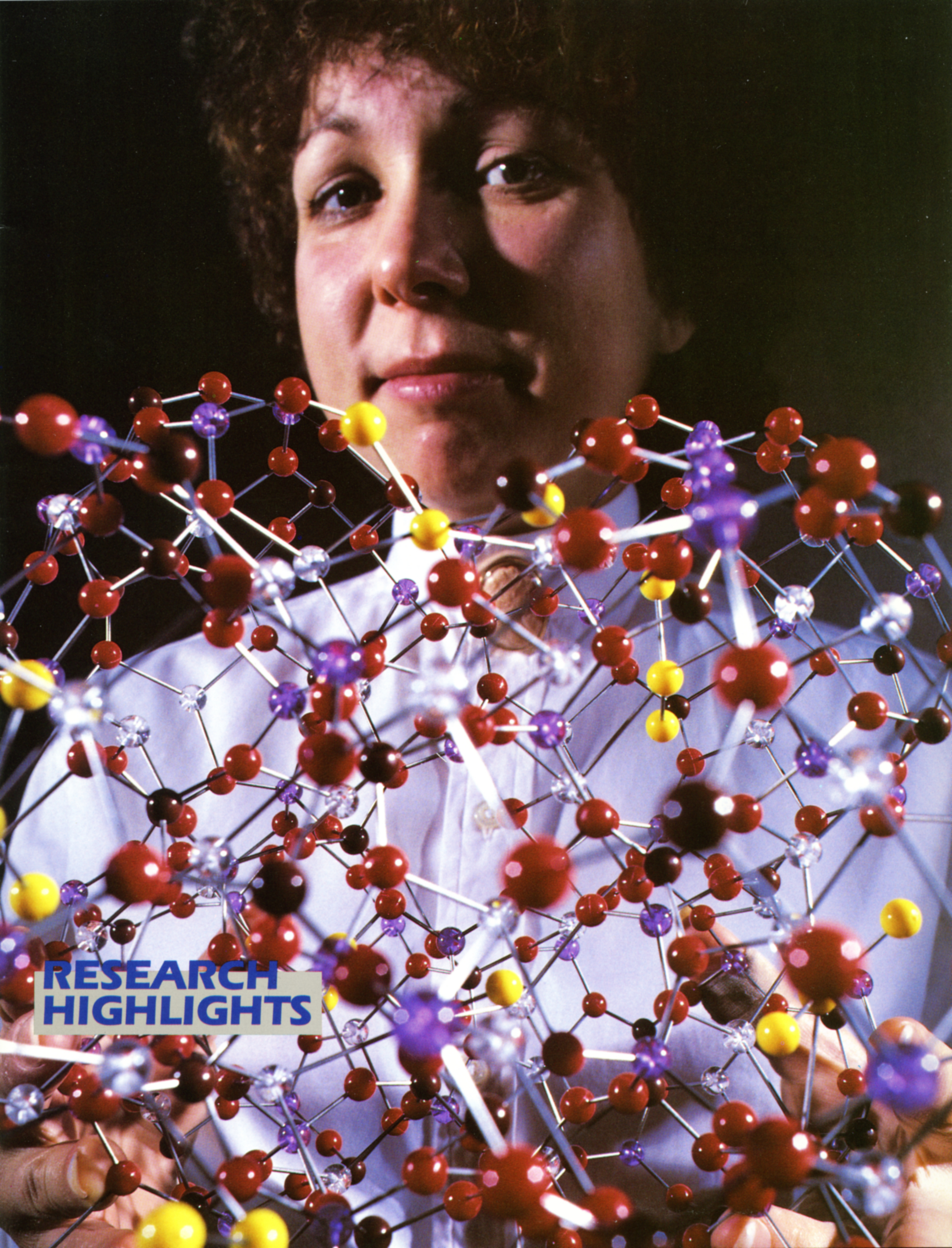
Distribution of SPONSORED RESEARCH AREAS — FY 1987

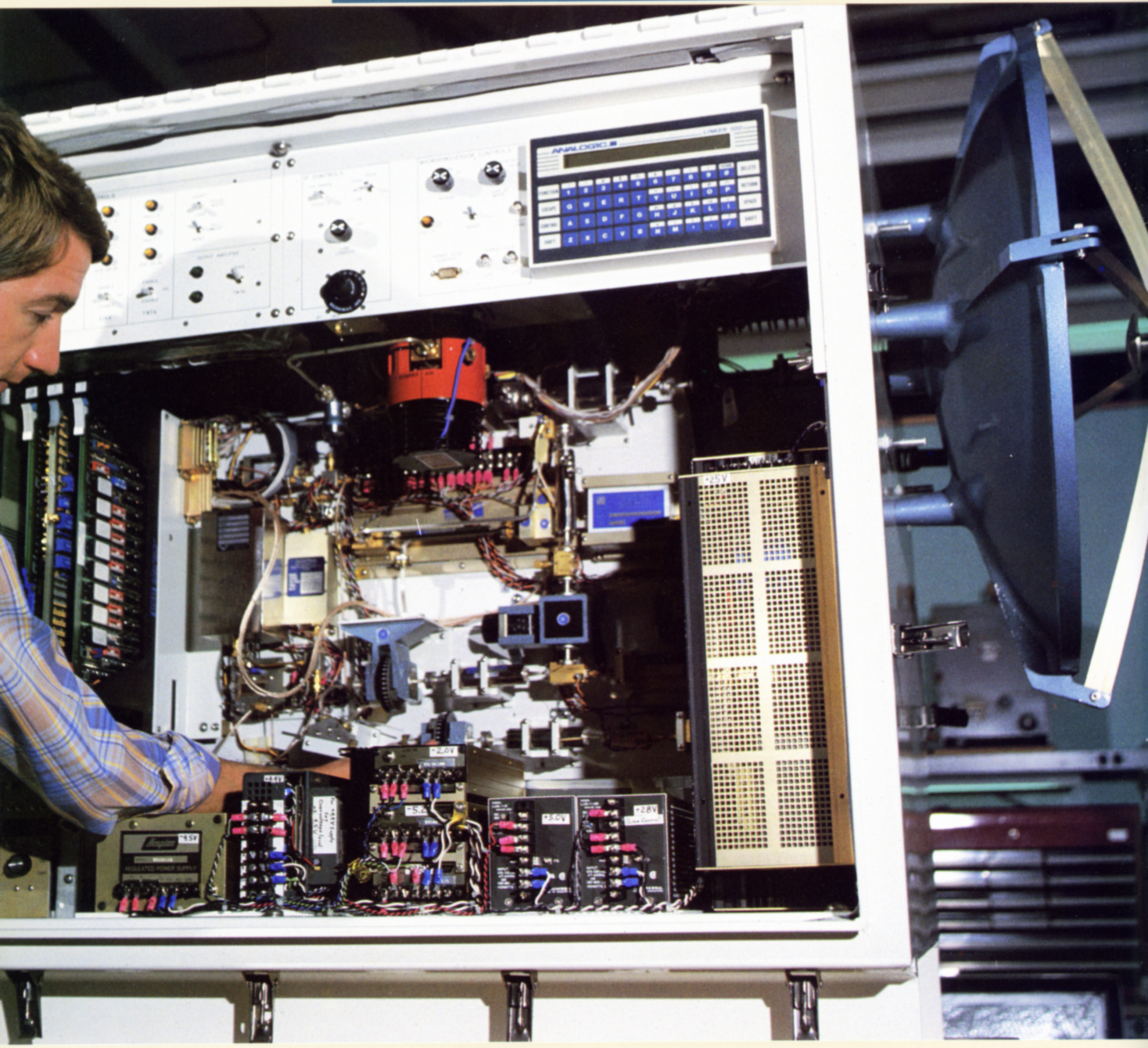
39%	Electronic Defense
17%	Electronic Systems
16%	Antennas, Electromagnetics & Optics
9%	Electronic Techniques & Components
8%	Computer Technology
3%	Physical, Chemical & Materials Sciences
4%	Economic Development/ Technical Assistance
1%	International Development
1%	Energy Conservation
2%	Manufacturing Technology

Above, **working with an Emory University physician, GTRI scientists developed a magnetic intrauterine device which eliminated the need for a fibrous tail, the cause of health hazards in some IUDs.** *Right,* **a new synthetic version of the pigment for ultramarine blue was developed in GTRI's zeolites research program.**

In FY 87, GTRI implemented and expanded a number of new technologies, while extending the breadth and depth of more mature R&D programs. This research involved such topics as:

Advanced radar warning receiver systems
Anaerobic fixed-film reactor wastewater treatment
Antennas for conversion of solar radiation on space stations
Application of artificial intelligence to autonomous work cells (robots)
Application of artificial intelligence to hazardous material emergency response
Artificial intelligence in diagnosing cardiovascular disease
Artificial intelligence techniques in electronic defense systems
Automated aircraft maintenance systems
Automated guided vehicle system scheduling
Automated palletizing
Avalanche photodiodes
Chemical vapor deposition of ceramics
Command and control systems in missile defense
Computer-based machine maintenance systems
Cost/benefit analysis of automation
Digital coherent on receive radar
Electromagnetic susceptibility measurement of integrated circuits
Electronic sensing for paraplegic rehabilitation
Ergonomics
Free radical chemistry in cloud water
High-temperature millimeter wave measurements
Indoor air pollution
Interfacial science technology
Laser instrumentation and ranging systems
Machine vision
Modulated scattering technique for antenna measurements
Molecular sieves and zeolites
Off-wire guidance of automated guided vehicles
Phased array antennas
Robot safety
Solar-dynamic space power systems
Solar-unique materials processing
Spread spectrum techniques
Stratospheric bromine chemistry
Thermite synthesis
Three-dimensional tactile imaging
Use of the nematode as a bioassay tool
Variably spaced superlattices


RESEARCH
HIGHLIGHTS



Above, **engineers completed development of HIPCOR, the first high-power, coherent radar system operating at 95 GHz.** *Far right,* **this 90-foot source tower is part of a large Electromagnetic Test Facility which became fully operational during the past fiscal year.**

RADAR

The Electromagnetic Test Facility gives GTRI a unique tool for radar or antenna measurements.

As part of the Strategic Defense Initiative, GTRI engineers continued to support the U.S. Army Strategic Defense Command in its Terminal Imaging Radar (TIR) project. The TIR is designed to detect and image threat re-entry vehicles and to discriminate threats from decoys and other objects. It will validate technology that provides the capability to track identified threat missiles and relay their future predicted positions so that missile interception is possible. The technology will be experimentally validated in test operations at the U.S. Army Kwajalein Atoll.

To improve GTRI's radar modeling capabilities, researchers developed the MAX Geometric Data Base Editor. A licensed software product, MAX is a hierarchical data base graphics editor which permits users to interactively create, display, and modify computer models of three-dimensional objects. MAX has also been used for infrared studies, flight simulation, and for construction of models of the human heart.

Using MAX, engineers created and modified computer models of radar targets. The targets were fed into TRACK, a program that provides computer simulations of radar cross sections (RCS) and radar tracking.

In FY 87, GTRI provided technical support for the development of the Marine Air Traffic Control and Landing System (MATCALS). Designed to be quickly set up at a landing field area, MATCALS provides air traffic control of friendly aircraft — from initial detection to hands-off landing in "zero-zero" weather. GTRI is now serving as technical advisor to the Navy on development of MATCALS.

In the last year, GTRI engineers also worked for the U.S. Navy on the DCOR (Digital Coherent on Receive) program. Their objective is to achieve the advantages of a time-coherent radar system with either a locally generated noncoherent signal or a remotely generated signal with no local coherent reference.

GTRI began development of a design concept to allow use of available receiver modules in a prototype of a two-dimensional digital beam-forming array. Such processing has applications not only for radar detection and tracking but also for communications systems and electronic interception of signals.

During the year, GTRI's Electromagnetic Test Facility provided a unique and vital resource in support of Tech's radar research. This state-of-the-art facility includes a far-field antenna range and a turntable radar cross-section range. The facility is used for testing of antennas, receivers, and communications systems, and for measurement of target radar cross section (RCS) characteristics.

GTRI continued development of antenna measurement technologies and techniques through tests performed on GTRI's Compact Range. In a project for the U.S. Army Proving Grounds, GTRI engineers used the range to conduct research on the design of a seventy-foot diameter outdoor compact range which will operate into millimeter wave frequencies.

Work progressed on a second-generation Simulated Air Defense System (SADS) for the Air Force, and the Army's mobile version of SADS was modified to improve performance, reliability, and maintenance.

GTRI also maintained its long-time participation in a number of ITEAMS (Integrated Technical Evaluation and Analysis of Multiple Sources) efforts. Critical to national security, ITEAMS programs bring together government and industry scientists to analyze specific foreign systems.

Researchers completed the development of HIPCOR, a high-power coherent 95 GHz radar. HIPCOR provides a powerful tool for investigating target, clutter, and propagation phenomenology whose understanding is critical to the development of advanced millimeter wave seeker systems.

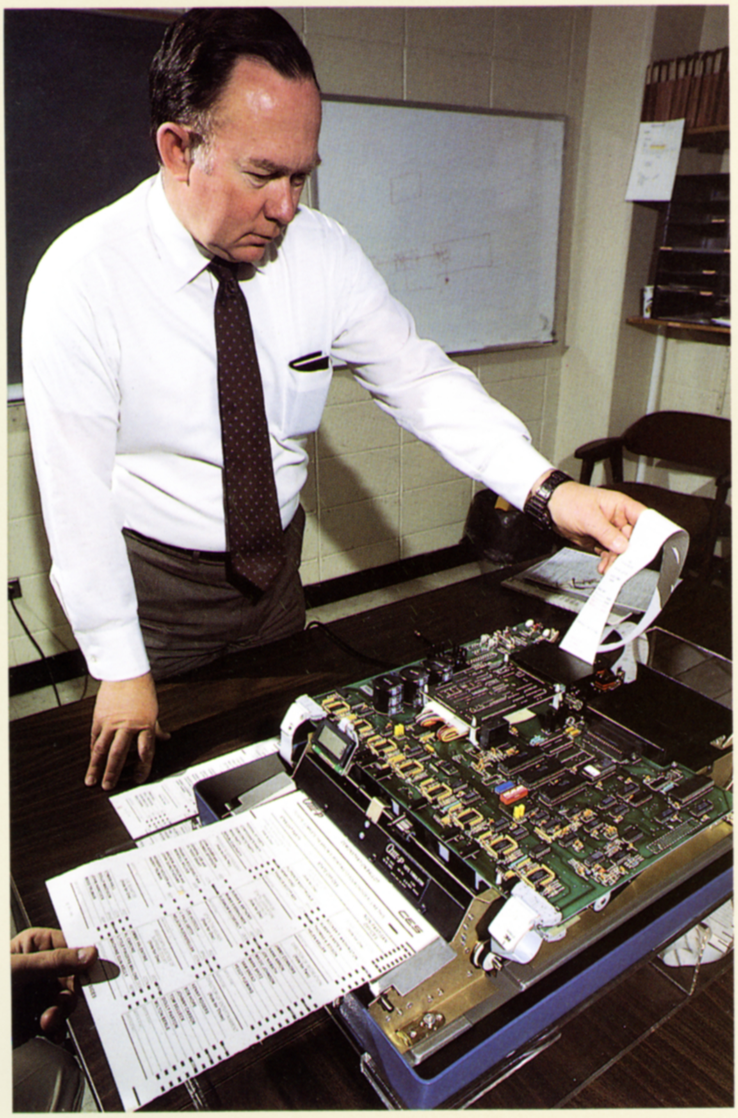
A variable-beam antenna under development will use the Wheeler twist-reflector/trans-reflector technique to continuously vary beam widths from one to seven degrees. The antenna will operate in a Cassegrain configuration.

Accurate testing of major weapon systems requires a realistic simulation of the threat environment, but construction of copies of high-cost "full-up" phased array radars is not economically feasible. GTRI began developing innovative antenna concepts using less costly techniques to mimic the scan characteristics of threat phased array radars. □

COMPUTER APPLICATIONS

A few large companies were once the only manufacturers of computer-based equipment to tally votes in governmental elections. With the advent of microprocessors, many small companies make these machines, and the quality of available equipment is not uniform. In FY 87, GTRI computer scientists, under contract with the Georgia Secretary of State, developed standards to assure that automatic, computer-based voting equipment is accurate and reliable. Their work will serve as a foundation for a state-sponsored equipment certification program.

Modern phased-array antennas rely heavily on computers to electronically steer their agile beams. In FY 87, engineers completed development of a dedicated computer controller for GTRI's airborne platform telemetry antenna. The controller must automatically find and track five separate targets in missile tests.



During the year, GTRI researchers evaluated components of Federal Express' new COSMOS system to ensure that it will meet the company's requirements for performance and ruggedness. The computer-based system will allow Federal Express to monitor thousands of priority packages daily.

Researchers continued investigating the impact of various constraints on computer hardware design imposed by Ada, the Department of Defense programming language. This long-term project focuses on simple VLSI processors for use in multiprocessing systems to be installed in the advanced fighter aircraft of the 1990s.

To minimize down-time and prevent breakdown of sophisticated industrial equipment, GTRI engineers developed computer-based systems for remote maintenance diagnostics and predictive maintenance. The diagnostic system utilizes the sensor-based technology previously developed at GTRI for a nuclear power plant safety monitoring system.

Another problem addressed in FY 87 was the automation of high-speed textile machinery. In a new generation of equipment, many microprocessors are used to control different components of the machinery. GTRI engineers began designing a host microprocessor to coordinate the activities of the other microprocessors and to handle data describing the fabric. □

Top of page, **researchers developed software so that a manufacturer can use machine vision to detect flaws in a commercial printed circuit board.** *Above,* **GTRI engineers tested computerized voting machines for the state of Georgia and began setting up evaluations criteria.**

ARTIFICIAL INTELLIGENCE

GTRI continued its involvement in the effort to develop an autonomous helicopter.

One of the primary missions of NASA's planned space station is to serve as an orbiting laboratory for scientific experiments. Tech researchers are defining the robotic capabilities needed for tele-operated equipment which will be used by ground-based scientists conducting experiments in space. Software under development by GTRI will enable robotic laboratory assistants to perform a broad range of activities. Special clamping fixtures, tactile sensors, and unique motion techniques will allow the robots to operate safely and efficiently in the zero-gravity environment.

A vital but tedious part of building design is the writing of specifications. In FY 87, GTRI continued development of an expert system that will allow architects using personal computers to write accurate, fully documented specifications by responding to queries from the expert system.

In a similar project for the Air Force, researchers worked to develop an expert system to generate specifications for vehicle procurement. Every year, the Air Logistics Center issues large numbers of purchase descriptions with exhaustively detailed specifications to solicit bids for vehicles. With demands for vehicle procurement increasing every year, GTRI's expert system will ease the burden of specification-writing while capitalizing on the expertise of Air Force personnel.

Equipment used to monitor nuclear power plants produce unwieldy amounts of data. GTRI is developing a computer program to convert data from gauges and dials into a graphic presentation that will be more understandable to plant employees. The Safety Parameter Display System — part of the Emergency Response Data System — will constantly monitor the vital signs of the power plant, offering a probable diagnosis and corrective action if it detects an anomaly. The system, which grew out of GTRI's work in developing computer programs that assess machinery performance, will not be limited to nuclear plants. It could also be used to monitor the complex operations of many types of industrial plants.

GTRI continued its involvement in the development of an autonomous helicopter capable of pilotless flight. Researchers provided technical assistance to NASA regarding the computerized route-planning approach for aircraft already pioneered by GTRI engineers. The route planner can select the best route through defensive points in a given scene.

To implement AI systems, researchers are exploring computer architectures, including a shared memory system that one day may be distributed throughout the airframes of the next generation of fighters. Designed in the 1990s, these aircraft will contain electronic flight associates, each expert in a particular aspect of the craft's mission. □

GTRI has developed a full-scale expert system shell known as the Generic Expert System Tool (GEST). It is similar to systems now available from commercial businesses and allows users to rapidly prototype expert systems.

MICROELECTRONICS

The variably spaced superlattice could be a milestone in microelectronics.

While continuing to design and model semiconductor devices and grow them through molecular beam epitaxy and ultraviolet lithography, GTRI engineers began screening microcircuits for durability and environmental stress.

Researchers also made advances in the development of new optoelectronic devices such as electroluminescence panels, avalanche photodiodes and infrared detectors. Molecular beam epitaxy was used to grow high-purity materials and superlattice structures for fabrication into avalanche photodiodes and high-performance microwave field effect transistors.

GTRI's invention of the variably spaced superlattice concept, which provides for high-energy injection of charge carriers into an adjacent semiconducting layer, represents a milestone in microelectronics. In this scheme, quantum well widths are progressively decreased through the structure; under the appropriate reverse bias voltage, the confined energy levels in each well are lined up. As a result, electrons resonantly tunnel through the structure and are injected at high energy into another semiconductor layer. When the injection energy exceeds the energy gap in this layer, impact ionization of valence electrons occurs, providing carrier multiplication.

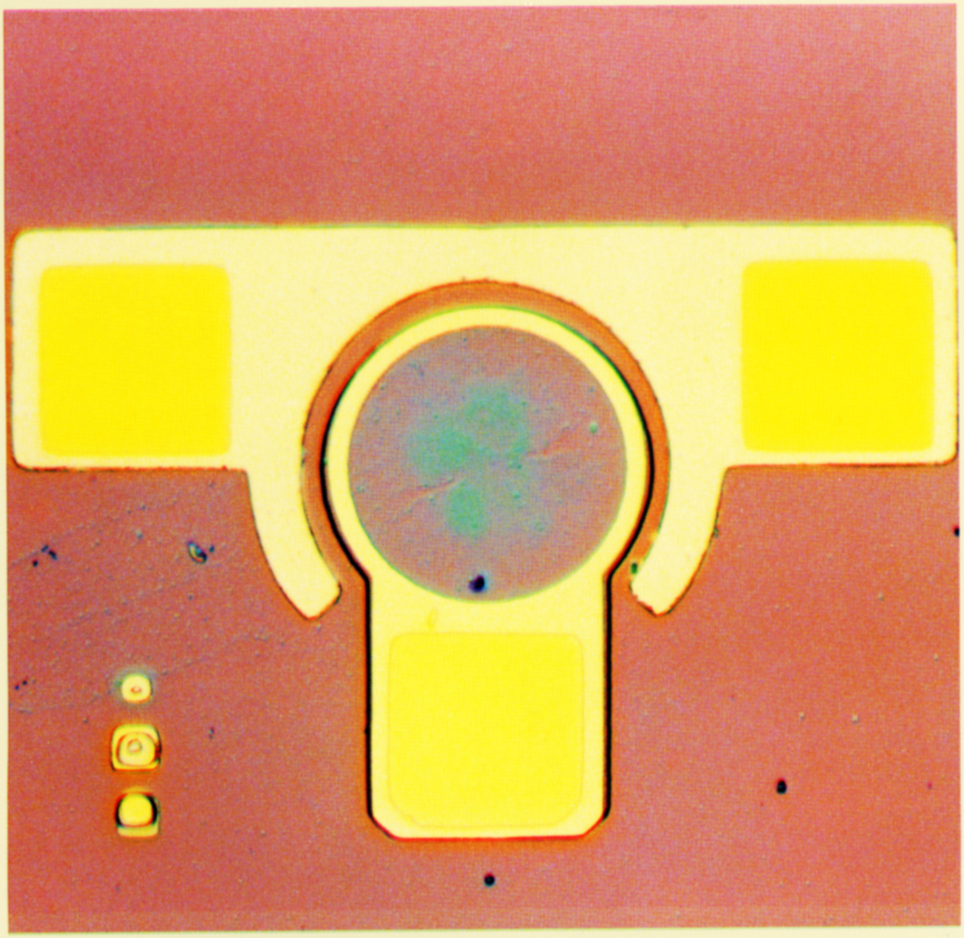
The advantage of this process is that it allows the production of a near-monoenergetic stream of electrons at low voltages, and the energy of those electrons can be tuned to optimize the operation of devices.

This process is also being used to improve the performance of electroluminescent devices (higher luminescent efficiency at low bias voltage) and avalanche photodiodes and microwave devices (increased sensitivity and lower noise). The improvements are achieved without using a high electric field bias voltage to heat the electron distribution, which normally is inefficient and noisy.

Improving the efficiency of avalanche photodiodes was made possible by the use of molecular beam epitaxy to grow high purity gallium arsenide (GaAs) with lower temperature mobilities exceeding 117,000 cm^2/Vs as well as aluminum gallium arsenide (AlGaAS)/GaAs superlattices.

Engineers began using AlGaAs in the growth and fabrication of superlattices for ultra-fast optically bistable switches and quantum well optical waveguide devices. These devices, along with new types of detectors now being examined, are the basic components used in the construction of optical integrated circuits; they have the potential of increasing computing speeds by several orders of magnitude over current technologies.

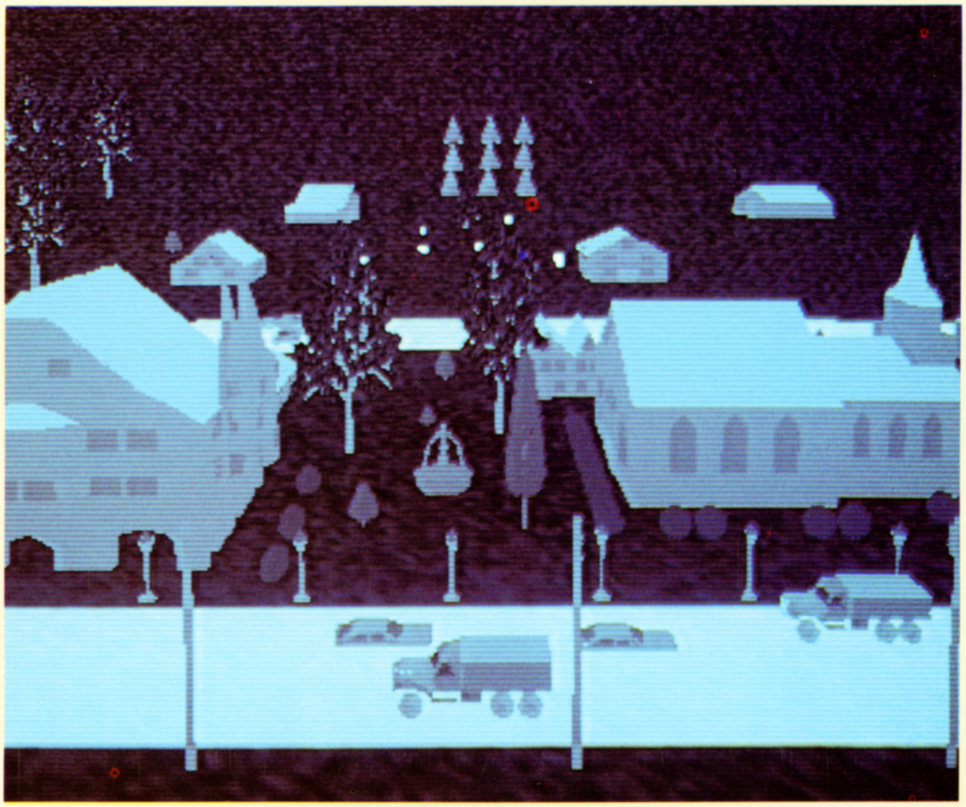
Studies also continued of the growth conditions for zinc cadmium telluride (ZnCdTe) and mercury cadmium telluride (HgCdTe) alloys for infrared detectors and solar cells. GTRI research has established a better understanding of the growth mechanisms of these materials. □



Last year, Tech researchers used molecular beam epitaxy to grow optoelectronics devices of high purity such as this gallium arsenide pin avalanche photodiode. The device is 150 microns in diameter.

INFRARED/ ELECTRO-OPTICS

To improve evaluation of infrared data, GTRI engineers developed the Tactical Expert System Simulation (TESS). A computer vision system using artificial intelligence techniques, TESS locates and classifies targets in infrared images. TESS is written in LISP (List Processing) programming language and uses the Generic Expert System Tool developed by Tech. With an image data base of approximately five hundred objects, TESS calculates the probable identity of targets based on comparisons with the data base and the target's context. For example, the simulation can determine objects moving in a column are probably tanks because they are on a road.



GTRI engineers created this thermal picture of a German village for use in infrared imagery studies.

Tech engineers are developing a new kind of laser instrumentation and ranging system (LIDAR).

Accurate surveys of underwater terrain are important to the Navy and Marine Corps. Last year, researchers continued to develop and test an airborne survey system using a copper vapor laser. The laser emits 65-kilowatt beams in 10-nanosecond pulses; its wavelength of 5106 angstroms will allow it to pass through water and bounce back to a receiver. Tech is building a receiver and equipment for sequencing, timing, and measuring the laser, which holds the promise of producing high-resolution images of underwater geography.

The U.S. Air Force must quantify atmospheric effects on the Infrared Search and Track System (IRSTS) performance as part of its flight test program. GTRI is integrating airborne and ground-based meteorological and laser instrumentation to provide this data. The airborne instrumentation, consisting primarily of a laser/receiver system and meteorological instruments, will be used to determine atmospheric attenuation, caused, for example, by thin cirrus clouds. This data will allow the program office to correlate IRSTS performance with atmospheric conditions. GTRI is also developing a mobile heterodyne laser instrumentation and ranging system (LIDAR) to be used for mapping the atmosphere before and during the flight tests.

A simulator under development by GTRI will acclimate soldiers to using infrared vision devices. With computer-generated battlefield scenes in conditions such as smoke, rain, and fog, the simulator will allow tank gunners to practice such tasks as locating targets in normal light and in infrared.

GTRI also continued development of user-friendly "turn-key" geographic information systems that convert satellite images into map form. And to help the Army determine what can be seen from vantage points in enemy territory, researchers combined satellite images with geographic data. This will improve location of forward observers and pinpoint potential choke points on the battlefield.

In a multi-year, joint program for the Army and Air Force, GTRI is determining target signatures in the infrared and millimeter wave regions. Researchers are also evaluating seeker performance through captive flight tests of terminal-guided submunitions in the infrared mode. □

Above, **researchers here developed this radar data acquisition system to quantify radar and electronic countermeasures signals in a flight test environment at Eglin AFB.** *Right,* **research continued on a laboratory prototype which delivers localized auditory cues to a pilot through earphones.**

ELECTRONIC DEFENSE

The F-16 Falcon is one of America's front-line fighter aircraft. To support the equipment that tests analog/hybrid circuit cards like those used in the avionics systems of the F-16, GTRI engineers are developing an Automatic Test Equipment Software Support Environment (ATESSE). The ATESSE will provide an integrated set of software tools to support all stages of the life cycle of the software used to control Automatic Test Equipment (ATE).

A prototype of the ATESSE's "core facilities" is under development and will include schematic capture, circuit simulation, component and subcircuit modeling, fault modeling and other simulation aids, as well as user interface and executive and hardware environments. In addition, the ATESSE will include a circuit simulation verifier and ATLAS code synthesizer to produce usable ATLAS code for DC circuit analysis.

GTRI is exploring the uses of artificial intelligence in electronic defense.

In another project during fiscal year 1987, researchers explored the development of range instrumentation for quantifying ECM (electronic countermeasures) signals and radar degradation caused by ECM. Radar instrumentation hardware was developed for operation with an IBM-PC-compatible computer. Real-time software was developed for signal calibration and storage of radar signals on a pulse-to-pulse basis. For the Qualification Test and Evaluation of the AN/ALQ-184 ECM system, Tech engineers designed software for reduction of test data.

In battle, airborne radar and communications systems must be capable of rapid reprogramming to overcome a hostile ECM signal environment that is constantly changing. Looking ahead to the year 2000, researchers explored the development of an ECCMS (electronic counter-countermeasures system) that would enable radars, communication systems, and general avionics to perform real-time, in-flight reconfiguration of ECCM elements to maximize performance in a hostile — and changing — ECM environment. In addition, GTRI established general requirements and broad specifications for an ECCM Advanced Extendable Integration Support Facility (AEISF) that could potentially replace the present-day Avionics Integration Support Facility (AISF).

A major challenge for electronic warfare (EW) systems is the provision of effective ECM techniques against the many threats encountered in combat. The selection of ECM techniques must make optimal use of limited ECM resources such as transmitter channels, waveform generators, and modulators. Moving beyond the relatively simple computer programs now used in ECM selection, GTRI will be developing an ECM Resource Manager that will use artificial intelligence (AI) to improve the overall effectiveness of available ECM systems.

During FY 1987, GTRI brought together experts in AI and design automation for a workshop to explore the use of AI in developing a formal science of design automation for military weapons systems. Sponsored by the Air Force's Wright Aeronautical Laboratories, the workshop examined the design of mission and sensor algorithms, processors, multiprocessors, and very-large-scale-integrated (VLSI) circuits. Also studied were engineering design, methodology and validation, and a design automation testbed. A follow-up workshop is planned. □

COMMUNICATIONS

Researchers are trying to find ways to transmit spread spectrum signals without jamming or detection.

Communications is one of the principal elements of complex military and civilian electronic information networks. GTRI conducts research to improve the performance of such networks and to better understand how disruptions affect reliability.

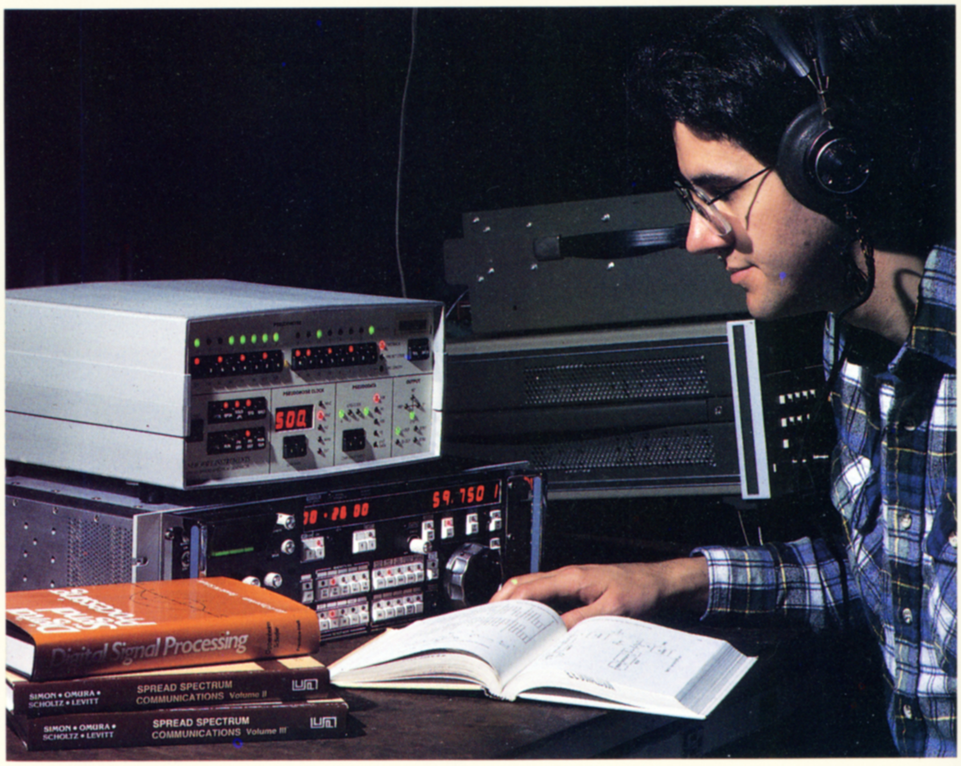
A major area of GTRI research during fiscal year 1987 was the analysis of advanced signaling waveforms and how they influence the operation and detectability of radio frequency military networks. Researchers investigated issues including the effect of deliberate enemy jamming, eavesdropping on network signals, and the design of improved electronic techniques. To prove concepts, engineers assembled and tested prototype devices and systems under realistic conditions.

Investigations continued on a special class of signals called "spread spectrum." Researchers are trying to determine if data can be transmitted without being detected and under what conditions such waveforms can be jammed if they are detected. An example of related work was a new project for the Air Force Wright Aeronautical Laboratory where a variety of unique waveforms for communication networks are being studied.

Increasing use of the electromagnetic spectrum has led to dense and often overlapping emitters employed in communications networks. A variety of methods for wideband processing of multiple signals were investigated last year by engineers to develop techniques for signal identification, measurement of signal parameters, and location of sources of emissions. These techniques incorporate automated computer measurements and improved signal processing devices.

Surreptitious monitoring of communication networks is an ever-present problem, and GTRI engineers have developed computer simulation models to investigate network susceptibility. These models allow engineers to predict the range over which signals can be detected and suggest remedial actions that may be taken. Developed over several years and used to support a broad range of sponsored research projects, these analytical tools account for propagation path loss, the location of emitters, and techniques used by potential jammers and interceptors.

Other research topics studied in FY 87 included methods to measure interference in spread spectrum communications equipment, design of millimeter wave RF hardware, and application of artificial intelligence (AI) techniques to network analysis. □



In FY 1987, GTRI continued to be one of the leading university research organizations working in the analysis and evaluation of advanced defense communications techniques.

COMMAND AND CONTROL

Keeping flights on schedule while meeting airplane maintenance requirements and crew work limits poses a complex challenge for the airline industry. To address this problem, GTRI researchers are developing a computer-based system to automate the intricate decision-making process used by a major U.S. airline. Designed to be user-friendly, the system will display information on computer monitors in a format that mimics the system now used by airline employees.

GTRI researchers are also developing an expert system to help the airline more efficiently use a variety of maintenance resources — from hangars to spare parts to specialized mechanics.

In a similar project for the U.S. Air Force, researchers are developing a computerized system to replace the "grease pencil and plexiglass" now used to monitor the maintenance status of planes and to implement flight schedules. The system will automate procedures which ensure that planes receive maintenance and that a sufficient number of planes are available to complete missions. Beyond automating the procedure, GTRI is examining the use of expert systems to increase the efficiency of the process.

For the Strategic Defense Initiative, researchers are exploring ways to streamline communications for more effective command and control. Because of the complexity of the proposed missile defense system, sending battlefield data to one centralized location could create an information bottleneck. Command and control architectures are being studied to identify the communication and decision support capabilities best suited for use against a specific threat. Using "end game models" to determine the performance of various SDI elements against hypothetical threats, GTRI researchers are establishing criteria for command and control.

In FY 87, GTRI began offering consulting services to enhance productivity of software development teams. In addition, Pen-Aids, the penetration analysis aiding system developed for the U.S. Tactical Air Forces, entered test and evaluation this year and is expected to be in operational use early next year. Using terrain data, maps and intelligence on enemy anti-aircraft systems, Pen-Aids determines which areas are shielded or masked from enemy radars and can be used as corridors of penetration for friendly aircraft. □

GTRI researchers developed a command and control system which allows aircraft maintenance to be conducted in an orderly, efficient way.

ELECTROMAGNETIC COMPATIBILITY

Engineers developed a technique to control electronic arcing on aircraft surfaces.

With society's mushrooming dependence on electronic devices, electronic interference and disruption are increasingly critical concerns. In FY 87, GTRI brought its decades-long expertise in electromagnetic compatibility to bear on several electromagnetic interference problems in both the military and civilian arenas.

Engineers developed a technique for locating and repairing areas on the surface of an aircraft that are subject to arcing from on-board, high-power transmitters. This arcing causes interference to sensitive radio-frequency equipment also carried on board. Arcing occurs at points where metal joints have become loosened or where dirt has infiltrated underneath. When arcing is severe, it can disrupt critical systems. Since arcing happens only in flight, the arc locations are difficult to pinpoint. GTRI is seeking ways to locate the general position of the arc while in flight, and then to pinpoint the malfunctioning joint once back on the ground.

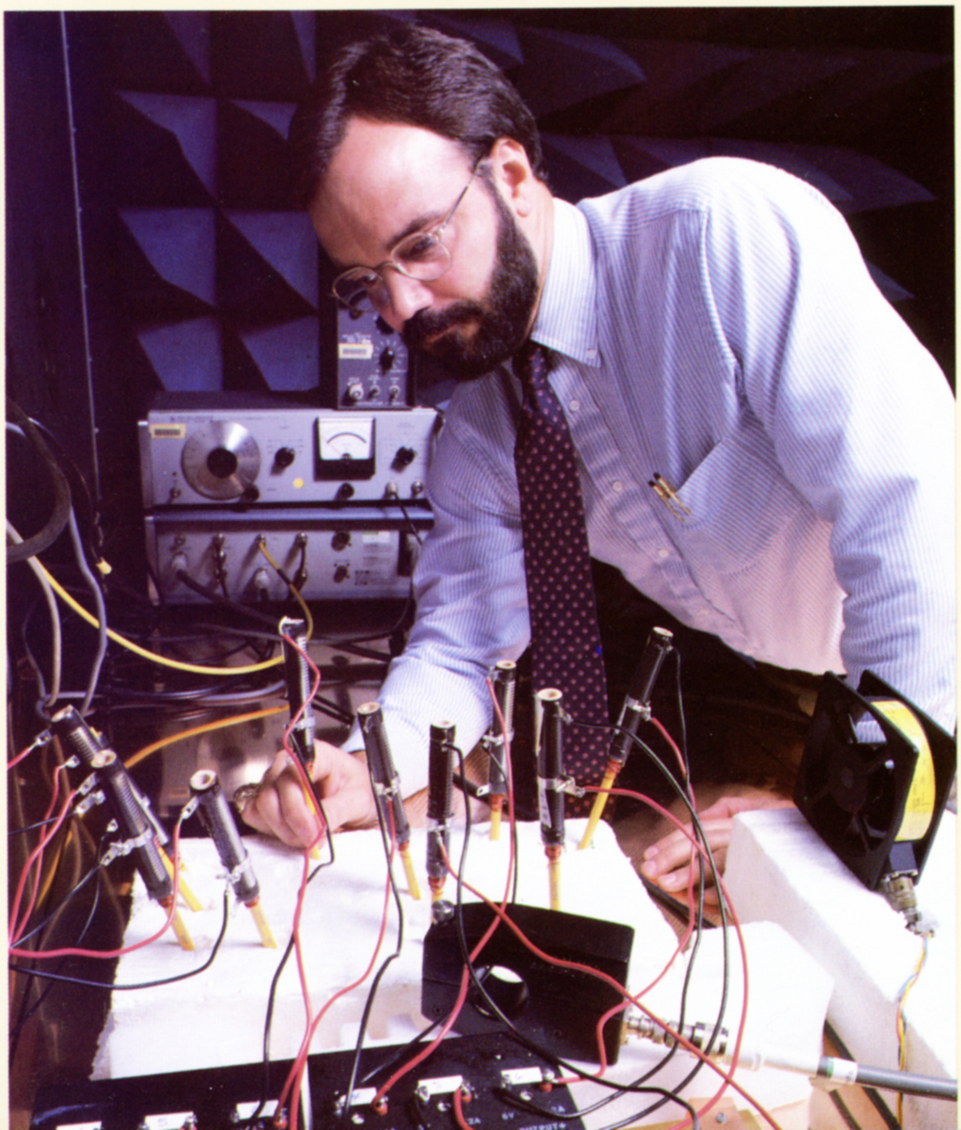
GTRI expanded its study of spread-spectrum communications, developing new procedures to analyze and evaluate the interference characteristics of spread-spectrum equipment. This new technology is believed to be much less susceptible to interference than fixed- or narrow-band radio, but operates so differently that new test procedures are needed. GTRI's tasks were to formulate and adopt standardized test procedures for evaluating spread-spectrum equipment and performance criteria for spread-spectrum equipment and performance criteria for spread-spectrum electromagnetic interference.

During FY 87, engineers developed specialized hardware items for measuring the interference properties of large-scale integrated circuits. They also wrote and implemented computer software for automated testing.

GTRI continued to make refinements to an automated test facility to evaluate the effects of electromagnetic fields on aircraft. One task was the installation of specialized test equipment for generating strong electromagnetic fields. Researchers also improved the software which controls the testing and the gathering and analysis of data.

As a service to city and state governments, engineers began developing techniques for protecting computerized traffic controllers from lightning and other transients. The next step will be to develop training manuals and video training tapes for traffic engineers and installation/maintenance personnel.

Other activities during the year included verifying the compatible performance of a large airborne phased array antenna designed and built at Tech, initiating a program to analyze and measure the electrical behavior of bonding straps used on ships at sea, and revising a handbook on circuit design procedures for protecting electronics from electromagnetic transients. □



Many electromagnetic interference tests were made at GTRI during the year, including this conduction emission test of the power supplies for a large antenna array.

MILLIMETER WAVE TECHNOLOGY

Development of HIPCOR — the first 95 GHz millimeter wave radar to combine high power (2 kilowatts) with coherency — reached a successful conclusion in fiscal year 1987. Sponsored by the U.S. Army Missile Command, the HIPCOR program gives researchers a powerful new tool to investigate targets, clutter, and propagation phenomenology. Measurements made with this radar will be critical to the development of other advanced millimeter wave systems. HIPCOR incorporates state-of-the-art components and subassemblies to generate a range of sophisticated waveforms. The radar's wide band width, polarization and frequency agility, and coherency make it a unique tool for electromagnetics research.

NASA is exploring the use of radiation from the Earth instead of the sun to power low-orbit satellites. GTRI engineers have built prototypes of rectifying small antenna arrays to convert terrestrial radiation into usable energy. Similar techniques are being investigated for the transfer of power from low-orbit to high-orbit satellites via millimeter wave transmissions.

To shield tanks, trucks, and even soldiers from hostile millimeter wave radar systems, researchers are developing "low observable" materials, mostly textiles. Potential targets covered with or actually made of these materials would be significantly less visible to millimeter wave seekers because of the materials' electromagnetic-scattering characteristics.

Understanding how radar performs in the often inclement weather of Europe is vital to the defense of the West. Moisture on an object or in surrounding clutter changes radar images. During fiscal year 1987, engineers used GTRI's radar cross section range to gather target signatures in wet and dry conditions. Nozzles controlled the amount of water falling on the objects — from a light mist to a downpour.

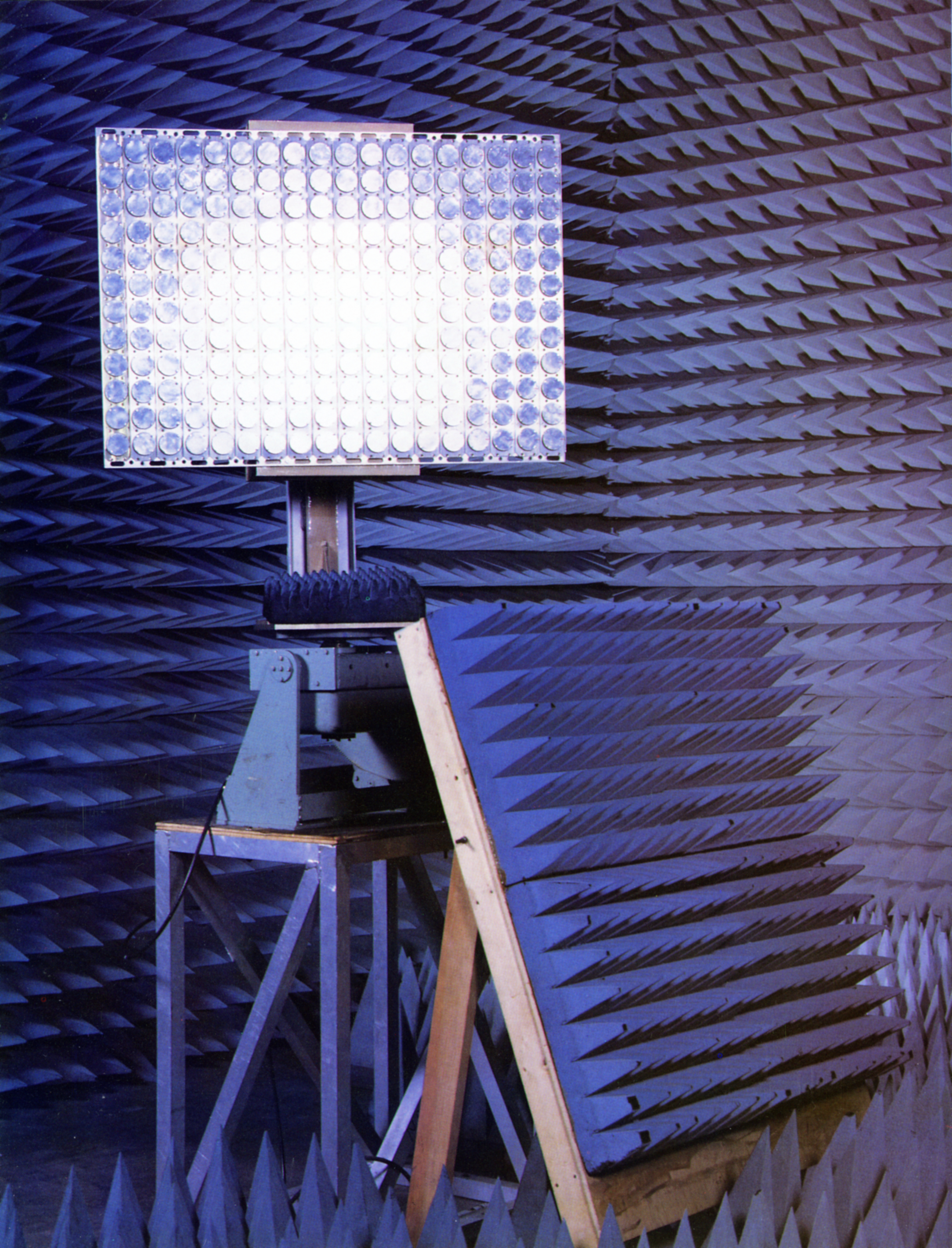
In a project for the Army Missile Command (MICOM), GTRI collected signatures of approximately twenty military targets at millimeter wave and infrared frequencies. The millimeter wave measurements were taken in Ka band (30-40 GHz) and M band (90-100 GHz). Researchers at Tech simultaneously conducted infrared and millimeter wave measurements as part of the Defense Department effort to evaluate and eventually develop dual-mode seekers.

To increase the efficiency of millimeter wave research, GTRI engineers have improved the state of the art in precision measuring technology. Through the creation of software and use of automatic network analyzers, researchers have cut the time required for calculating dielectric constant, permeability, and tensor permeability from days or weeks to hours.

GTRI has also pioneered in precise millimeter wave measurements at temperatures above 2000° C. These experiments are important in testing the durability of low observable coatings on missiles during atmospheric reentry.

Finally, research engineers were able to improve spectral purity through "phase locking" high-power/high-output orotrons which produce millimeter waves in a broad tuning range of 50 to 75 GHz. □

GTRI engineers developed this horizontal reflectivity arch for measurements in the 2-60 GHz frequency range.



ANTENNA DEVELOPMENT

GTRI engineers continued development of one of the largest phased array antennas ever to fly on an aircraft. The 1,728-element antenna will track targets over a frequency range of 2.2 to 2.4 GHz, allowing the Air Force to collect telemetry data on up to five missiles and drones simultaneously. Under development for the Air Force Systems Command, the antenna will be one part of a $34 million airborne electronic platform for tracking missile tests at Eglin Air Force Base.

Two antennas are under construction. Measuring thirty feet long and 2.5 feet wide, each phased array antenna will weigh only 2,700 pounds, light enough to be mounted along one side of the fuselage of a DeHavilland-8, an economical twin-engine aircraft commonly known as the Dash-8. Engineers used computer simulations of the antenna's design to determine the combination of aluminum alloys that would provide maximum strength and minimum weight.

Unique features of the antennas include polarization insensitivity and low noise temperature. From an altitude of 25,000 feet, the antenna will cover an area reaching from sea level to 30,000 feet and +/- 60 degrees along the horizon.

In another project for the National Aeronautics and Space Administration (NASA), GTRI engineers continued to evaluate antenna designs for the initial configuration of the proposed U.S. Space Station. The antennas will be used in two types of zones — one for command and control, the other for co-orbiting satellite operations.

The command and control zone, which must be able to accommodate six users simultaneously, will receive status information that will be used to determine allocation of resources. The space station will have two co-orbiting satellite zones — one in each orbital direction — that can accommodate five users simultaneously (the requirement will be expanded to twelve to sixteen simultaneous users). The co-orbiting satellite zones will be used for operations such as servicing spacecraft, retrieving high-orbit satellites, and dispatching repair crews to spacecraft.

GTRI has surveyed a number of candidate antennas, examining such factors as bandwidth, reliability, packaging constraints, and switching network complexity. Preliminary findings suggest that mechanically steered antennas may be best suited for the command and control zone, while multiple-beam reflector antennas may work best for the two co-orbiting satellite zones. Next, GTRI engineers will analyze electromagnetic interference, determine optimum locations for antenna mounts, and develop the antenna management system.

GTRI is developing one of the largest phased-array antennas ever to fly.

GTRI engineers also continued to serve as technical consultants to the Johnson Space Center during the procurement and installation of a large planar near-field measurement facility at the NASA Houston complex. The planar scan area is approximately forty by forty feet with a 1-60 GHz measurement frequency range.

In another project for NASA, researchers are exploring the use of patch antennas as part of a mobile (and inexpensive) system to track satellites. The patches, or printed circuits, can be arrayed and electronically steered like a conventional phased array but at much lower cost. GTRI is also evaluating patch antennas for a number of other applications requiring low-cost phased arrays.

To speed up near-field measurements of radar antennas, GTRI engineers developed a modulated scattering technique and constructed a 128-element linear array device. Measurements that took hours using older mechanical systems now take minutes using GTRI's electronic scanning system. With its swift operation, the new system is feasible for routine production testing of antennas.

Engineers also updated the computers and graphics capabilities of a conventional mechanical planar scanner used for near-field measurements. The addition of color graphics permits a rapid visual assessment of antenna performance.

At GTRI's compact range, researchers installed a CW (continuous wave) 2-18 GHz amplitude/phase radar cross section system. With a range resolution of 3/10 inch, the system is used to calculate high-resolution, band-limited impulse responses and scattering characteristics of radar targets.

To reduce unwanted backscatter on the compact range, researchers developed a wing-shaped, low radar cross section (RCS) support column to hold targets during RCS measurements. Capable of holding five hundred pounds, the column has an extremely low radar cross section, reducing the column's interference with the backscatter produced by targets.

Researchers are also measuring statistical and median gain characteristics of different classes of millimeter wave antennas, and work began on the calculation of scattering by arbitrarily shaped overmoded wave guides. □

Left, **a subarray for a large phased-array antenna system is tested on an indoor compact range at the Research Institute.** *Right*, **this signal receive tower is part of a new Electromagnetic Test Facility, which will greatly enhance GTRI's ability to conduct antenna and radar cross section measurement programs.**

BIOMEDICAL ELECTRONICS

Georgia Tech joined Emory University in a new Biomedical Technology Research Center.

The hospital of the future will be "wired" for continuous monitoring of patient vital signs. Such a computerized central monitoring system will be much less expensive to use than the current instrumentation in today's intensive care units. The wired hospital will rely extensively on non-contact monitoring, which is less disturbing to the patient. Monitoring will be continuous and more reliable. In addition, computer expert systems will aid doctors in emergency situations and save precious time.

In FY 87, GTRI engineers made contributions to the development of this technology by working on short-range vital signs monitors that can be adapted for ceiling-mounting in hospitals and clinics. Efforts will concentrate next on adding blood pressure and temperature monitoring capabilities to the heart and respiratory rate measurements already achieved.

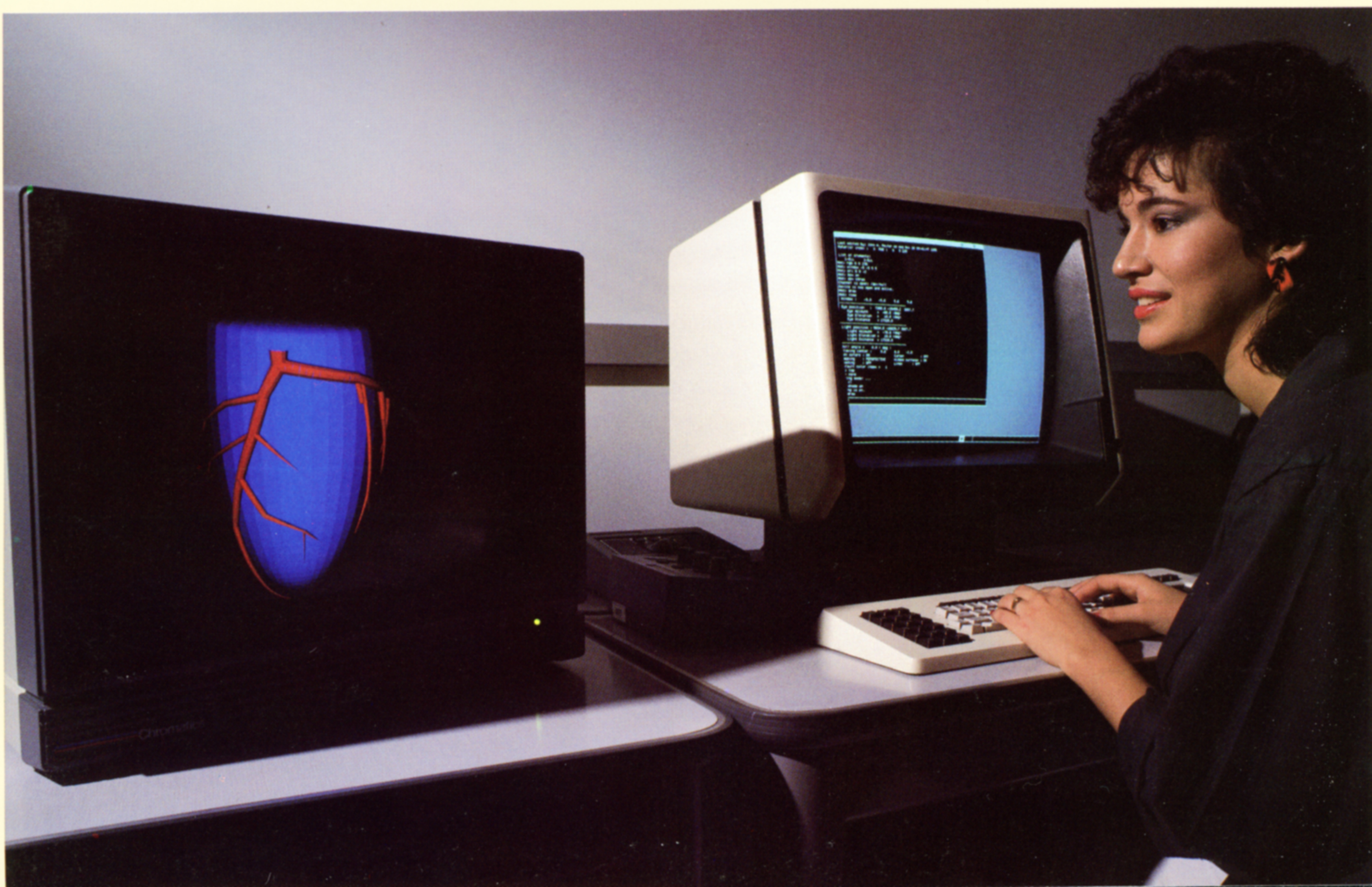
Georgia Tech and Emory University joined hands in FY 87 to create the Biomedical Technology Research Center, formalizing a long-time informal relationship for collaborative research to improve health care delivery. Seed grant money from both institutions will enable faculty to expand their joint research efforts and enhance their ability to capture major research funding.

One joint program already in place, the development of artificial intelligence techniques to assist in diagnosing cardiovascular disease, continued to progress during the last fiscal year. The Tech/Emory team developed a computer expert system to aid in the difficult task of interpreting nuclear medical images representing the distribution of blood flow to the heart muscle. The researchers also devised a method to display a three-dimensional reconstruction of the arterial structure of a patient's heart and then to project it onto a two-dimensional polar map. Future plans include fully automating the interpretation process, adding the ability to make recommendations for diagnosis and therapy, and combining different imaging modalities for more accurate diagnosis.

In another joint project with Emory, GTRI engineers designed a system, based on carbon dioxide TEA (transverse excitation) laser technology, to vaporize plaque on the inner walls of narrowed arteries. A third project was the invention of a magnetic intrauterine device that eliminates the health hazards of standard IUDs.

Paraplegics one day may be able to walk almost normally, thanks to research initiated by GTRI in FY 87 with internal funds. Electrodes implanted in the brain would enable the subject to bypass the injured spinal cord, sending messages directly from the brain to motor nerves in the legs.

Biomedical specialists also continued their study to determine whether long-term exposure to low levels of microwave radiation increases the incidence of cancer in rodents. □

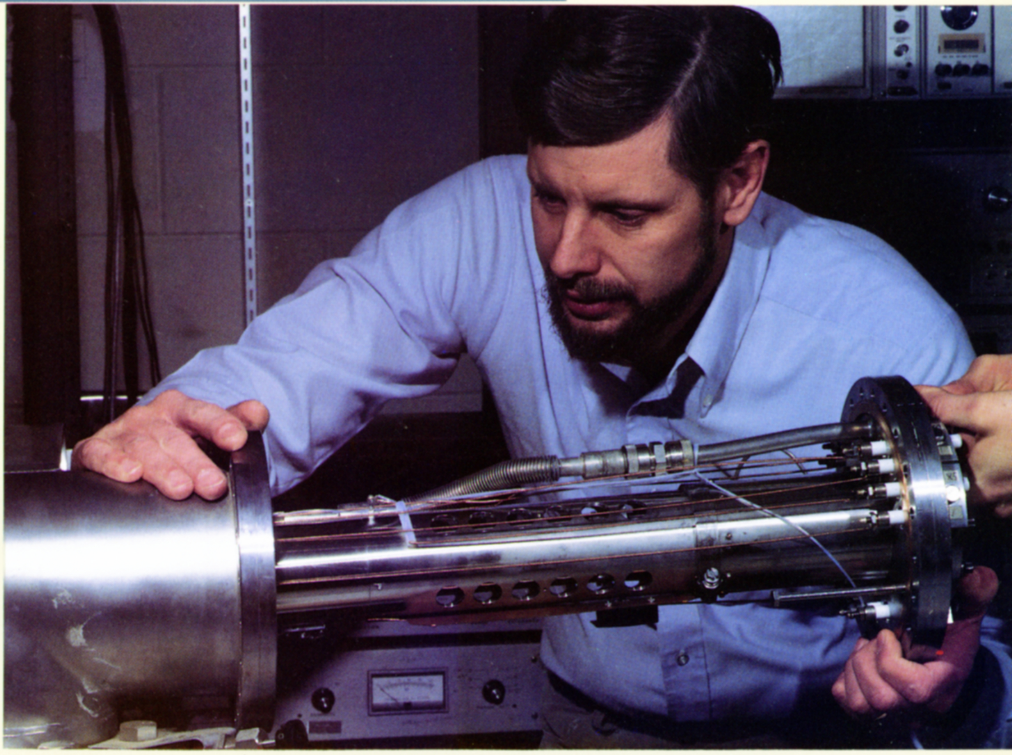


CHEMICAL SCIENCES

Four years ago, GTRI scientists were the first to identify and characterize gaseous ions in the lower atmosphere. In FY 87, GTRI added another first to its record: identification of previously unknown ions and neutral chemical species in the troposphere. This breakthrough was accomplished by incorporating a tandem mass spectrometer into their ion sampling apparatus. The new equipment enabled GTRI scientists to selectively fragment and chemically identify trace species that previously could only be mass identified. Three of these species — pyridine, picoline and ethyl pyridine — are very alkaline and could play a role in neutralizing the acidity of rain. This research into tropospheric ion chemistry is making important contributions to the basic understanding of trace neutral chemistry and its relation to the formation of aerosols (smog) and acid rain.

GTRI scientists began studies of bromine as a possible catalyst in the depletion of the earth's ozone layer.

At left, **GTRI engineers collaborated with Emory medical researchers to develop a computer expert system for diagnosing coronary disease.** *Top right,* **scientists at GTRI used this triple quadrupole tandem mass spectrometer to identify hard-to-detect gaseous ions in the lower atmosphere.**



The same apparatus was used to measure and identify ions under high-voltage DC power lines and in exposure systems at the New York Institute for Basic Research. These studies are helping to determine if the ions produced by DC power lines endanger human health.

In other basic atmospheric chemistry research, GTRI scientists continued to measure free radical reaction rates in both the aqueous and gaseous phases. Efforts in FY 87 concentrated on gaseous-phase studies of naturally produced sulfur compounds, which play a part in the production of acid rain.

Ongoing research into causes of ozone depletion in the stratosphere took a new direction with initiation of studies of bromine as a catalyst for destroying stratospheric ozone. Chlorofluorocarbons generally are considered the main cause of the depletion of the ozone layer, which is essential to protect life on earth from excessive solar ultraviolet radiation. However, bromine is thought to be a more efficient catalyst than chlorine. GTRI scientists studied a number of chemical and photochemical reactions that are important in the stratospheric bromine cycle. The results will be used elsewhere for computer model input to simulate stratospheric reactions and predict effects fifty years into the future.

GTRI continued to be at the forefront of molecular sieve and zeolite research in FY 87. Molecular sieves and zeolites are widely used as catalysts in the petroleum and related chemical industries, and as adsorbents in purification and separation processes. Georgia Tech scientists took steps to patent several compounds synthesized the previous year, and worked on characterizing and modifying their catalytic and adsorptive properties. Two specific applications involved using GTRI-synthesized iron silicate molecular sieves as catalysts. In one project for the U.S. Department of Energy, they began developing a simplified one-step process to make synthetic fuels from gasified coal. They also investigated molecular sieve catalysis as a means of improving the quality and usability of the oil produced in the Georgia Tech entrained pyrolysis process. □

MATERIALS SCIENCES

Smaller, higher-speed electronic devices require new substrates and packaging materials with lower dielectric constants than conventional materials used with silicon chips. GTRI scientists are experimenting with chemical vapor deposition as a method of laying down new materials for these new high-speed chips. In FY 87, researchers used chemical vapor deposition to form ceramic whiskers for reinforcing composites, to deposit anti-corrosion coatings on metal, to produce extremely fine and pure ceramic powders, and to make composites by filling the pores in a ceramic preform.

GTRI engineers continued work on advanced ceramic composites, further refining Tech's precursor resin infiltration process for silica matrix composites and its reaction sintering process for silicon nitride composites. FY 87 research focused on investigations of the fiber/matrix interface for optimum mechanical properties. These dense, strong composites are needed for high-temperature applications in the aerospace, automotive, and electric power industries.

Engineers continued to develop strong composites for high temperature uses.

Flame spray equipment was installed which enabled GTRI to begin "hands on" research into engineered surface coatings for particular service applications. Flame spraying is a metallurgical technique for applying metals, ceramics, and other materials onto surfaces to protect them from wear or to impart specific thermophysical or electrical properties.

New polymeric materials were developed in FY 87 for use as corrosion-resistant sealants for aircraft joints and as touch-sensitive coverings for robot fingers. GTRI scientists developed and tested several sealants and coatings that preserve the electrical conductivity of the outer shield that protects aircraft from the electromagnetic effects of lightning strikes and nuclear blasts. The new polymeric matrix material for robots is as elastic as human flesh, providing a high degree of tactile sensing accuracy.

New Fourier transform infrared equipment was acquired to spectrally characterize chemicals and to measure the infrared properties of materials from the millimeter-wave region to ultraviolet wavelengths. The results will help in selection of materials for defense applications such as imaging and tracking systems, missile nose cones, and for emissivity control.

Using the novel thermite process developed at GTRI to produce high-purity, highly reactive titanium diboride powders, researchers were able to hot-press materials to 98.6 percent theoretical density at temperatures some 300 degrees lower than feasible with commercially available materials and processes. The extreme hardness and temperature resistance of titanium diboride make it ideal for a wide range of defense and domestic applications.

Researchers used thermite reactions to synthesize an extremely pure form of titanium diboride powder.

In FY 87, researchers used GTRI's patented molecular monolayer deposition process for improving the anti-fouling characteristics of separatory membranes in reverse osmosis for water purification. They adapted the process as an anti-fouling treatment for heliostat mirrors made of plastic film, a material that normally attracts and holds dirt. They also investigated adapting the process to reduce the biofouling of ship hulls and propellers. □

MANUFACTURING TECHNOLOGY

An automatic package handling system for the Post Office was completed in FY87.

Flexible, adaptive equipment is becoming increasingly valuable in factories and warehouses. To meet this need, industry is turning more and more to automated guided vehicles (AGV) for materials handling.

In FY 87, GTRI's research into off-wire guidance of AGV systems culminated in development of a vehicle that can move freely around a room without following wires or stripes. Researchers improved the AGV's operational safety, equipped it to learn from errors, upgraded the camera which orients the vehicle to landmarks, and taught it to program flexible paths more efficiently and learn new programs quickly. Researchers also explored opportunities for more efficient AGV scheduling control with plan-ahead capability for assigning tasks.

In a new materials handling project, researchers evaluated the speed and mechanical strength of a conveyor/sorter system, exploring new design options to improve performance. The automated package-handling system designed and built by GTRI engineers for the U.S. Postal Service was tested in a post office with real mail. Results were encouraging.

Distribution centers and warehouses often need to palletize orders consisting of many unequal-sized containers. Current technology has been unable to automate this complex task, which is still done by skilled workers. In FY 87, GTRI engineers collaborated with other researchers at Georgia Tech to develop computer software tools for determining good pallet load-building plans.

GTRI engineers developed a completely new technology for tactile sensing: conducting elements are embedded in a polysilicone matrix material to be used as sensitive finger pads for an intelligent robot designed at GTRI. Although the robot was developed to support manufacturing in space, the technology will be adapted to terrestrial applications.

The Tech research team is among the first to develop three-dimensional tactile imaging for robotics applications. They are building in artificial intelligence for adaptive planning and process control. This technology is considered the wave of the future for batch-oriented light manufacturing.

The researchers also began investigating several medical applications of their new tactile sensing technology, including use in artificial limbs.

Another project involved the evaluation of cost advantages in a robotic aircraft repair facility under development by an Air Force contractor. GTRI engineers also prepared a set of robot safety schemes and guidelines to assist the robot cell designers and installers. □

GTRI engineers have developed an automated guided vehicle which can operate without having to follow guidelines of fluorescent tape or wire along a factory floor.

ASSISTANCE TO INDUSTRY AND GOVERNMENT

Five offices in GTRI's industrial extension network became full-fledged Georgia Technology Centers.

Five of GTRI's twelve industrial extension offices across Georgia became officially designated as Georgia Technology Centers in FY 87. Each of these offices — in Albany, Augusta, Gainesville, Macon, and Savannah — now is staffed by three engineers, two cooperative program students, and a secretary. The expansion enabled Georgia Tech to provide more short-term technical assistance, with some two thousand companies currently assisted annually.

The Macon office became the first open site for delivery of satellite-based televised continuing education coruses for engineers. The GTRI staff also conducted more short courses in the field, bringing educational resources from the campus to industry and local development groups in a half-dozen locations.

The Industrial Educational Group, specializing in on-site training courses for Georgia businesses, completed a revamping of its human resources development curriculum and developed a new technical curriculum.

Due to opportunities identified and researched at GTRI, three companies announced plans to build Georgia plants at a total investment of nearly $130 million, and two other plants became strong possibilities. These reports identified support resources for the food processing industry, analyzed present and future Japanese investment in the state, assessed the economic impact of Georgia ports, and identified industrial opportunities based on the available resources in several multi-county rural areas in Georgia.

Industrial energy specialists broadened their efforts to focus on energy conservation studies in military, institutional, commercial, and industrial facilities. The Industrial Energy Extension Service continued to make energy conservation recommendations for industrial plants, serving some sixty-five plants in FY 87. More than 80 percent of these recommendations were implemented.

Several federally sponsored programs of technical assistance to industry continued. GTRI specialists aided companies hurt by competition from imports, advised Georgia companies on how to sell their products and services to the federal government, and helped industries in rural areas to survive and grow.

On the international scene, Georgia Tech experts provided on-site technical consultation services to small and medium-sized industries in South Korea. GTRI also supplied the leader for a multi-university, multi-disciplinary team which developed a manual to guide the Agency for International Development in doing cost-benefit analysis of its projects.

During the year, GTRI assisted some 450 firms with on-site occupational health and safety problems in order to reduce workplace injuries and increase productivity. Also, environmental specialists helped 150 small-quantity hazardous waste generators to identify problems on-site and comply with government regulations. □

Boiler efficiency tests are among the services offered to Georgia industries through the Industrial Energy Extension Service operated by GTRI.

ENVIRONMENTAL SCIENCES AND ENGINEERING

GTRI is rapidly becoming a major national resource in applied environmental science and engineering. In FY 87, Tech researchers began developing a computer expert system to assist state organizations charged with emergency response to hazardous material spills. The system enables people without technical training such as night watchmen to respond immediately and appropriately in emergency situations. GTRI also started a new hazardous material control and emergency response school to train industrial, fire, and public safety personnel, as well as handlers of hazardous waste. The course is one of only two such publicly offered classes in the nation.

Programs expanded for the abatement of lead paint pollution.

In another new thrust, GTRI researchers are helping the U.S. Department of Housing and Urban Development (HUD) with the emerging national problem of lead-based paint in residences. The level of lead in the blood deemed "safe" is steadily being lowered as study results come in. GTRI researchers evaluated the portable X-ray lead analyzers used by HUD inspectors in public housing, established guidelines for their operation, and set up training courses for operators.

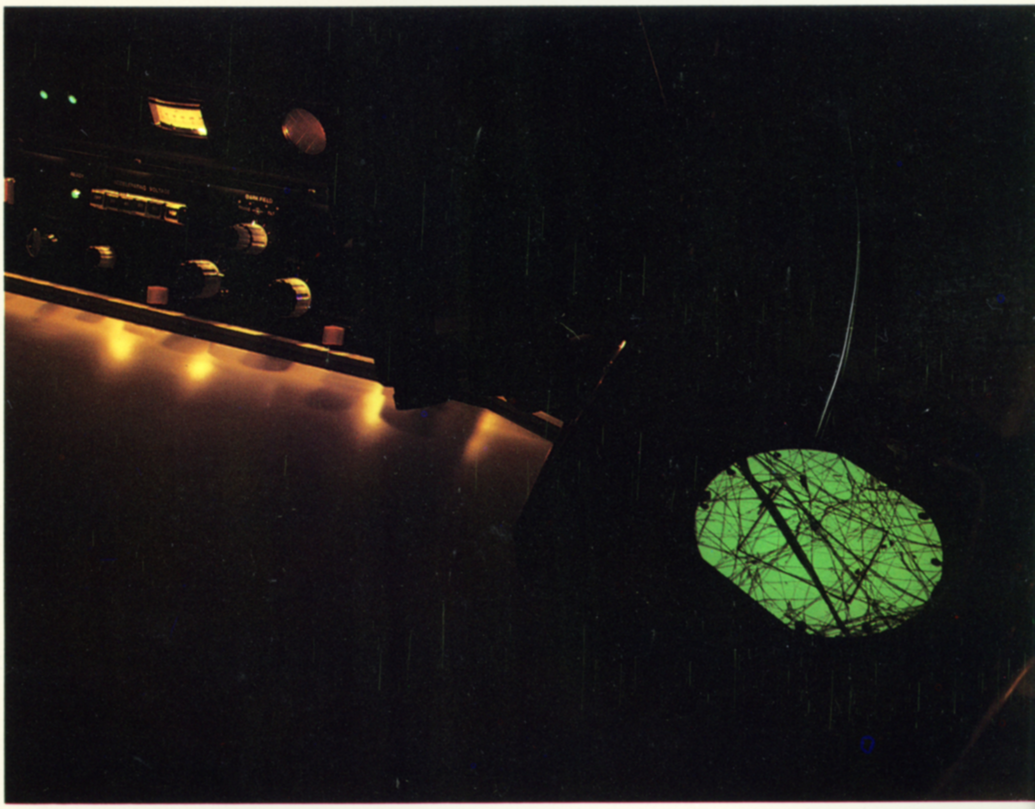
GTRI has become a nationally known center for training in environmental, health, and safety issues, offering more than one hundred programs in the fields of asbestos abatement, hazardous materials control, occupational health and safety, and construction safety.

GTRI cooperated with the state government to make Georgia the national leader in asbestos abatement in public buildings. The course to train supervisors of asbestos abatement projects was carried to numerous locations over the United States, as well as to Toronto, Canada, and London, England. Asbestos research and training capabilities were significantly enhanced during the year by the acquisition of a scanning transmission electron microscope from the U.S. Environmental Protection Agency.

Indoor air pollution research continued, with emphasis on the effects of passive smoking and pesticides. Plans were initiated for a multi-agency study of the relationship between indoor air pollution and Georgia's high infant mortality rate.

Preliminary results of research into the behavior of the nematode worm indicated that this microscopic organism may be more scientifically reliable and cost-effective as a bioassay tool than many organisms currently used to measure the potential impact of environmental contaminants on humans.

GTRI engineers completed a project for the Environmental Protection Agency to extract lignin from wood for use as an environmental cleanup agent. They found that lignin was potentially more cost-effective than activated carbon in handling certain types of organic hazardous waste and heavy metals like chromium and lead. □



GTRI acquired a sophisticated scanning transmission electron microscope for research and training in asbestos abatement. This asbestos fiber is magnified ten thousand times.

ENERGY ALTERNATIVES

In FY 87, GTRI shifted its solar energy research away from large energy systems to solar-unique processes — those which use photon (light) energy as well as thermal energy. Tech scientists designed an ultra-high flux solar furnace and scientists produced several unique, patentable materials, including single crystals of ultra-high strength and purity called "ceramic whiskers" and new types of carbon and graphite fibers.

The research team also investigated prospects for using concentrated sunlight to modify the crystalline structure of existing materials. The first materials they looked at were carbon-carbon composites,

Oil yields rose to 60 percent in GTRI's entrained pyrolysis process.

which are extremely hard and durable materials used in missile nose cones, rocket nozzles, and advanced brake systems. The researchers believe that carbynes, new high-temperature forms of carbon as hard as diamond, can be produced by solar radiation.

In FY 87, GTRI engineers continued working with NASA and major industrial contractors to develop power systems for the first U.S. space station. They also laid the groundwork for involving Tech's solar thermal test facility in simulation testing of space station power system components. In addition, GTRI personnel developed a point-focus camera for realignment of the solar thermal facility's mirror field. The camera scans the field and provides feedback to a control system so that proper corrections can be made.

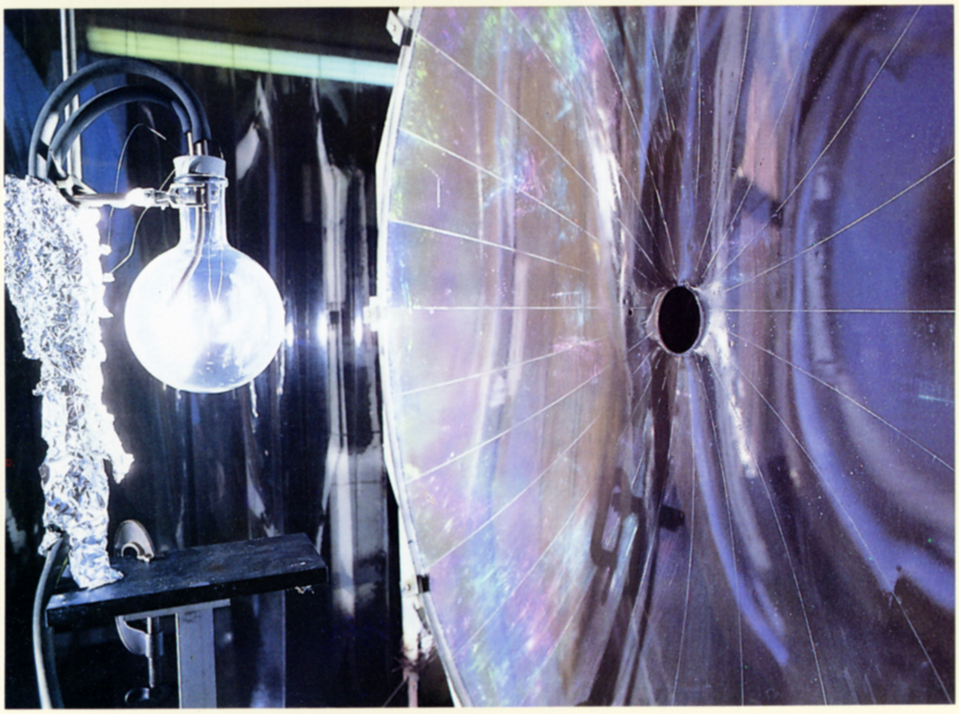
The biomass research team continued refining the GTRI entrained pyrolysis process, raising oil yields to 60 percent. An independent economic analysis showed that the oil can be produced at a cost of $20 per barrel. Efforts in FY 87 focused on catalysis to stabilize the oil in a usable liquid form and to improve its quality.

A study of refrigerated warehouse infiltration sought to validate existing analytical models that predict the amount of warm air entering when storage doors are opened. These models will be improved based on data gathered from field experiments, and the results eventually will be incorporated in the handbook of the American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE). The ultimate result will be improved warehouse design and operation.

GTRI also completed a multi-year study of the feasibility of using heat pipes to dissipate waste heat in missile bases located deep underground. FY 87 work involved in-depth engineering feasibility studies.

Under sponsorship by the Georgia Power Company, GTRI engineers assisted in the establishment and operation of a testing and demonstration center to promote the use of electro-technologies to improve productivity and product quality in Georgia industries.

Several projects involved electrical energy load research: a survey of customer needs, statistical data analysis to help Georgia utilities move toward a state power pool, and design of forecasting modules to facilitate statewide energy planning. □



Above, **GTRI engineers focused on the uses of solar processes for development of high temperature materials in FY87.** *At right,* **agricultural researchers in GTRI have installed an experimental poultry processing line to develop machine vision technology for the grading and sizing of poultry.**

AGRICULTURAL RESEARCH

For a dozen years, GTRI has been cooperating with the Georgia Poultry Federation to respond to the technological needs of Georgia's largest agribusiness — the poultry industry. In FY 87, engineers continued to seek solutions to pressing problems and to find new ways to increase productivity in this important industry.

A major new thrust involved computerized machine vision. For this research, Tech engineers acquired a laboratory-scale, computer-controlled poultry processing line, one of only three such research lines in the country. Studies concentrated on developing a vision system to size and grade slaughtered birds, with the ultimate goal of adding in the capability to assist in on-line product inspection activities. Automated classification of birds should relieve humans of this tedious yet important repetitive task and improve accuracy, speed, and efficiency on processing lines.

GTRI engineers also gave high priority to rapidly developing a simple, low-cost sludge dewatering system. The effort began in response to a critical need among poultry processors, whose wastewater treatment methods generate sludge that often is more than 90 percent water. The volume of sludge currently produced is so great that most renderers either refuse to accept sludge or charge a premium to recover the high cost of handling it. GTRI researchers discovered a method of using heat to speed natural separation of water from solids and rushed a prototype dewatering unit to the field for on-site tests at several north Georgia poultry plants. If the final test results are positive, the industry is expected to immediately begin adopting this new technology.

Another emerging problem is the reprocessing of birds contaminated with fecal matter. GTRI engineers conducted field studies in conjunction with the U.S. Department of Agriculture and Wayne Poultry to evaluate the effectiveness of on-line acetic acid washing techniques as opposed to current off-line processing techniques for cutting away affected areas.

GTRI continued laboratory experimentation with anaerobic fixed-film reactor treatment of processing wastewater and readied a pilot-scale system for field trials. The process generates a potentially useful biogas and produces little or no sludge.

For the poultry farmer, GTRI expanded the capabilities of its environmental computer system that monitors broiler house conditions such as temperature, humidity, and ammonia levels. Engineers added control functions to the field prototype, allowing the computer to take corrective action based on observed changes in monitored conditions. □

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Below **is Donald J. Grace. On stairs** *from left* **are: James C. Wiltse, Patrick J. O'Hare, Howard G. Dean Jr., Robert G. Shackelford, and Gerald J. Carey.**

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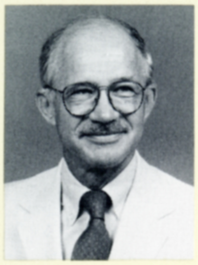

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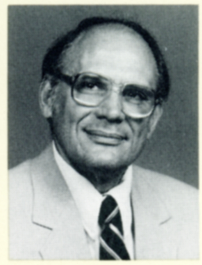

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This publication was produced by Georgia Tech's Research Communications Office, (404) 894-3444
Mark Hodges, Editor
Charles Haynes, Photographer
Martha Ann Stegar, Staff Writer
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