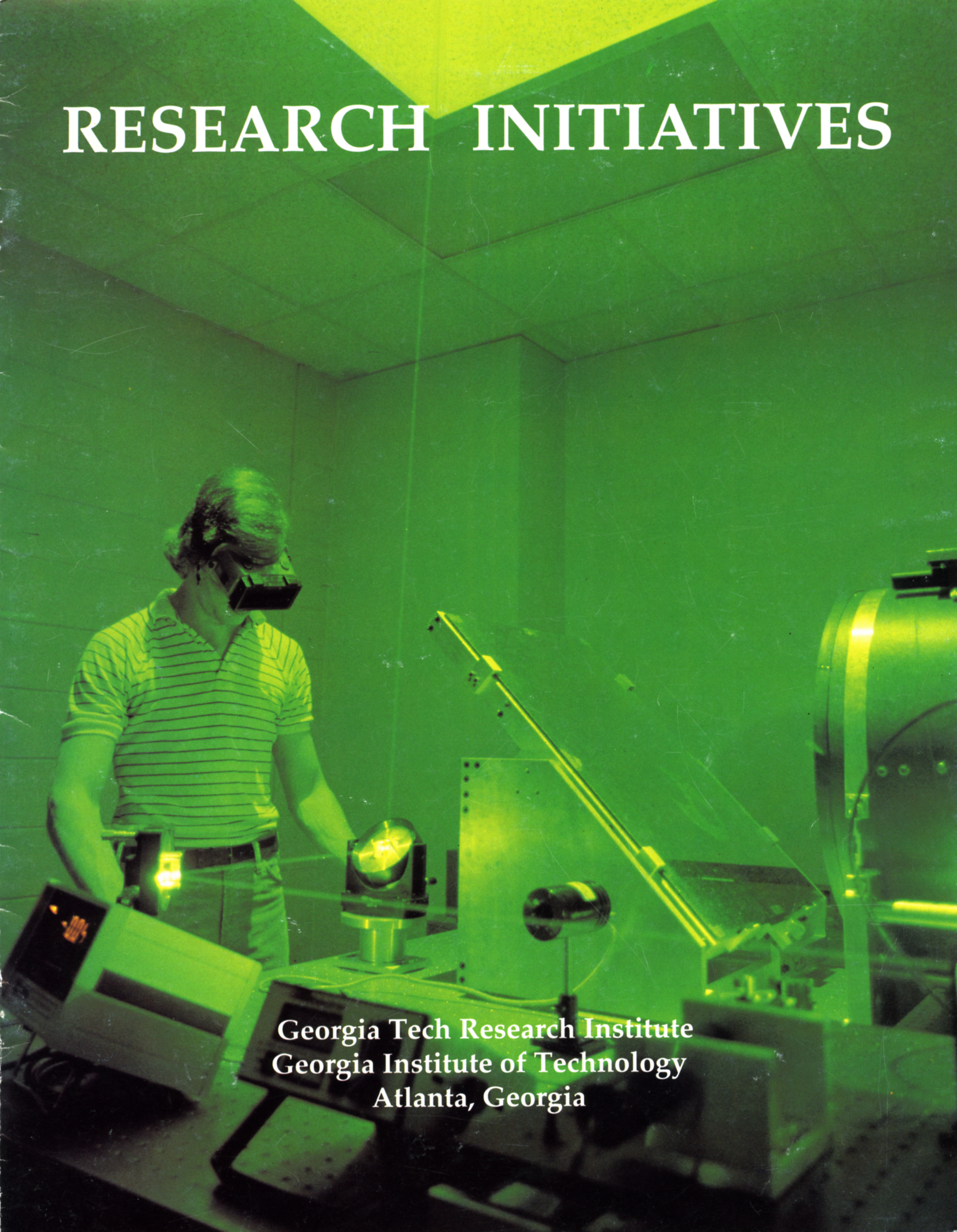
RESEARCH INITIATIVES



Georgia Tech Research Institute
Georgia Institute of Technology
Atlanta, Georgia

INTRODUCTION

The Georgia Tech Research Institute (GTRI) invests in and conducts a program of wide-ranging R&D initiatives to maintain its research vitality and to inject cutting-edge technology into its applied research. Projects are selected for the program based on their potential for strengthening existing areas of important activity or for building areas of future research strength. Leading scientific and engineering personnel are committed to these projects to insure quality results.

Research topics and projects are chosen with the assistance of the Senior Technology Guidance Council (STGC), a group of distinguished engineers and scientists representing a variety of research activities at Georgia Tech. The selection process gives consideration to the availability of GTRI skills for conducting outstanding research, the potential national visibility and impact of research results, and the potential to involve doctoral students and academic faculty in these efforts to enhance Georgia Tech's stature in the chosen research areas.

The following paragraphs summarize all projects active in FY89. Most of these projects continue through FY90, and some extend into FY91. Additional new projects will be funded in July 1989.

Donald J. Grace

Dr. Donald J. Grace
Director
Georgia Tech Research Institute
(404) 894-3400

On the cover:
Researchers at GTRI are using this neodymium-YAG laser to create a visible-light lidar (light ranging and detection) system. The lidar will be used in a four-sensor, multi-spectral system for studies of the atmosphere.
Photo by Joe Schwartz

Special photo

GTRI researchers have pioneered many developments in radar and antenna technology over the past several decades, and initiatives in these areas are continuing.

RESEARCH TOPICS

Coherent Radar System Performance Theory, E904-001
Researchers are developing a theory and models to define the values of key parameters in a stable, coherent radar system. Parameters to be evaluated include phase noise, timing jitter, and A to D quantization. The performance of system applications such as moving target indication, pulse Doppler processing, and synthetic array processing is part of this research. A laboratory validation test will confirm the integrity of the theory.
Project Director: Mr. James A. Scheer, (404) 421-7689

Digital Beamforming/Compressive Receiver Technology, E904-002
The tactical radar of the future is likely to employ digital beamforming and bistatic technology to combat the emerging threats of anti-radiation missiles, electronic countermeasures, and dense target environments. In this project, GTRI researchers are developing digital data processing algorithms that enhance digital beamforming and bistatic processing functions.
Project director: Dr. E. J. "Jeff" Holder, (404) 421-7759

Ultra High Stability Microwave Sources and Measurements, E904-003
Recent advances in radar and communications technologies have generated requirements for extremely stable signal sources. This project is focusing on approaches for generating high-stability signals and on developing methods for measuring their stabilities. Researchers are stabilizing more conventional sources by closely coupling them to a superconducting resonant cavity.

Initially, conventional superconductors such as niobium and lead operating at liquid helium temperatures are being used. High-temperature superconductor technology also is being monitored to determine if such an approach is feasible in this application.
Project director: Dr. George W. Ewell III, (404) 894-3532

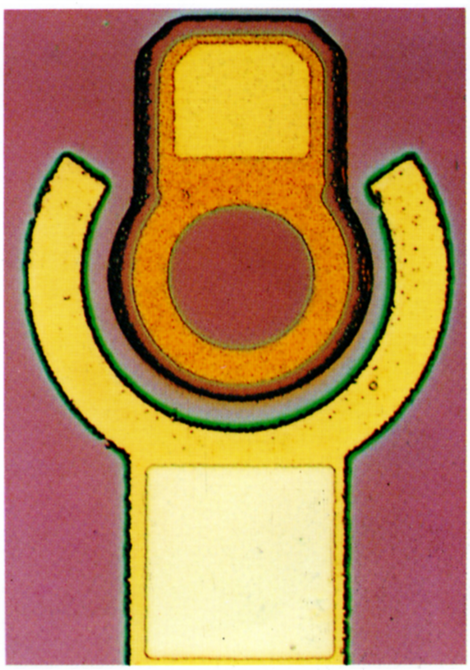
Broadband Microstrip Elements: Phased-Array Antennas, E904-004
Researchers are developing a model that will calculate the electrical performance characteristics of a microstrip patch element in an infinite array environment. The element will be fed via multiple probes to develop either linear or circular polarization. The array initially will have a triangular lattice, but the model will be general enough to allow other configurations. Finally, the model will be implemented in a computer program to be used as a design and analysis tool.
Project director: Mr. B. Keith Rainer, (404) 421-7162

Multispectral Signal Processing and Signature Modeling, E904-005
Researchers are investigating the modeling and signal processing issues involved in fusing a passive infrared sensor and a millimeter wave radar into a dual-mode sensor. This signal processing study is focusing on infrared/millimeter wave scene registration and the fusion of algorithms for detection and discrimination by the sensor. The capability for analytically modeling dual-mode sensors is being developed from existing radar and infrared signature research at GTRI. This modeling capability is essential for the signal processing studies performed in this program.
Project director: Dr. William A. Holm, (404) 421-7748

Phased-Array Polarization Investigation, E904-006
GTRI engineers have performed extensive research to define the polarization characteristics of reflector type antennas for applications in electronic countermeasures and target identification. In this project, they are extending this capability to phased-arrays, an antenna type presenting an entirely different technical challenge. Researchers are attempting to understand, model and predict the mechanisms of cross-polarization. Users then can determine the susceptibility of various phased-arrays to different types of jamming and evaluate whether they are appropriate for use in polarimetric radars.
Project director: Dr. Larry E. Corey, (404) 421-7156

Sensing of Atmospheric Pollutants Using Laser FM Spectroscopy, E904-007
A frequency-modulated laser spectrometer based on the CO_2 laser is being assembled at GTRI. This instrument is believed to be the first such device based on the CO_2 laser, and it is expected to provide sensitive detection of atmospheric species, including pollutants, through most of the mid-infrared spectral region covered by this laser.
Project director: Dr. Robert W. McMillan, (404) 894-3503

Nonlinear Optical Organics, E904-008
New classes of π-conjugated and strongly dipolar organic molecules are being evaluated for their third-order nonlinear susceptibilities. The methods being used to measure these effects include intensity-dependent birefringence and intensity-dependent index of refraction. Researchers hope these molecules will provide the basis for the integrated optics device interests of Georgia Tech.
Project director: Dr. Daniel P. Campbell, (404) 894-3503



Special photo

Quantum well structures are under development at GTRI that should result in improvements in optical and electronic devices.

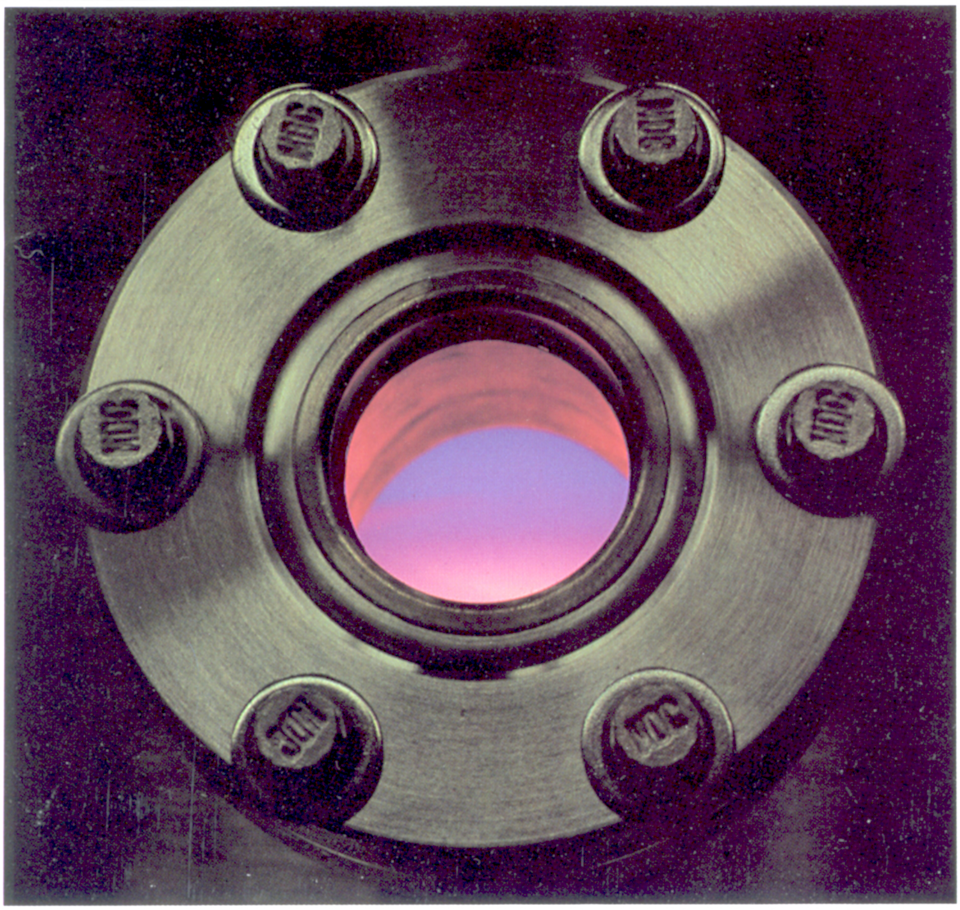
Heterostructure Solid State Sources, E904-009
Gallium arsenide (GaAs) field effect transistors fabricated at Georgia Tech on conventional epitaxial materials have demonstrated performance up to 20 GHz. Through this research initiative, GTRI researchers are growing selectively doped heterostructures of aluminum gallium arsenide (AlGaAs) and GaAs by molecular beam epitaxy, then fabricating the field effect transistors on these materials. Operating frequencies are 30 to 50 GHz. Demonstration of device performance at these frequencies will enhance GTRI's capabilities for monolithic microwave integrated circuit development.
Project director: Mr. H. Mike Harris, (404) 894-3420

Integrated Optic Chemical Sensors, E904-010
Integrated optics provides a new class of chemical sensors based on sophisticated two-dimensional optical circuits fully integrated onto compact planar substrates. These devices offer very high detection sensitivity, active or passive measurement techniques, and freedom from electromagnetic interference. Researchers are developing an interferometric integrated optic chemical sensor capable of sensing refractive index changes in the surrounding fluid or in a chemically selective film applied to the surface of the device. The success of the device is dependent on a design that substantially reduces or eliminates the temperature dependence and sensitivity to mechanical disturbances. These devices are expected to find applications in the detection of toxic or hazardous chemicals, biomedical or biochemical sensing, and process control.
Project director: Mr. Nile F. Hartman, (404) 894-3503

High Temperature RAM, E904-011
Temperature-dependent dielectric properties of single crystals exhibit a general increase with temperature. The goal of this research is to validate theoretical models for temperature dependence of dielectric/magnetic mixtures. Samples of silica/Fe and silica/SiC mixtures are being prepared as test samples. Comparisons are being made between Maxwell-Garnet and other Effective Medium Theories. Models for temperature-independent mixtures will be suggested.
Project director: Dr. Rick L. Moore, (404) 894-6197

Electro-Optic Materials and Applications, E904-012
This project is devoted to the development and exploitation of materials whose millimeter wave and microwave properties can be switched rapidly by optical means. Anticipated applications include optically switched modulated scattering arrays and control of radar cross section.
Project director: Dr. Barry J. Cown, (404) 894-3567

Superconducting Ceramic Properties at CM/MMW Frequencies, E904-013
Four high T_c ceramic samples are being prepared by the Georgia Tech School of Physics and GTRI. The permittivity of these samples is being measured from 300 to 3000 K, and X, Ka, W and D (110-170 GHz) band frequencies (free space and cavities). Effective Medium Theory is being used to infer ceramic/conductor ratio. The validity of BCS theory to predict frequency-dependent dielectric properties is also being determined. These data are being correlated with infrared reflectivity and physical/chemical characterization.
Project director: Dr. Rick L. Moore, (404) 894-6197



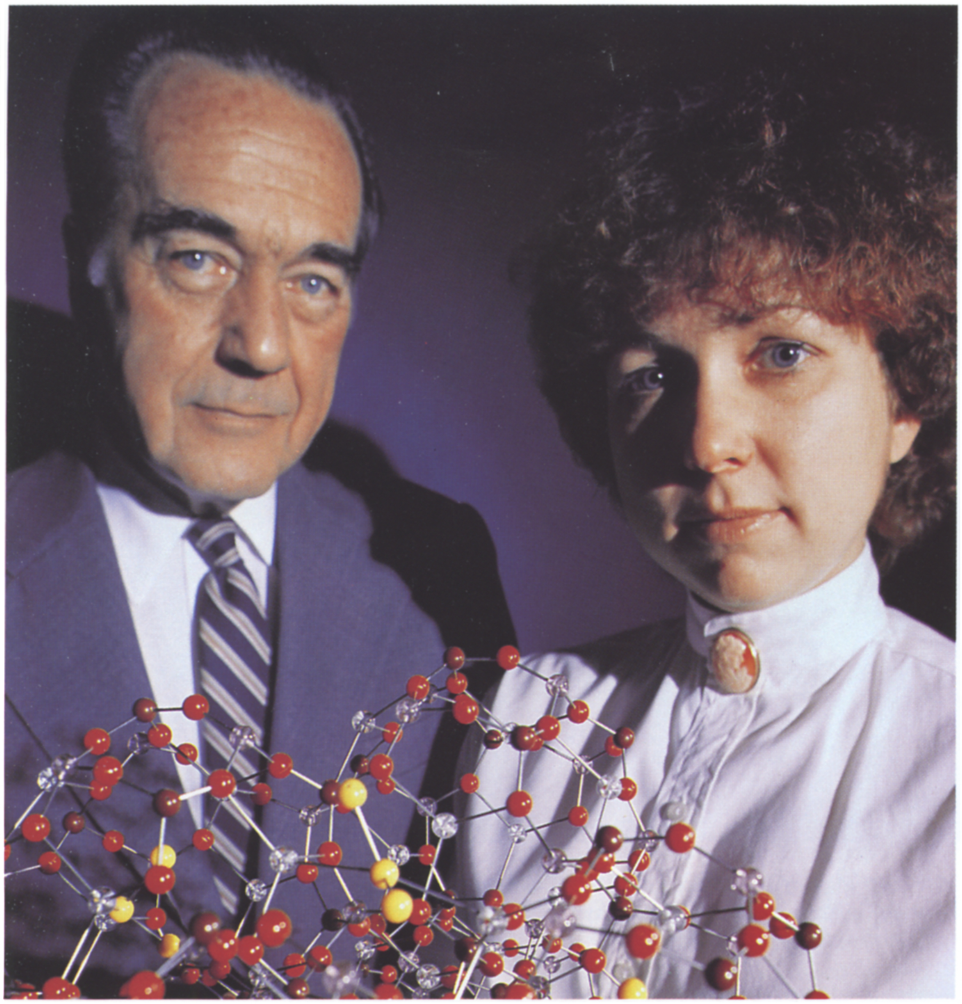
Joe Schwartz
Tech researchers are using the technique of plasma-assisted chemical vapor deposition to create improved methods for laying down thin-film diamond coatings on materials.

Thin-Film Superconductor Technology, E904-014
The primary task of this project is to develop thin-film superconductors of sufficient stability to be useful in the fabrication of millimeter wave devices and systems, and then to produce prototype devices. Current research is centered on producing thin films of the yttrium-barium-copper oxide composition using thermal evaporation techniques.
Project director: Mr. James W. Larsen, (404) 894-3357

New Toxicological Bioassays Using Nematodes and Computer Tracking, E904-015
Researchers have noted that the responses of nematodes and rodents to certain toxic substances are very similar. In this project, scientists are evaluating the utility of one type of nematode for toxicological bioassays of environmental contamination. The nematodes are being placed in both soil samples and liquid suspension to test their sensitivity to contamination. The end-points of the studies are acute lethality, reproductive effects, mutagenesis, and behavioral alterations. *Project director: Mr. Paul J. Middendorf, (404) 894-3806*

Radon Exposure Research, E904-016
Radioactive radon gas may contribute to as many as 20,000 lung cancer deaths a year, and in recognition of this threat, efforts to control the pollutant are increasing. GTRI researchers are designing a highly specialized test chamber to evaluate a variety of solid sorbent samplers for radon measurements.
Project director: Dr. Chrysanthos D. Papanicolopoulos, (404) 894-3806

Millimeter Wave Substrate Mounted Antennas, E904-017
Researchers are attempting to understand and optimize the reception of a new type of integrated circuit antenna. These antennas are manufactured on the same substrate as the integrated circuit electronics so that the incoming signal can be received and processed on a single chip. Measurements are being taken of the field patterns of dipole antennas on electrically thick substrates (one to ten wavelengths in the medium) at 230 GHz. This technology has appli-



Charles Haynes

Among the projects undeway in GTRI's molecular sieve zeolite program are efforts aimed at hydrothermal synthesis of a superconducting oxide and molecular sieve carbon dioxide removal with an oxgen regeneration system.

cations to free-space power transmission, millimeter wave-length imaging, and submillimeter/far-infrared radiation detection.
Project director: Mr. James J. Gallagher, (404) 894-3503

Four-Sensor Multi-Spectral Remote Sensing, E904-018
A unique atmospheric remote sensing capability is being created by combining four sensors: a visible-light lidar; an infrared spectro-radiometer; a TV camera; and a thermal imager. These instruments are being used in a study of the effects of various types of clouds on radiative transfer in the atmosphere. Researchers also are using the instruments to evaluate a passive approach to estimate winds aloft through measurements of cloud motion. This project combines the expertise of GTRI and Tech's School of Geophysical Sciences.
Project director: Dr. Gary G. Gimmestad, (404) 894-3357

Novel Laser Spectroscopic Techniques, E904-019
GTRI researchers are using single-photon laser-induced fluorescence to detect silicon oxide (SiO) molecules. This study should provide important new information about the photodynamics of electronically excited SiO. It also will establish the utility of this laser detection technique as a diagnostic in silicon plasma etching systems and in silicon doped flames used in fiber optic production. In another phase of this program, sequential two-photon laser induced fluorescence is being used to detect very low concentrations of phosphorous oxide (PO), including an important class of organophosphorus compounds that contains the PO unit. These compounds include nerve agents and pesticides.
Project director: Dr. Anthony J. Hynes, (404) 894-3424

Clean Coal Technology, E904-020
Elimination of nitrogen oxides from chemical and utility plant stack gases soon will be required by many governments. Platinum metal, with added ammonia, can reduce nitrogen oxides to nitrogen. GTRI researchers are loading various catalyst bases (alumina, zeolites, carbons) with various noble metals (platinum, palladium and/or rhodium) and screening them in microreactors to determine the activity and selectivity of the reactions.
Project director: Dr. Tudor L. Thomas, (404) 894-3487

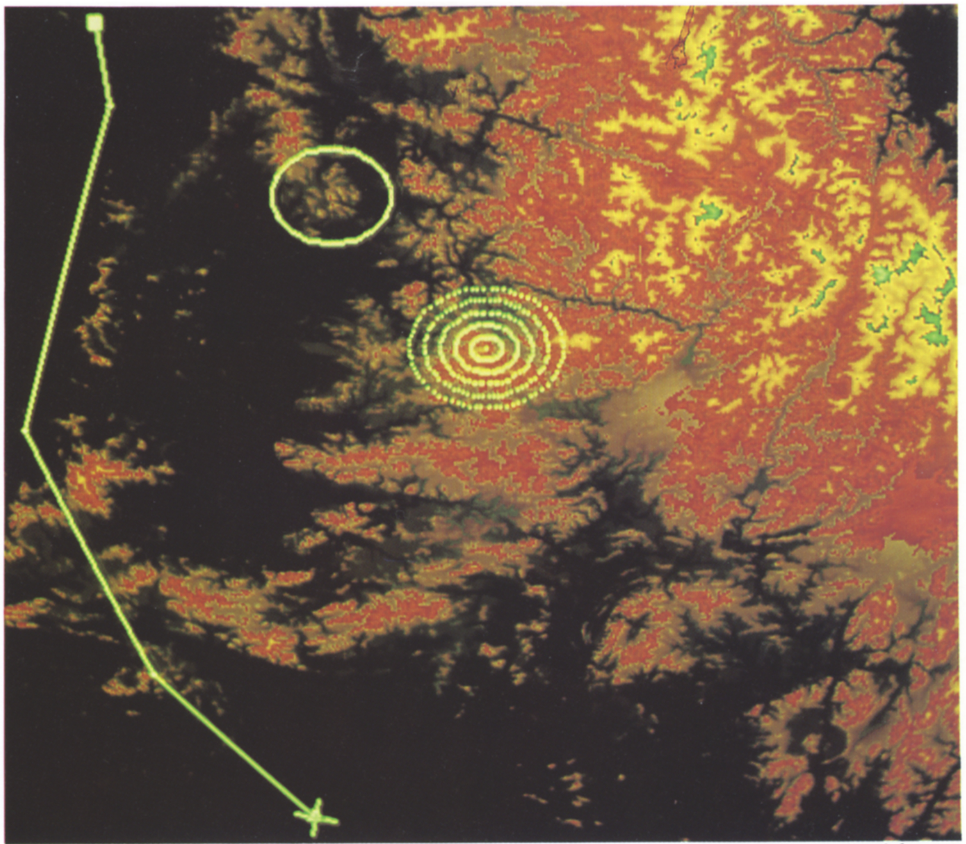
Diamond Coatings, E904-021
Diamond films are of great interest for potential electronic and tribological applications. Specific uses include high thermal conductivity insulators for microelectronic devices, coatings for infrared and other electromagnetic windows, and biological implants such as heart valves. In this project, diamond films are deposited and made operational by the technique of plasma-assisted chemical vapor deposition. Initial deposition experiments will explore methods for producing finer grained, smoother films. Researchers will use X-ray diffraction as well as scanning and transmission electron microscopy film characterization.
Project director: Dr. W. Jack Lackey, (404) 894-3665

Signal Classification Using Optical Processors, E-904-022
Signal classification speed and accuracy in a complex and time-varying signal environment are two important problems faced by modern intercept receivers. Massively parallel processing, which occurs naturally in optical signal processing, provides the potential for greatly increased speed. Unique characteristics of optical signal processing such as spatial light modulation and intensity summation may allow the implementation of "soft" decision logic which will provide robust classification in the face of signal parameter variation.

in the face of signal parameter variation. The application of optical technology to the signal classification problem will be investigated in this project. Research centers on the use of optical processors to extract important parameters from incoming signals and for implementations of signal classifiers. Proof-of-concept experiments will be performed on developed processors. This project includes researchers from GTRI and the School of Electrical Engineering.
Project director: Mr. Harold F. Engler, (404) 894-7276

Atmospheric OH Measurement, E-904-023
The OH radical is an extremely important photo-chemical species that is responsible for initiating much of the photochemistry of the lower atmosphere. Its accurate measurement, however, has eluded researchers for more than a decade. The present task is to develop a new and highly sensitive technique capable of measuring OH in the 10^5 molecules/cm^3 concentration range. Researchers will use the highly reactive nature of OH in conjunction with an extremely sensitive ion measurement capability developed at Tech.
Project director: Dr. Fred L. Eisele, (404) 894-3424

Molecular Sieve Carbon Dioxide Removal with an Oxygen Regeneration System, E-904-024
Interest in removal of high carbon dioxide concentrations from work and living areas has been high for many years. Application of existing molecular sieve technology has two major drawbacks: the need to dry the gas stream to be cleansed of carbon dioxide and the inability to regenerate oxygen bound in the carbon dioxide. In response to these problems, researchers propose the development of a hydrophobic zeolite molecular sieve that is capable of using catalytic metal deposits to regenerate carbon dioxide. Such a molecular sieve would have direct applications in the military, the manned space program, health care, and environmental control in high pollution areas.
Project director: Dr. Rosemarie Szostak, (404) 894-6286



Joe Schwartz

The optimization of route planning is a key part of GTRI's research initiative into unmanned aerial vehicles. This program is bringing into play established capabilities in expert system development.

Generic Doppler Processor, E-904-025
The advent of integrated high-speed digital signal processing (DSP) chips has suggested the capability of producing a relatively low-cost generic Doppler processor for application to both advanced pulsed-Doppler (PD) radar systems as well as to PD radar simulators. The purpose of this project is to design and build a proof-of-concept generic Doppler processor to replace the traditional, special-purpose, high-cost PD signal processors currently being fielded. The system being developed under this program is a highly parallel, reconfigurable processor that may be configured to implement Fast Fourier Transform, filter-bank, and correlator type Doppler processing.
Project director: Mr. Harold F. Engler, (404) 894-7276

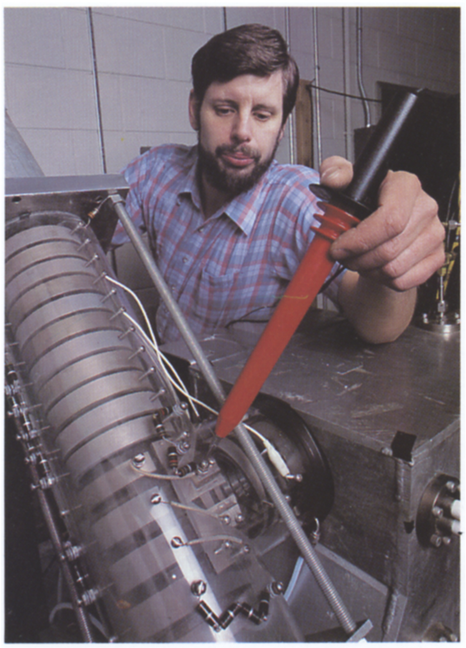
Hydrothermal Synthesis of Superconducting Oxide, E-904-026
The newly discovered $Bi_2CaSr_2Cu_2O_x$ superconducting oxide offers better properties than $YBa_2Cu_3O_7$ oxide. These properties include higher T_c, higher stability in the presence of water and air, better ease of handling, and less expensive starting materials; however, the present method of synthesis is difficult and expensive. In this project, the $Bi_2CaSr_2Cu_2O_x$ superconducting oxide will be synthesized by a hydrothermal process. Success in this study will lead to a new technique for fabricating high-quality $Bi_2CaSr_2Cu_2O_x$ superconducting material at low cost. Hydrothermal processing has been employed successfully to synthesize a variety of oxides from high-quality quartz to polycrystalline zeolite.
Project director: Dr. Tudor L. Thomas, (404) 894-3487

Advanced Superlattice HgCdTe Infrared Photodiodes, E904-027
The development of long-wavelength (5-20 μm) HgCdTe focal plane arrays is critically dependent on advances in materials technology. HgTe-CdTe superlattices have demonstrated improved control over the spectral re-

sponse characteristics and area uniformity of HgCdTe FPA materials. These structures also have the potential to enhance detector performance because of their ability to reduce diffusion and tunneling currents in long-wavelength photodiodes. This research program is therefore structured to develop the theoretical and experimental capability to design, grow and fabricate advanced infrared superlattice detectors. Theoretical models will be developed to predict the photoconductive response, gain, noise and detectivity of these devices as a function of the material structure parameters. These materials will be grown by photon-assisted chemical beam epitaxy. Using these structures, researchers will fabricate and evaluate prototype devices.
Project director: Dr. Christopher J. Summers, (404) 894-3420

Millimeter Wave Measurements and Analysis in Support of International Sample Exchange, E904-028
Over the past three years, the complex permittivities of a single set of samples have been measured independently by a number of laboratories at millimeter and near-infrared frequencies. Considerable discrepancies exist, particularly with respect to loss factor, in the frequency range of 30 to 300 GHz. Even for moderate loss material, 20% discrepancies corresponding to greater than 5% errors in raw transmission data occur between measurement groups. GTRI has a two-fold opportunity to contribute to the resolution of this imbroglio. 1) GTRI has an open resonator and a newly acquired W-band synthesized source with HP-8510 analyzer to acquire precision resonance data from 70 to 110 GHz; and 2) Codes recently developed at GTRI demonstrate that a full-field theoretical analysis of the fields in the sample — including surface wave effects (e.g., edge diffraction) — is practical. The Surface Wave Method of Moments code is being modified for cylindrical samples and cylindrical Gaussian beams. The resulting code will be used to analyze open resonator permittivity measurements and diffraction effects in other measurement configurations.
Project director: Dr. Tom B. Wells, (404) 894-3550

Unmanned Aerial Vehicles, E904-029
Autonomous vehicle systems have been identified as a key technology development area by the Department of Defense. Through its success on several sponsored programs, GTRI has become a recognized leader in the development of knowledge-based autonomous vehicle systems. The goal of this project is to investigate the translation of autonomous helicopter software simulations into a real-time hardware system as a proof-of-principle validation. GTRI has developed an extensive autonomous vehicle system incorporating route planning, vehicle modeling, and threat response through the use of blackboard architecture. This project analyzes the route-planning and threat-response software to determine the real-time hardware requirements. Several processors are being analyzed including numeric parallel processors and symbolic processors such as the Compact LISP machine. Researchers hope that the autonomous vehicle software evaluation will identify the hardware configuration best suited to real-time processing. Portions of the autonomous helicopter will be implemented into a real-time hardware architecture.
Project director: Mr. John F. Gilmore, (404) 894-3560



Charles Haynes

This flow-opposed drift tube concentrates and extracts ions from air. It is used in atmospheric science research at GTRI.

Atmospheric Investigations in a Large Cryogenic Pressure Chamber, E-904-030
GTRI investigators have initiated an experimental research program to study the formation of high-altitude cloud particles. The study will utilize a large cryogenic pressure chamber that will be capable of simulating all possible combinations of the atmospheric temperature and pressure that can be found from locations near the Earth's surface to altitudes in excess of 100 km. Initial studies will concentrate on how subvisual cirrus cloud particles near the troposphere might affect the propagation of infrared radiation, and on the effect of stratospheric cloud particles on the chemical reactions that have been proposed to explain the "ozone hole" that has been observed in polar regions.
Project director: Dr. Gerald W. Grams (404) 894-3628

Cold Fusion, E904-031
In March 1989, researchers at the University of Utah and Brigham Young University independently announced the discovery of nuclear fusion of deuterium at room temperature. Researchers at GTRI soon began performing experiments to confirm these results. This program has focused on detecting the material products of fusion, including neutrons, tritium, He^3 and He^4. In these experiments, heavy water is electrolyzed in the presence of a palladium electrode. Palladium readily absorbs hydrogen and its isotopes into its crystal lattice. If fusion occurs, it is thought to result from the high density of deuterons which is attained in the palladium. Several types of detectors have been used to search for signs of neutron emission from the electrolytic cell, including boron trifluoride neutron detectors, helium-3 neutron detectors, a sodium iodide gamma ray spectrometer, and an instrinsic germanium gamma ray spectrometer. If fusion occurs, then tritium, He^3 and He^4 can be created in the palladium. Mass spectroscopy will be performed to identify the quantities of these isotopes in one of the palladium electrodes. Experiments are also being done to show if gas-phase hydriding can lead to neutron emission.
Project director: Dr. James Mahaffey, (404) 894-3456

Senior Technology Guidance Council

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