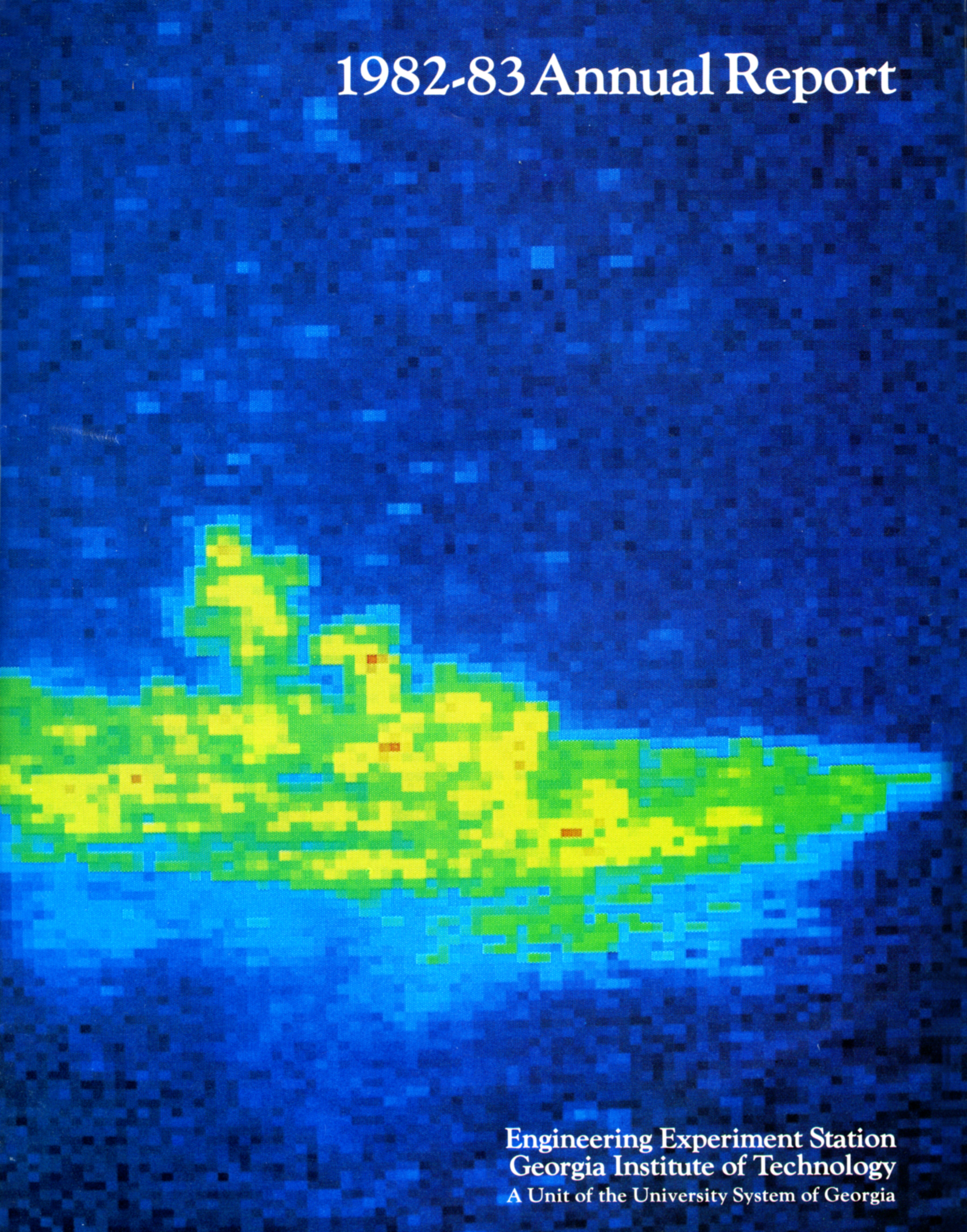
1982-83 Annual Report



Engineering Experiment Station
Georgia Institute of Technology
A Unit of the University System of Georgia

(Cover Photograph) This computer graphic of a ship was generated from radar data. The data was reduced by engineers in the Station's Radar Data Processing Facility. (Below) Station engineers developed this Transportable Electronic Defense Support System for an EES mobile laboratory which measures and analyzes radar signal characteristics.

EES Annual Report

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Message From The Director

(Above) EES Director Dr. Donald J. Grace. (Below) EES conducted more than 800 R&D projects last year in such diverse areas as (from left) semiconductor device fabrication, solar energy and materials characterization.

Better electronic devices for warning pilots away from enemy radars. Computer technology to enchance nuclear power plant safety. A major new economic development thrust into Africa. A new way to generate electricity from the sun.

These were just a few of the research highlights at Georgia Tech's Engineering Experiment Station (EES) in 1982-83.

In Georgia, EES continued to look for ways to make the state's economy more productive while on the national level its engineers met critical needs in energy and defense electronics. Internationally, it was the Station's most active year yet, as engineers broadened their involvement in underdeveloped nations and met high technology requirements in Western Europe. EES researchers are managing the European Research Institute of Ireland as well, and this organization is serving as the Station's associate in Western Europe.

The body of this report offers summaries of EES work in 20 major areas of research and development. Below, at a glance, are some of the most important accomplishments in these fields.

In 1982-83, the Station:

- Developed state-of-the-art facilities to study how millimeter and microwave radiation affect the human body.
- Built a radar with an antenna that can be raised above tree level to serve as a forward observation post.
- Mapped Arctic ice formations with a millimeter wave radiometer for sea traffic planning and safety.
- Finished a pilot plant which optimizes pyrolysis of wood into synthetic gas.
- Built fused silica radomes to protect millimeter wave antennas in missile nosecones.
- Improved a computer model which helps utilities prepare for the future though its forecasts of long range energy consumption trends.
- Took computer technologies into places they've rarely been used before: poultry growout farms.
- Developed a methodology for predicting the kind of missile guidance systems which can be used best in varying weather.
- Investigated new techniques for growing a microelectronics chip material which could dramatically improve missile guidance.
- Improved the Federal Communications Commission's system for monitoring broadcaster compliance with government regulations.
- Helped the Army acquire fast-changing computer technologies for intelligence operations before they are obsolescent.
- Produced a versatile antenna for use in the MX missile testing program.
- Determined how cables and connectors on ships and aircraft cause electromagnetic interference in military communications systems.

As these capsule descriptions suggest, research at EES is exciting and diverse. To manage and maintain its broad base of activities, EES employs 600 fulltime scientists and engineers and nearly 800 research support personnel. The most recent accomplishments of EES and its staff are summarized in the following pages of this 1982-83 annual report.

Donald J. Grace

Dr. Donald J. Grace, Director
Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia

Program Growth

Research and development efforts at EES expanded markedly in 1982-83, both in the scope and dollar volume of sponsored programs.

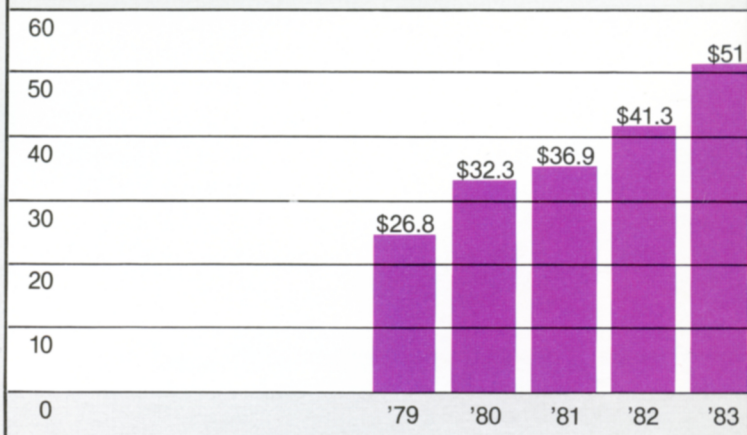
The Station performs more than 70 percent of all sponsored research at the Georgia Institute of Technology. In 1983, total EES expenditures rose to $51 million, a 23 percent rise in funding over the previous year for research, technological services and economic development programs. Of this total, approximately $4.7 million was provided by Georgia for services to the state and special research programs.

More than 800 research and development programs were active in 1982-83. Roughly 83 percent of the Station's programs involved electronics and related specialties. Seventeen percent concentrated on the resources area—energy, industrial productivity, economic analysis, materials sciences and technology transfer.

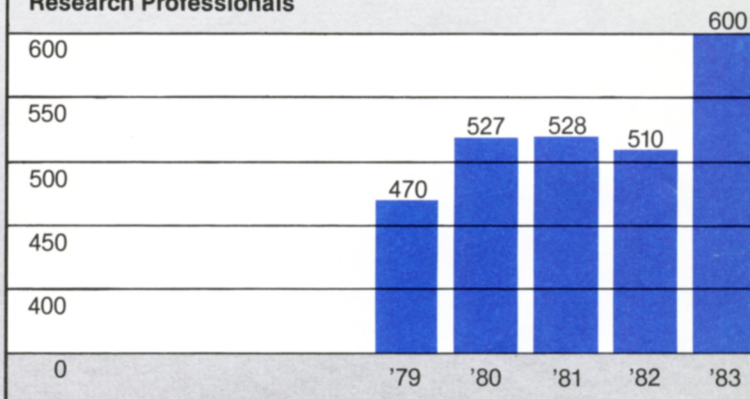
Last year, researchers wrote 900 new contract proposals valued at approximately $200 million. These proposals resulted in new contract awards valued at approximately $60 million.

More than 250 different organizations sponsored research programs at the Station in 1982-83. Federal government agencies continued to fund just over three-quarters of the Station's externally-supported R&D programs. Industrial support remained at approximately 19 percent, and funding from state and local government agencies stayed at approximately three percent.

Research Funding Growth (Millions of Dollars)



Growth In Number of Fulltime Research Professionals



Continuing Research

(Above) The Station's R&D programs are enhanced by sophisticated equipment like this EES airborne electronics laboratory. (Top Center) A number of new laboratories were developed in 1982-83, including this photovoltaics solar research facility.

In 1982-83, EES electronics engineers continued to enhance established programs in defense electronics, near-field antenna research, threat radar system development, electromagnetics and measurement technology.

Research and development expanded in infrared materials and devices, electro-optical countermeasures, digital image processing, psychological systems and man-machine interface studies, electromagnetic window applications and high resolution millimeter wave development.

Outside the electronics area, established capabilities were expanded in economic analysis, materials characterization and development, manufacturing technology, biomass conversion, high temperature materials applications, solar thermal technology and applications, industrial safety and health technology, and energy conservation assistance.

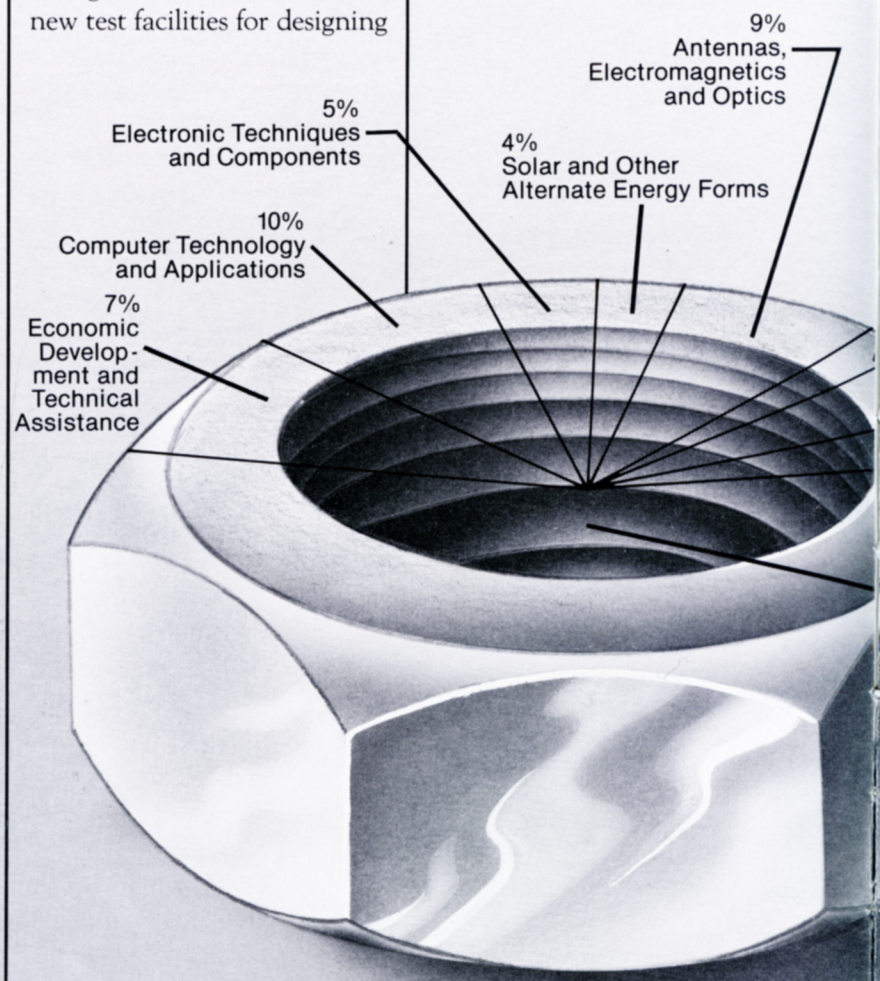
New Facilities

The Station's comprehensive inventory of research laboratories and support equipment is now valued at more than $20 million. EES adds to this inventory each year to keep pace with technological advances.

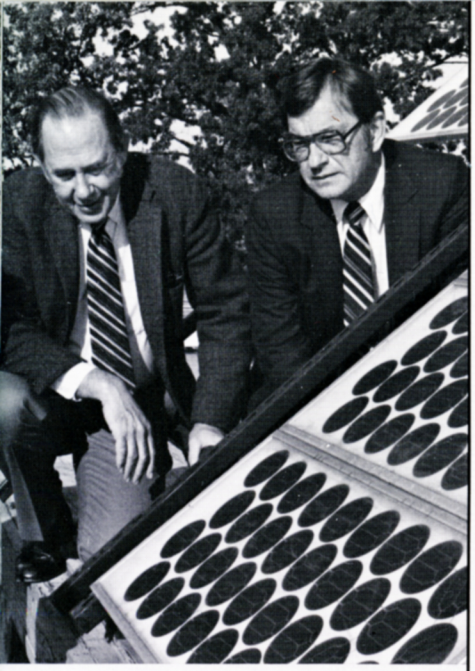
Important facilities for conducting electronics research were developed during 1982-83. Examples include a microwave to millimeter wave reflectometer, a boresight antenna test facility, color display systems for image analysis research, and an infrared materials and device analysis facility.

Engineers at EES also built new test facilities for designing residential photovoltaic electric energy systems. A state-of-the-art nitriding furnace was acquired to enhance the Station's capabilities in materials sciences. Researchers also completed a large prototype system for converting wood to synthetic gas through a process known as entrained pyrolysis.

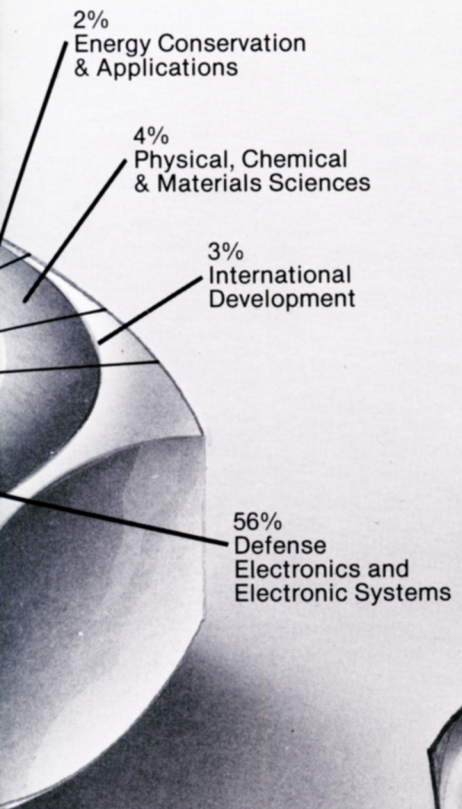
New laboratory facilities also were assembled for solid fuels characterization services, paints and protective coatings research, waste water treatment studies, and chemical analysis of materials important to industrial safety and hygiene.



1982-83 Distribution of Sponsored Research Areas



Service to Georgia



One of EES' primary missions is to help Georgia companies remain productive and competitive. As a center for high technology research and development, the Station is ideally suited to give the state's economy the assistance it needs most.

In recognition of this capability, the state legislature has chosen EES as the Georgia Productivity Center. In 1982-83, the state appropriated an additional $100,000 to enable the Productivity Center to help Georgia industries upgrade manufacturing technologies. The Station concentrates its productivity efforts on small- to medium-sized manufacturing firms, primarily through its network of eight regional field offices. In 1982-83, technical assistance and information was provided to companies in more than 900 cases.

Occupational safety and health is an increasingly important concern to businesses, and the Station has broadened its services in this area. Last year, EES safety and health specialists made more than 750 consultation visits to Georgia firms and identified approximately 2,000 serious hazards.

EES also continued to address other specialized business needs, including:

• **Energy.** One of the quickest ways a business can cut operating costs is fuel conservation. The Station's Industrial Energy Extension Service assisted nearly 150 companies in Georgia with technical support. Workshops were conducted and publications compiled to help firms reduce energy consumption without downgrading efficiency. Work also progressed on an ambitious project to make a Georgia dairy farm energy self-sufficient. This demonstration could have broad application for the state's dairy industry in years to come.

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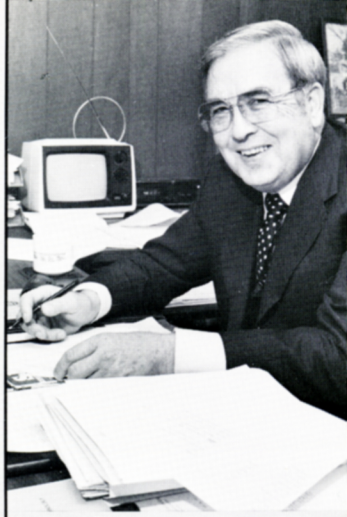
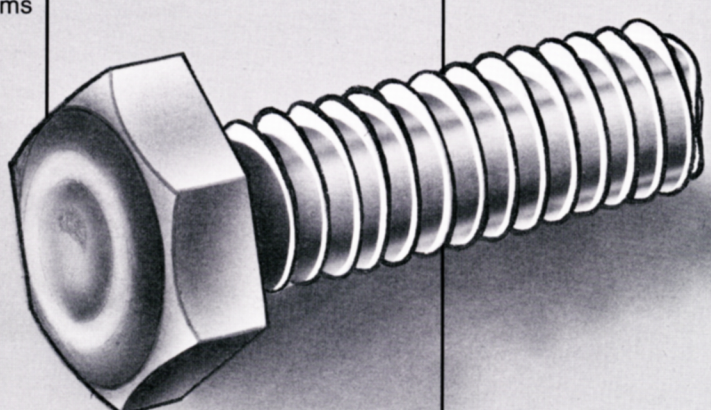


(Above) EES operates several specialized centers which provide business and technical assistance to Georgia firms.



(Above) An analytical laboratory was established last year to help Georgia firms to control environmental health and safety hazards. (Right) This CALMA Chips 220 design system is used to develop large and very large scale integrated circuits.

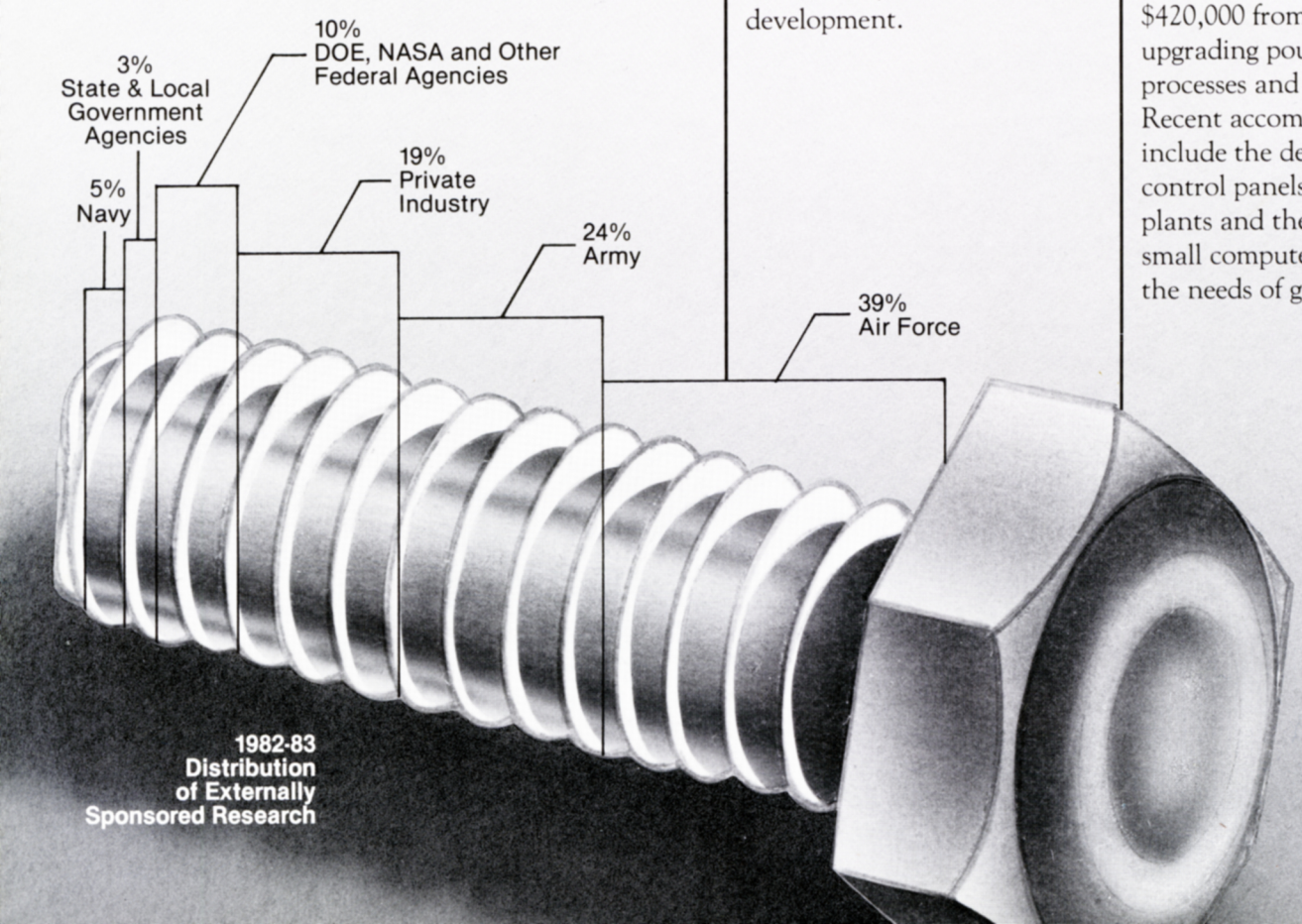
Service to Georgia

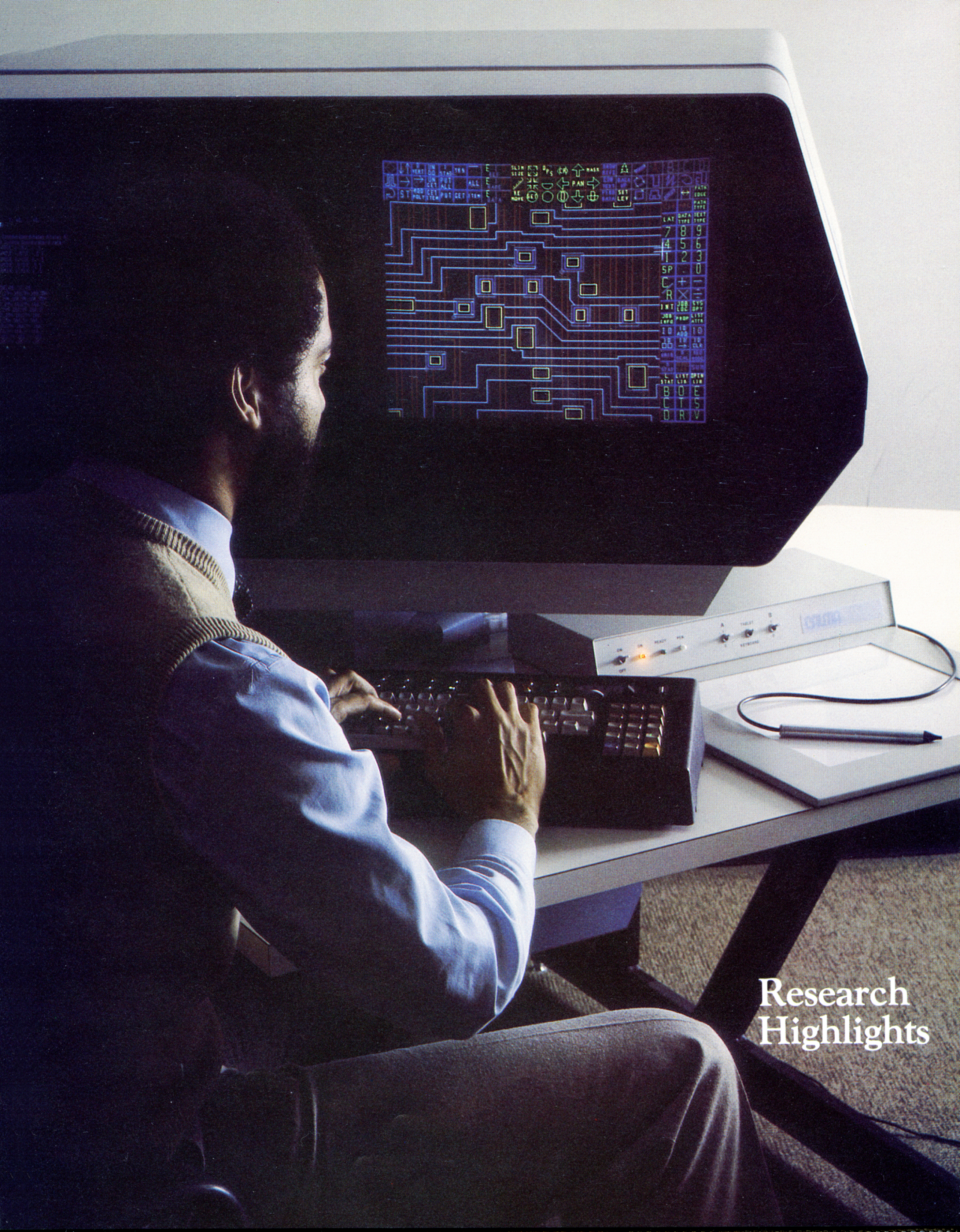
• Imports Competition. Many American businesses are being hurt by imported products. The Station operates the Southeastern Trade Adjustment Assistance Center to help American firms regain competitive positions in the marketplace. This EES center was rated the best of its kind in the nation for helping companies to offset imports competition.

• Minority Business Development. Minority-run industries often lack the experience and financial resources to develop a product idea from the conceptual stage to actual commercialization. EES provided that assistance last year through its Technology Utilization and Commercialization Center. These efforts were recognized by the National Business League, which awarded the Station its Berkeley G. Burrell Award for minority business development.

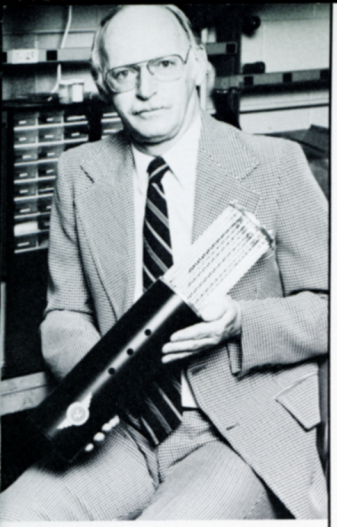
• High Technology. The State of Georgia has inaugurated an intensive effort to bolster high technology industry. EES is playing a key role by supporting the state's Advanced Technology Development Center with technical resources, administrative guidance, offices and laboratory space. In support of this concept, EES established a regional ATDC in northeast Georgia to serve the high technology development needs of Barrow, Madison and Jackson counties. An EES report also contributed to a decision by the state legislature to appropriate $4 million more for high technology training in Georgia's post-secondary vocational education program.

• Poultry Industry Assistance. Georgia's poultry industry recognizes the need to improve productivity but lacks the capital to risk developing untested new technologies. EES is filling this technological gap. In 1982-83, the Station received approximately $420,000 from the state for upgrading poultry industry processes and technologies. Recent accomplishments include the design of noise control panels for processing plants and the application of small computer technologies to the needs of growout houses.





Research Highlights



Defense Electronics

(Above) This scale model is three times larger than the multipurpose expendable vehicle which EES developed for the military's ALE 29/30 series of chaff/flare dispensers. (Below) EES designed this central processor unit for the first Air Force radar warning receiver to employ E²PROM technology.

Last year, EES researchers completed a new design for a central processor unit in a radar warning receiver. Industry is producing the circuit board which contains the central processor unit. Radar warning receivers are used on military aircraft missions to warn pilots when they are being detected by radar or actually attacked.

This new central processor board will be the first Air Force radar warning receiver to employ electrically erasable programmable read only memory. This feature is known to professionals in the electronic defense field as E²PROM. Its memory can be erased and changed like a cassette tape, without removing the printed circuit board inside the receiver which contains the data files. In current receivers, several components must be replaced each time mission data are revised.

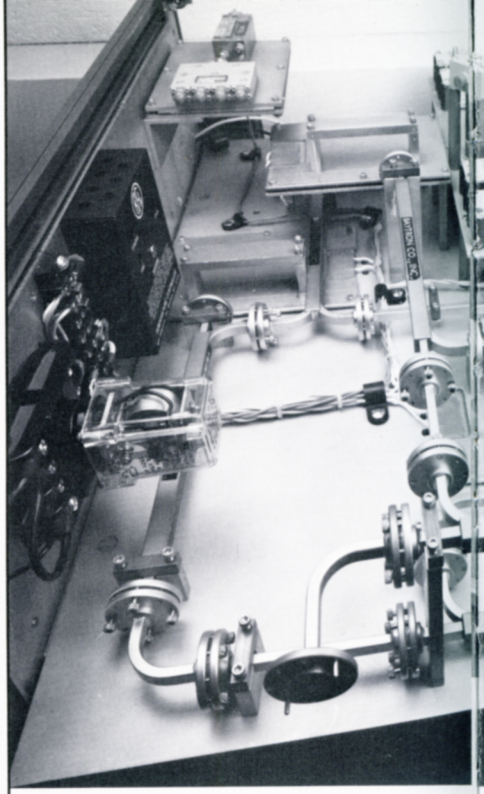
The introduction of E²PROM technology into radar warning receivers is important because:

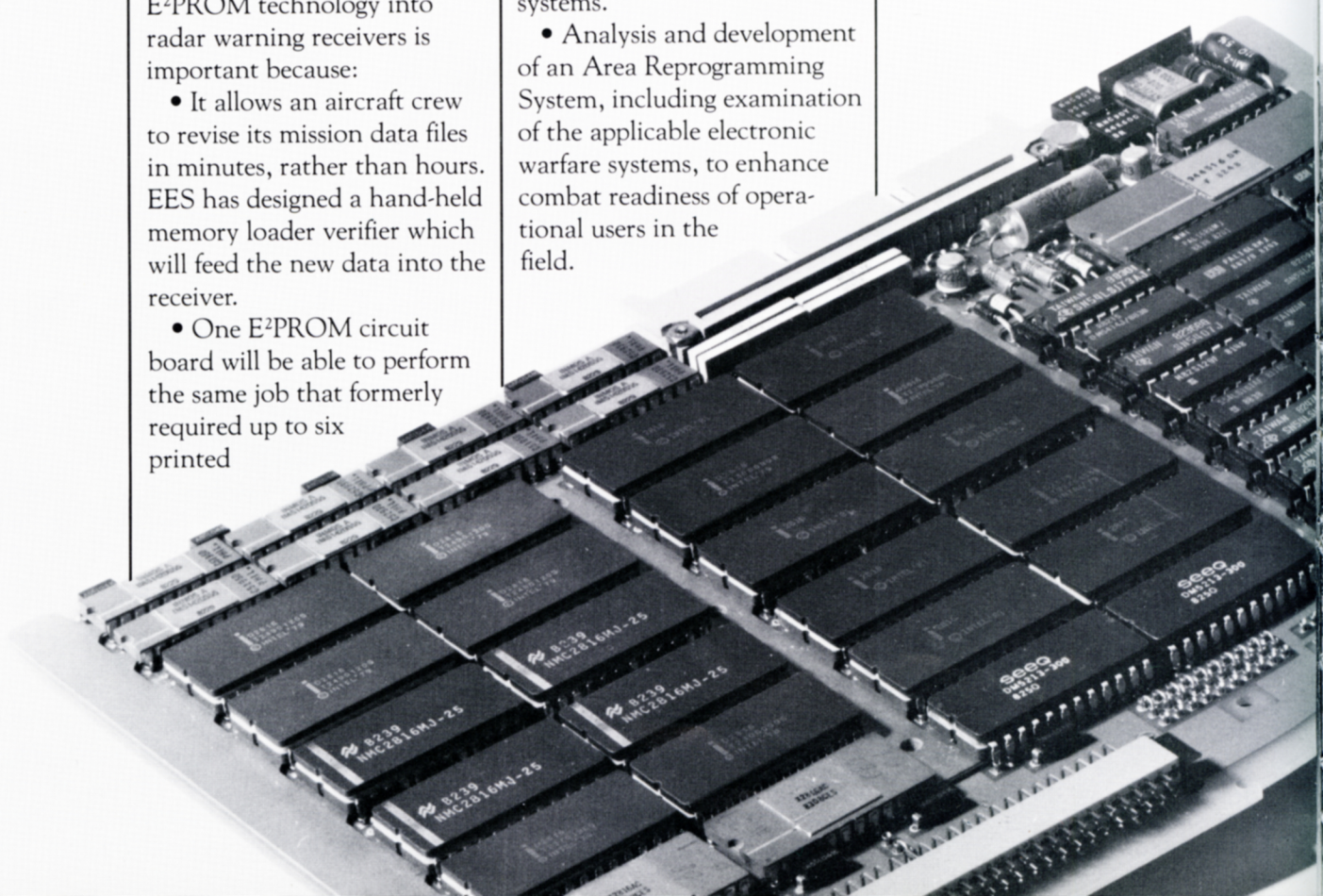
- It allows an aircraft crew to revise its mission data files in minutes, rather than hours. EES has designed a hand-held memory loader verifier which will feed the new data into the receiver.
- One E²PROM circuit board will be able to perform the same job that formerly required up to six printed circuit boards.
- The new receiver will require less maintenance and be less subject to breakdowns.

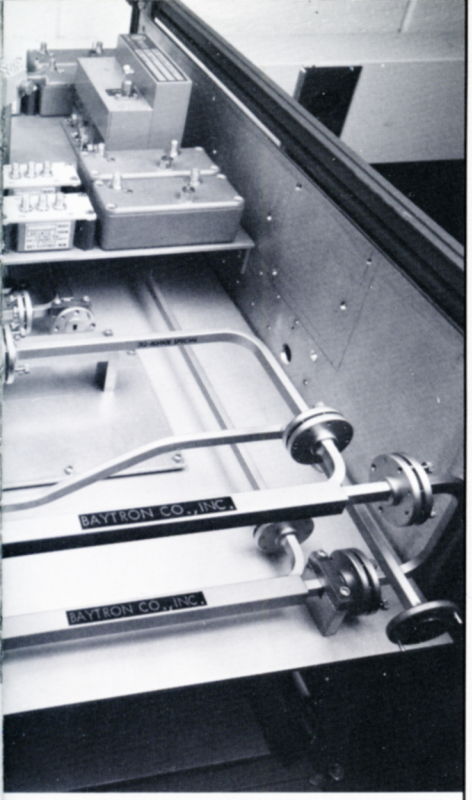
The Station's work on the new radar warning receiver is continuing. EES researchers are writing the software for the memory loader verifier which will be able to diagnose the operational condition of the new central processor unit.

Progress was made in other important electronic defense programs involving:

- Evaluation of the operational performance of the F-15, AN/ALE-45 chaff and flare dispenser system.
- Development of a multipurpose expendable vehicle for the military's ALE 29/30 series of chaff/flare dispensers.
- Integration of an advanced electronic countermeasures system into the C-131 Georgia Tech test bed aircraft.
- Analysis and experimental validation of advanced electronic countermeasures techniques, components and systems.
- Analysis and development of an Area Reprogramming System, including examination of the applicable electronic warfare systems, to enhance combat readiness of operational users in the field.







Millimeter Wave Technology

The recent proliferation of millimeter wave systems has led to studies of how this radiation affects the human body. In 1982-83, EES contributed to this effort by developing a unique six-port network analyzer and a companion frequency synthesizer which can be used to characterize the electrical properties of various biological tissues. These properties are important since they may be used in studies to determine the effects of different levels of millimeter wave radiation on biological tissues.

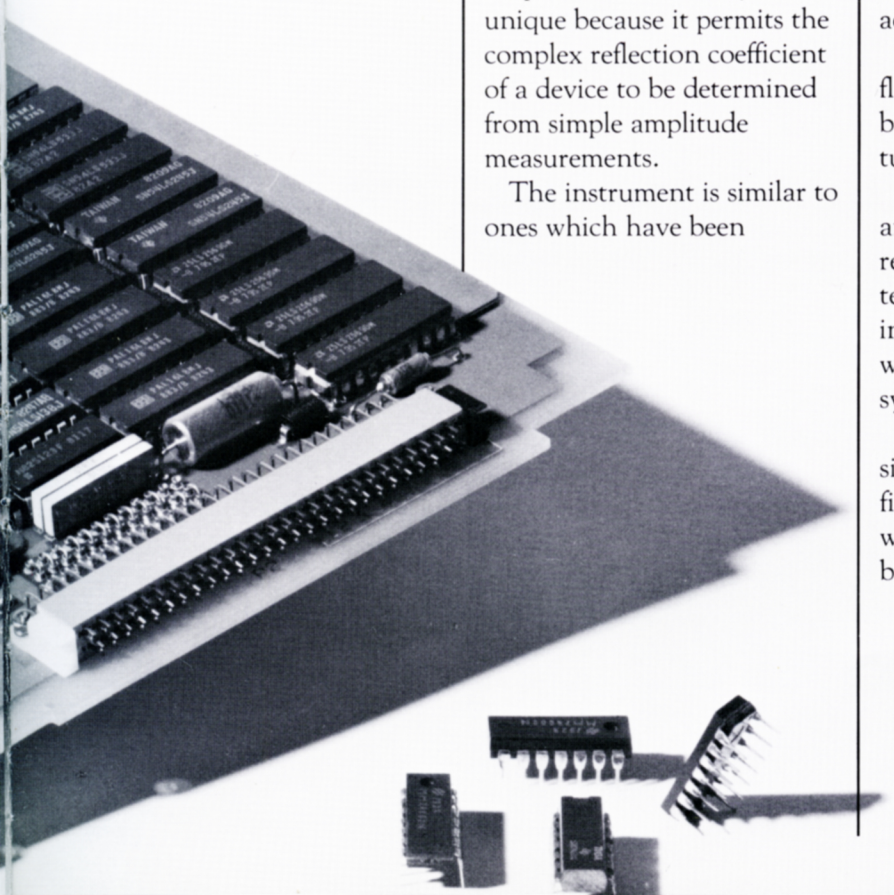
The six-port network analyzer and companion frequency synthesizer are wideband instruments that will operate over the entire 40 to 60 GHz band. The output of the frequency synthesizer is extremely stable due to phase-lock techniques that have been built into the synthesizer's hardware. The six-port network analyzer is unique because it permits the complex reflection coefficient of a device to be determined from simple amplitude measurements.

The instrument is similar to ones which have been designed to perform highly accurate tests on microwave components. Improved detectors have been incorporated, however, due to the need for greater sensitivity in measuring tissue properties. In addition, the test circuit is a versatile one which will permit research to be done on several alternate procedures to determine which is most sensitive or reliable. This makes it an ideal vehicle for future tests to compare the relative effectiveness of these operational modes.

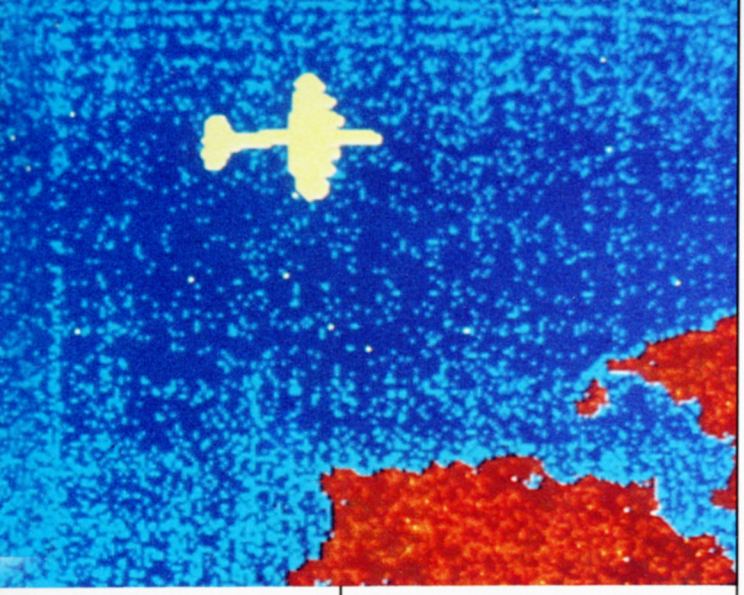
EES has made significant contributions to basic and applied research on the millimeter spectrum for the past 25 years. The Station works primarily in the areas of phenomenology, systems development, components and technology, measurements and materials development. EES engineers routinely apply these capabilities in the 35 to 220 GHz range and are making an intensive effort to extend the technology farther into the near-millimeter range.

Other notable 1982-83 accomplishments included:

- Measurements of fluctuations in millimeter wave beams propagated through turbulent atmosphere.
- Data collection and analyses of background reflectivity/emissivity characteristics of clutter and targets in clutter for new millimeter wave missile seeker/guidance systems.
- Design and fabrication of a signal intercept and direction-finding system at millimeter wave frequencies emphasizing broadband, low-loss operation.



(Top Center) This EES six-port network analyzer, and its companion frequency synthesizer, are used to characterize the electrical properties of various biological tissues. (Above) The Station is building the first millimeter wave direction finding system for the Department of Defense.



Radiometry

(Below) This 140/220 GHz radiometer was developed to help the Navy obtain high resolution images of ground and sea details. (Above) The first radiometric image of an aircraft taken at 140 GHz with this instrument. (Photo courtesy of NRL).

Last year, EES researchers added a 220 GHz channel to a 140 GHz airborne radiometer that the Station had built for the Naval Research Laboratory (NRL). The Navy used this instrument in 1982 to collect the first high-resolution radiometric images of ground details at both of these frequencies.

Passive images of arctic sea ice in the Greenland Sea and its marginal ice zone were made from NRL's P-3 Orion aircraft at altitudes ranging from 3,000 to 21,000 feet. Highly resolved images were obtained through complete cloud cover. Among them were images of land/sea interfaces and other interesting features.

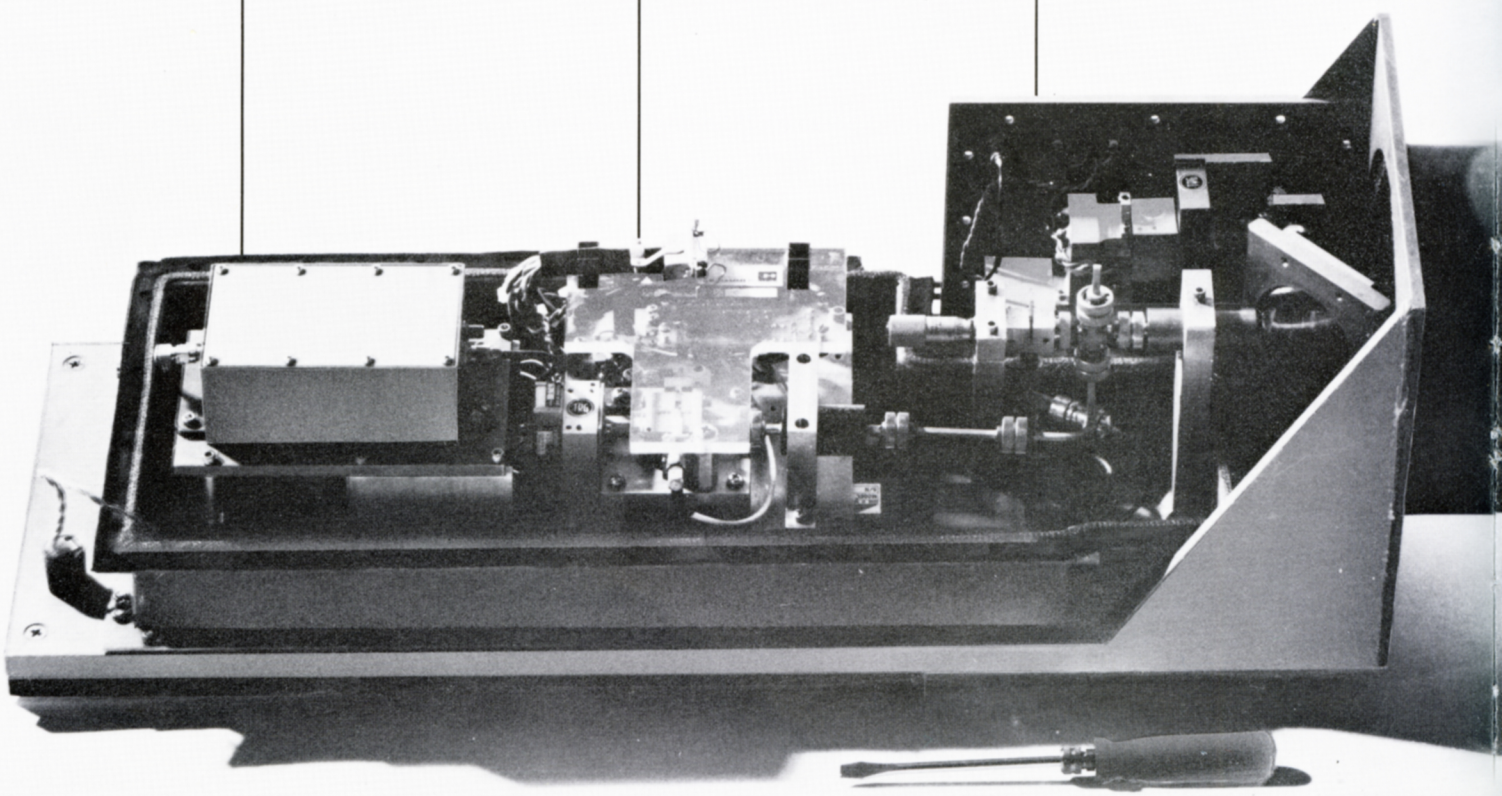
Sea ice images are important because they show where edges of ice formations lie, and they identify regions of densely compacted ice. This information is very useful in sea traffic planning and safety.

The EES 140/220 GHz radiometer has allowed NRL to collect the first measurements of high-resolution passive images at two key atmospheric "window" frequencies. These data will greatly expand the data base needed for passive measurement of targets and clutter. This instrument also is collecting data on the atmospheric effects of fogs, clouds, rain, snow, and moisture on radiometric sensing.

NRL's P-3 Orion passive imaging program is an ongoing effort to collect data on many types of targets in different areas of the world. This research is leading to the development of satellite-borne radiometers which may provide continuing and comprehensive coverage of global geographic details. These satellites will be able to spot ground targets through clouds which now nullify satellite infrared remote sensing capabilities.

Significant contributions were also made in projects involving:

- Satellite-borne detection of aircraft and ships with millimeter wave radiometers.
- Development of an advanced airborne millimeter wave imaging system for the P-3 aircraft.
- Data collection on high-altitude target detection and moisture sounding using a 94/183 GHz radiometer aboard NASA's ER-2 research aircraft.
- Real time data processing by the 94/183 GHz radiometer of water vapor profiles above the Caribbean Sea and marginal ice zones over Alaska. These measurements were made in NASA's Convair 990 aircraft.



Radar R&D

EES completed a prototype unit of an advanced surveillance and target acquisition radar (ASTAR) in 1982. A highly mobile radar station was integrated into an M-113 armored personnel carrier which may be used as an autonomous forward observation post in tactical military operations.

The ASTAR station will be capable of moving undetected by the enemy into a forward battlefield area, where its mast-mounted radar will be raised to an optimum vantage point just above treetop level. There, ASTAR can observe battlefield operations with minimal susceptibility to detection by hostile forces. Use of a pneumatically extendable mast is relatively new in the radar field.

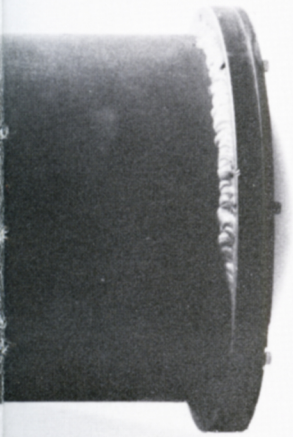
A new type of radar antenna employed in the ASTAR system will reduce the likelihood of radio frequency detection or jamming by an enemy. The radar will be able to pinpoint enemy tanks, radio their location to friendly artillery many kilometers away, then direct fire power as necessary until the hostile forces retreat or are destroyed.

Radar specialists at the Station modified an existing military surveillance radar design to build the hardware and software for ASTAR. The system was integrated with a distributed processing architecture which allows ASTAR to be used as a generic ground surveillance radar test bed.

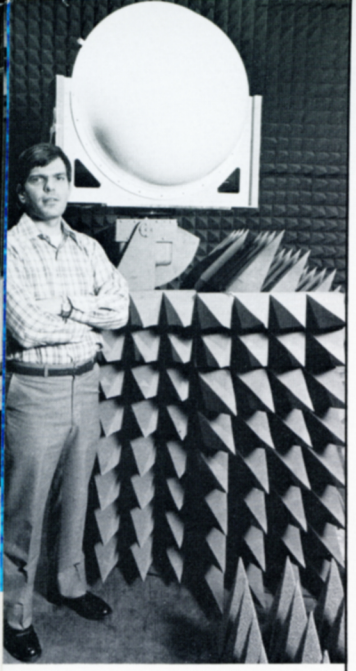
ASTAR was successfully field tested in 1982. Additional tests and field demonstrations are continuing in 1983.

Other exceptional radar R&D programs involved:

- Development of a state-of-the-art 95 GHz extended interaction oscillator modulator/power supply for the Talons program.
- Development of computer models to predict radar images produced by inverse synthetic aperture radar (ISAR) systems.
- Conversion of the basic radar in the AN/MPS-36 instrumentation radar to dual-frequency and three-channel full monopulse operation.
- Conceptual study and preliminary functional system design of a radar target signature and antenna measuring system for upgrading a radar target backscatter facility.
- Use of 35 and 95 GHz instrumentation radars to identify the major sources of radar reflections for several classes of airframes in a program sponsored by the Air Force Wright Aeronautical Laboratories.



(Top Center) EES has more than 30 years of experience in radar R&D. Field testing programs, like this one in Hawaii, are conducted throughout the world. (Above) The EES-developed ASTAR radar system is housed in this M-113 armored personnel carrier.



Antennas

(Above) This S-band telemetry antenna system collects data during MX missile testing programs. (Below) EES built these spiral antennas and this log periodic dipole antenna as broadband receivers for detection systems.

EES delivered a unique S-band telemetry antenna system last May for use in the MX missile program. The antenna now flies aboard a C-7 aircraft, collecting data on missiles descending at Kawjalein Missile Range several thousand miles southwest of Hawaii. The Station developed this prototype under subcontract to Kentron International, Inc., Huntsville, Alabama. The antenna system was completed in nine months, an exceptionally short deadline for building a system with such stringent performance specifications.

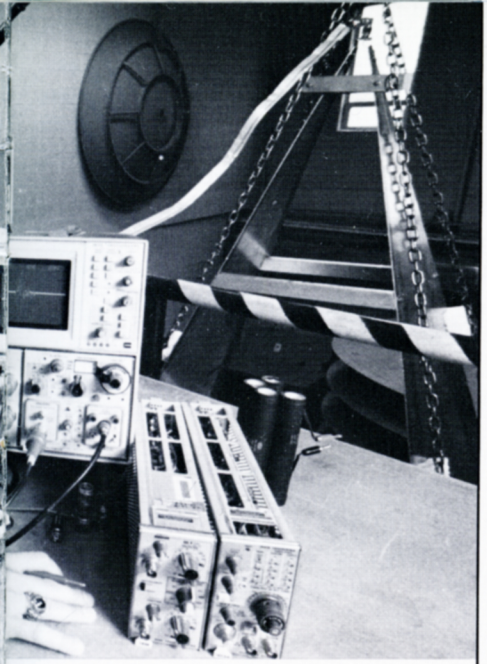
The 156 pound antenna operates in the 2.2-2.3 GHz frequency range, using a lightweight Luneberg lens. The aperture of the lens is illuminated by a four-element array consisting of four circular waveguide feeds. These specially designed devices are capable of instantaneous left and right hand circular polarizations. The system has four modes of operation:

- A manual mode where all four feeds can be selected individually;
- An automatic mode where any feed can be selected automatically by the electronics depending upon which beam contains a signal;
- A two-beam combined mode where the two interior feeds are coherently summed; and
- A four-beam combined mode where all four feeds are coherently summed.

Other significant antenna programs involved:

- A numerical analysis to improve the performance of arbitrarily shaped microstrip antennas by surface-patch techniques.
- Development and evaluation of phased arrays and radomes for hypersonic missiles.
- Evaluation of the performance of the AN/MPS-36 antenna five horn feed, and modifications to a system component.
- Analysis, design and fabrication of a 140-340 GHz millimeter wave antenna with an asymmetric off-axis parabolic section fed by a corrugated rectangular horn.
- Development of a multimode Cassegrain feed for accurate measurements of meteorological depolarization effects.
- Development and evaluation of a Ku-band, multimode feed with low sidelobes and high aperture efficiency to improve noise temperature in a satellite communications antenna.

- Conceptual development and implementation of a method for testing antennas with low cross-polarization levels using a variable polarization source.
- Development of a very low sidelobe electronically scanned phased array antenna for airborne surveillance of battlefields.
- Development of a new method of dielectric matching for millimeter wave lens antennas.



Electromagnetic Compatibility

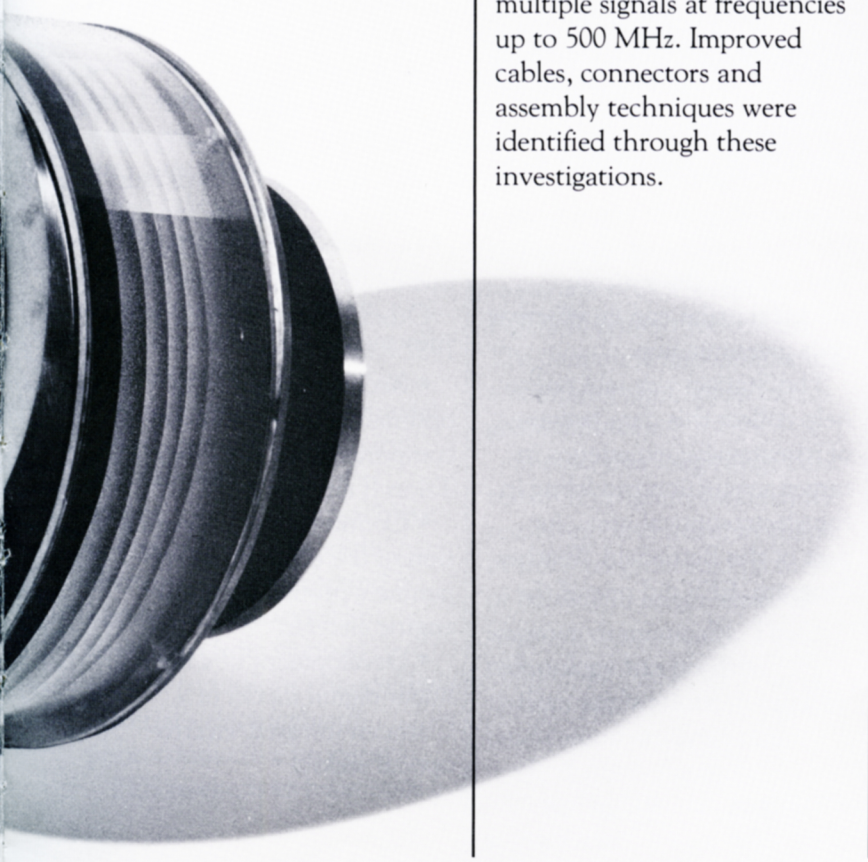
When two high-powered radio frequency (RF) signals are simultaneously present in a cable or connector, interference often results. This problem is especially critical on military ships and aircraft. There, many electronic systems work close to each other and even low levels of interference can obscure their performance.

In 1982-83, EES became the first research institution to make a comprehensive study of the interference characteristics of RF cables and connectors commonly used in military communications systems. Through this R&D program, the Station refined an existing technique for measuring the very low levels of interference generated by cables and connectors. From their studies, EES researchers were able to describe and predict the behavior of cables and connectors when carrying multiple signals at frequencies up to 500 MHz. Improved cables, connectors and assembly techniques were identified through these investigations.

Another phase of this program focused on the interference properties of various metal-to-metal junctions used in assembling aircraft bodies. EES found that commonly used joint treatments appear to make joints more prone to interference. A third part of this research effort involved the search for a technique for locating poor cables, connectors and joints. Researchers identified a promising approach and validated it through laboratory evaluations.

Other important electromagnetic compatibility projects include:

- Planning and upgrading of a military facility used to test strike aircraft in simulated high-power electromagnetic environments.
- Development of advanced measurement and analysis technologies for determining electromagnetic susceptibility/vulnerability of weapon systems.
- Experimental validation of the electromagnetic pulse coupling levels of the EES-developed ECAM computer model.
- Design and construction of a spherical antenna and radiating source for use as an electromagnetic field reference.
- Compilation of a set of preferred circuit designs for maximum protection against large and very fast voltage transients.
- Measurement and assessment of the electromagnetic radiations from prototype electric powered vehicles.



(Top Center) EES is experimentally verifying the accuracy of a computer code for assessing electromagnetic coupling to power lines. (Above) This highly specialized spherical transmitting device was developed for an industrial sponsor.

Infrared/ Electro-Optics

(Above) This synthetic image is one of many generated with computers to evaluate electro-optical sensor systems on military aircraft. (Right) The EES image analysis lab is employed in modeling, simulation and systems analysis programs for the military.

Bomber pilots may have a better chance of surprising their enemies thanks to the work of EES and other research laboratories in the military's Battlefield Weather Program. The Station is developing a methodology for predicting the performance of electro-optical sensors on guided missiles in a variety of weather conditions and geographic terrains.

When imbedded in the nose cone of a flying missile, an electro-optical sensing device can give a bomber pilot a recognizable view of a landscape up to six kilometers away. With this picture on a display screen, the pilot can direct the weapon toward a target, then leave the scene before the weapon explodes and enemy retaliation begins.

Unfortunately, electro-optical sensors operating at television or infrared frequencies are only effective in relatively clear weather with

limited background clutter. Mission planners need to have more precise information on these constraints to decide whether electro-optically guided missiles can be effective on a given mission.

The Station was selected to help collect this data because of its extensive experience in target acquisition modeling in the electro-optical area. As part of the Battlefield Weather Program, EES did one of the first in-depth studies of how background clutter can affect a pilot's target detection range performance. The Station found that certain kinds of clutter can confuse a pilot so much that it can reduce detection range performance by up to a factor of three and a half.

This information is becoming a part of the Tactical Decision Aid which will help the military to use its arsenal of electro-optically guided missiles more effectively.

Other important efforts in 1982-83 involved:

- Recommendation of optimal infrared defensive components for the Combat Talon II aircraft.
- Countermeasures evaluation of the effectiveness of jammers protecting multi-engine aircraft.
- Development of a non-linear digital model of a Conscan infrared/electro-optical seeker.

Physical Sciences

Last year EES was one of a few research institutes investigating new techniques for growing mercury cadmium telluride (HgCdTe) as a microelectronics chip material. HgCdTe is able to accurately sense a wide range of thermal radiation frequencies. The Army is sponsoring this research because it wants to use HgCdTe chips to fabricate large focal plane detector arrays, and to improve the sensitivity of infrared detectors in guided missile seekers.

The creation of large monolithic integrated photodiode arrays will increase the information gathering capacity of current detector systems by two to three orders of magnitude. It also will greatly simplify sensor and system design, allowing smaller and less costly systems to be built.

The Station is investigating the feasibility of growing HgCdTe films by molecular beam epitaxy. Through this process, elemental sources are evaporated and their molecular beams directed onto a substrate, where condensation into a thin film crystalline liquid takes place.

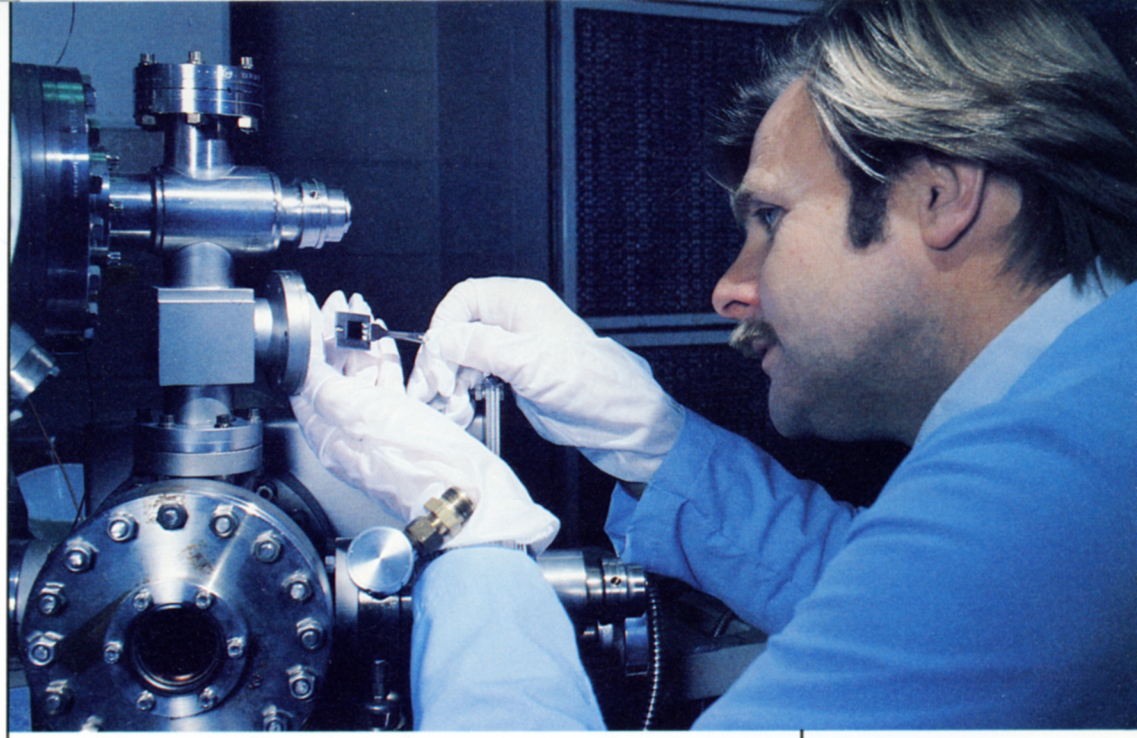
This technology is used routinely to grow other semiconductor materials, but HgCdTe presents an unusually difficult technical challenge. Precise control of the epitaxial growth process is necessary. The required degree of accuracy is difficult to achieve in HgCdTe because each element of the compound is highly volatile, and slight deviations from optimal growth conditions change the material's electrical and photoconductive properties.

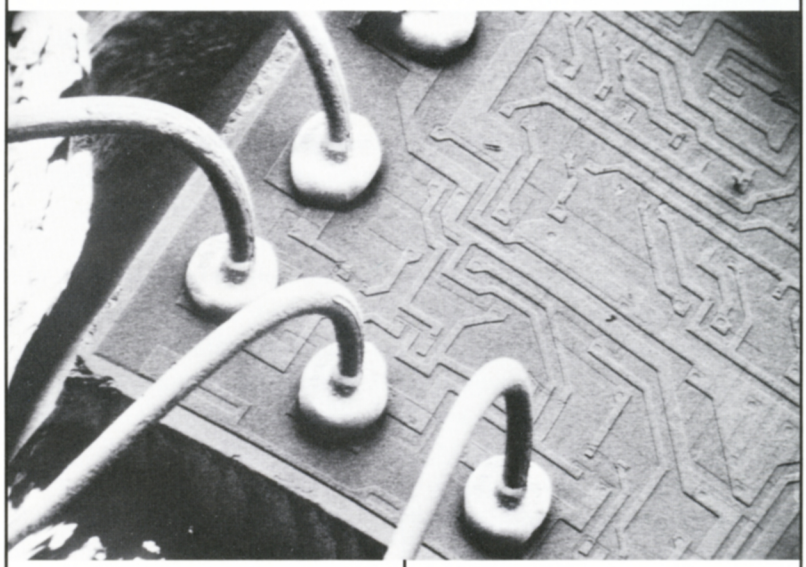
EES researchers have built a special molecular beam epitaxy system to investigate the requirements for a reliable HgCdTe growth technique. The Station is also developing a computer simulation of this growth process.

Should this long-range basic research program succeed, the resolution and detail available in infrared-generated pictures of battlefield target areas could improve dramatically. This technology has possible civilian applications in satellite land resources surveys and medical mammagrams.

Other significant physical sciences projects include:

- A study to determine if the opening times of electron beam sustained plasma switches can be shortened by photon induced electron attachment within switch gas mediums.
- Investigations of ion transport properties, ion reaction rates and trace neutral concentrations leading to the design of sensitive techniques for monitoring trace neutral specimens in the troposphere.
- Design, development and production consultation on solid state microwave devices and circuits for industries.





(Above) This special MBE system was developed to investigate techniques for growing mercury cadmium telluride as a microelectronics chip material. (Left) EES designs, develops and evaluates semi-conductor devices.

Biomedical Electronics

(Above) Biomedical engineers are studying whether long-term exposure to low-level microwaves is hazardous to laboratory rodents. (Below) These probes were developed at EES to study the dielectric properties of cancerous tissues.

For many years, scientists have debated whether long-term exposure to low-level microwaves is harmful to humans. Some researchers claim that this radiation causes headaches, fatigue, nausea or general irritability. But little in-depth experimentation has been done in the United States.

Last year, EES built one of the nation's first laboratories designed specifically for comprehensive studies of this question. EES is one of only two research centers ever to receive government funds to design and construct a facility of this kind, and engineers are using the new eight-room lab for a unique R&D program.

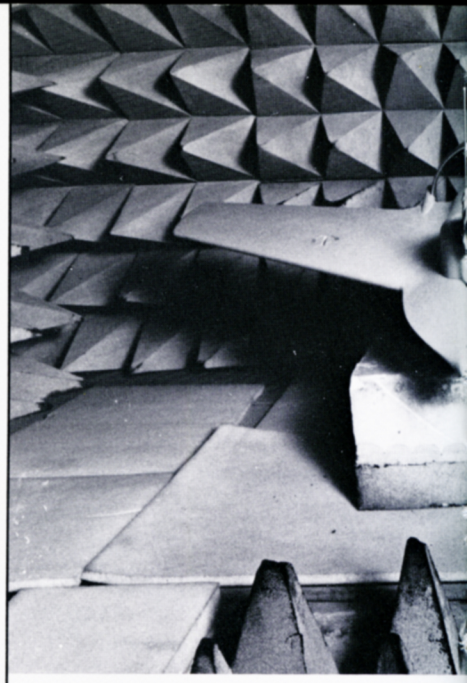
The Station is attempting to establish whether extended exposure to low-level microwaves causes physiological stress. EES engineers are irradiating a population of 100 rodents in the microwave lab, while periodically sampling the blood of these test animals for changes in key hormones which are particularly responsive to stress. The rodents are being subjected to pulsed radiation which has a pulse width of 1 microsecond, and a pulse rate of 1,000 times per second. These pulse parameters were chosen because they are representative of many military and civilian radar systems.

The major problem in past radiation effects research has been that the process of sampling blood *in itself* can produce stress unless careful precautions are taken. EES researchers have solved this problem by surgically implanting a cannula into an artery in each rodent. Researchers can now open the cannula as necessary and remove minute quantities of blood without disturbing the animal significantly.

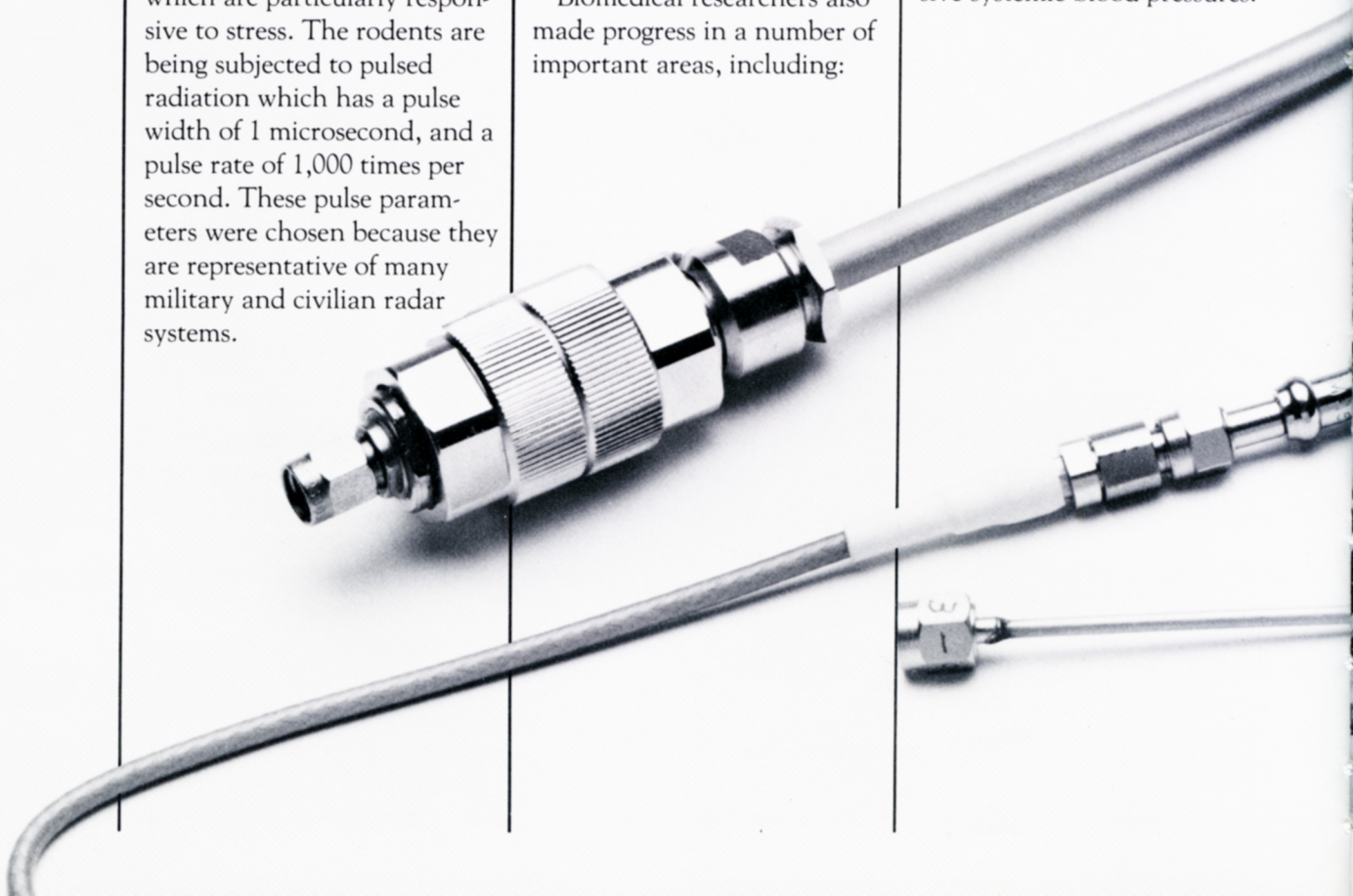
Two anechoic chambers were built to house control rodents and rodents irradiated with microwaves. The animals are individually housed in Plexiglas cages on special platforms designed and built at EES. These platforms consist of four tiers of circular parallel plates made of aluminum. Each pair of plates forms an open-ended circular waveguide for irradiating the rodents.

This testing program will run for several years, but preliminary results may be available by late 1983.

Biomedical researchers also made progress in a number of important areas, including:



- Development of electromagnetic techniques and instrumentation for non-invasive monitoring of physiological parameters such as respiration and heart rate.
- Adaptation of a probe dielectric measurement technique for *in situ* dynamic evaluations of intrarenal blood flow distribution at different normotensive and hypertensive systemic blood pressures.



Communications

Last year, the Station delivered to the Federal Communications Commission (FCC) a completely automated, computer-controlled measurement system which should dramatically improve the agency's ability to enforce government broadcast regulations. Housed in a van which travels around the country, this prototype mobile measurement facility records pertinent data on the broadcast and mobile signals of FCC licensees.

Before this prototype was installed, the FCC monitored radio transmitter stations with manually operated equipment. The new computerized system is a test bed for determining if substantial improvements can be made in the monitoring process.

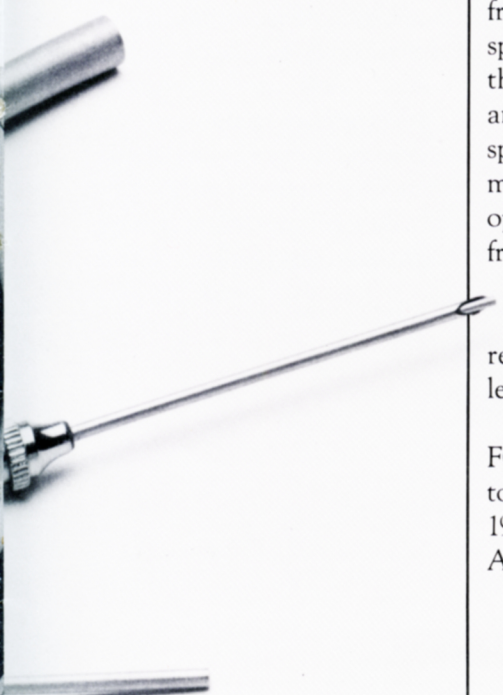
The prototype equipment can be operated manually, but it is most effective when automatically scanning the frequencies in the radio spectrum. Data collected through this process can be analyzed to determine if spectrum users are properly modulating their signals, operating off their assigned frequencies, occupying spectral space outside their assigned bandwidths, or failing to regularly identify their call letters.

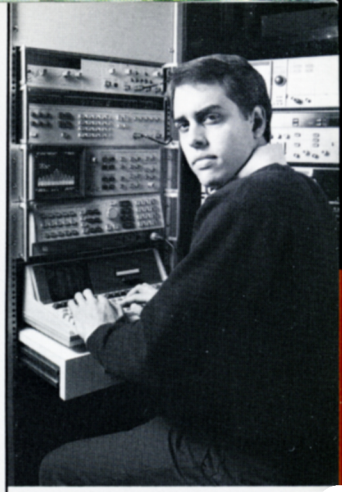
EES has worked with the FCC to improve signal monitoring activities since the early 1970's, when the General Accounting Office reported that the agency's surveillance of radio regulation compliance needed improvement. Station engineers did a comprehensive study of FCC enforcement procedures in 1972 and recommended at that time that the commission automate its signal monitoring system. EES designed the computer-controlled measurement hardware in the late 1970's, and the delivery of the prototype was the culmination of several years of research. Development of this system is expected to continue.

Systems of this kind are not limited in application to civilian radio monitoring. EES also is adapting similar equipment and techniques to military communications, command and control (C^3) problems in the areas of surveillance, signal intercept, and counter C^3.

Other significant computer applications programs include:

- An examination of the performance of high-speed digital transmission systems used in a tactical environment.
- Research on new design, development and testing techniques for advanced broadband, low-profile airborne antennas.
- Development of a computer model for analyzing the effectiveness of jamming against digital data links.





(Top Center) EES tests broadband, low-profile airborne antennas for optimal electrical and aerodynamic performance. (Above) This prototype equipment was developed to help the FCC improve its signal monitoring capabilities.

Command and Control

(Above) Command and control specialists are developing software for a color graphics training device for operators of energy control systems. (Top Center) Color graphics, like this battlefield scenario, were developed to help the military computerize its intelligence operations.

Last year, EES played a major role in the military's effort to computerize rapidly its intelligence operations. Traditionally, the military has equipped itself by defining a system to meet a given requirement, then developing hardware over a lengthy period. Under an acquisition procedure like this, computer systems selected for military use can be obsolete by the time they are fielded.

To avoid this problem, the military has acted on previous EES research findings and is employing the Station to help develop microcomputer-based intelligence analysis systems through an evolutionary process. Intelligence operators are experimenting with a series of application models in trial and error fashion. The military will progressively refine the models to fit its needs.

When this research began, EES developed courses and training devices to accustom intelligence personnel to working with computers, and led training sessions at two Army locations. Station researchers also provided analysts with an interactive trainer consisting of a microcomputer, video-disc player and appropriate software.

EES also developed an analyst's work station composed of a microcomputer, hard disk storage, floppy disk, video player and color monitor. Additional research is determining whether these systems can effectively display terrain in digitized form for intelligence purposes.

This program began with 33 microcomputers, but initial successes have led the military to purchase 400 more microcomputer systems to support military intelligence operations in the United States, Western Europe and the Western Pacific Ocean area.

Achievements were also gained in programs involving:

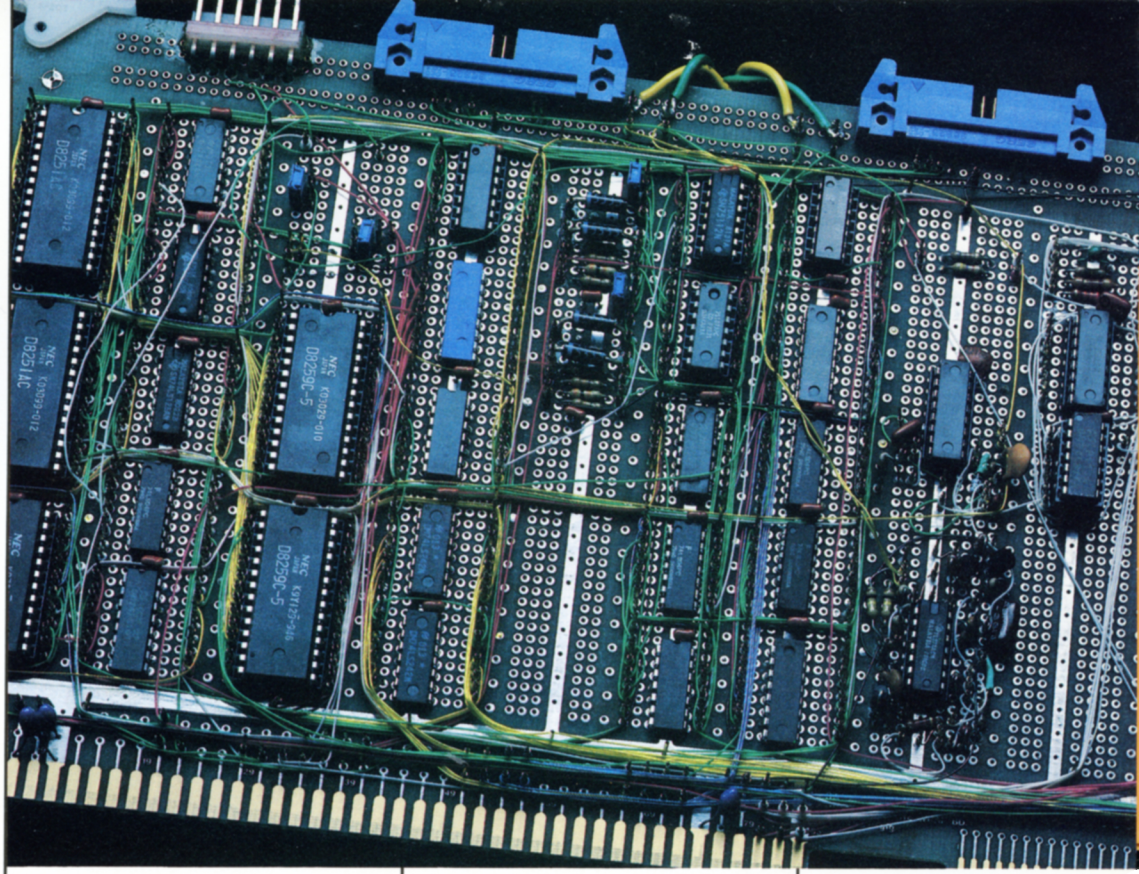
- Software development for a color graphics training device for operators of energy management control systems.
- Technical assistance and evaluation of a maneuver control system for battlefield commanders.
- Assistance in the development and use of an analytical computer model to aid tactical officers in charge of directing and controlling military forces.

Computer Applications

Last year, engineers tested and assembled much of the hardware for a Station-designed computerized safety monitoring system to be installed at Georgia Power Company's nuclear-powered Plant Hatch. This Safety Parameter Display System (SPDS) will allow control room operators to survey potential emergency conditions quickly and accurately on computer terminal screens.

Most nuclear control rooms now perform this task with meters connected to sensors in the plant. As a result, the typical nuclear plant control room resembles that of a large ship, with row after row of dials, indicators and controls. Keeping up with this array can overload human operators and diminish their capacity to respond adequately to possible threats.

This program is an example of how utilities are using computer technologies more extensively to monitor plant reactor safety. In the past, the nuclear industry has hesitated to rely heavily on computers because of doubts about the durability of commercially available models.



The minicomputer system which EES is building for Georgia Power Company has extraordinary sturdiness. Station engineers adapted military specifications into the hardware so that it will be able to resist earthquakes, abnormal vibrations and temperature extremes. The system is built in detachable modules, which can be replaced if they fail.

During 1982-83, EES proceeded on schedule in its testing and assembly of this system. One time-consuming element was the complex task of interfacing the SPDS with the various electronic systems in operation at Plant Hatch.

Computer applications experts at the Station also worked on significant programs involving:

- Software and hardware support for a computer and tape gathering facility at a U.S. military base.
- Modification of an EES computer energy management system which has been licensed by a major U.S. corporation.
- Implemention of a computer system to calibrate and validate the performance of a radar system.

(Above) Station engineers research and design custom circuitry for a variety of applications. (Left) EES is developing this computerized Safety Parameter Display System for the control room of a nuclear energy plant.

Materials Sciences

(Above) The Station is developing paints and protective coatings which can withstand severe environmental conditions. (Below) A small von-Karman radome is centered between two larger radomes which were also fabricated at EES.

In 1982-83, EES successfully fabricated small thin-wall von Karman radomes for use in a small experimental missile. The radomes were made from slip-cast fused silica with wall thicknesses of one twentieth to one tenth of an inch. They will protect a millimeter wave antenna.

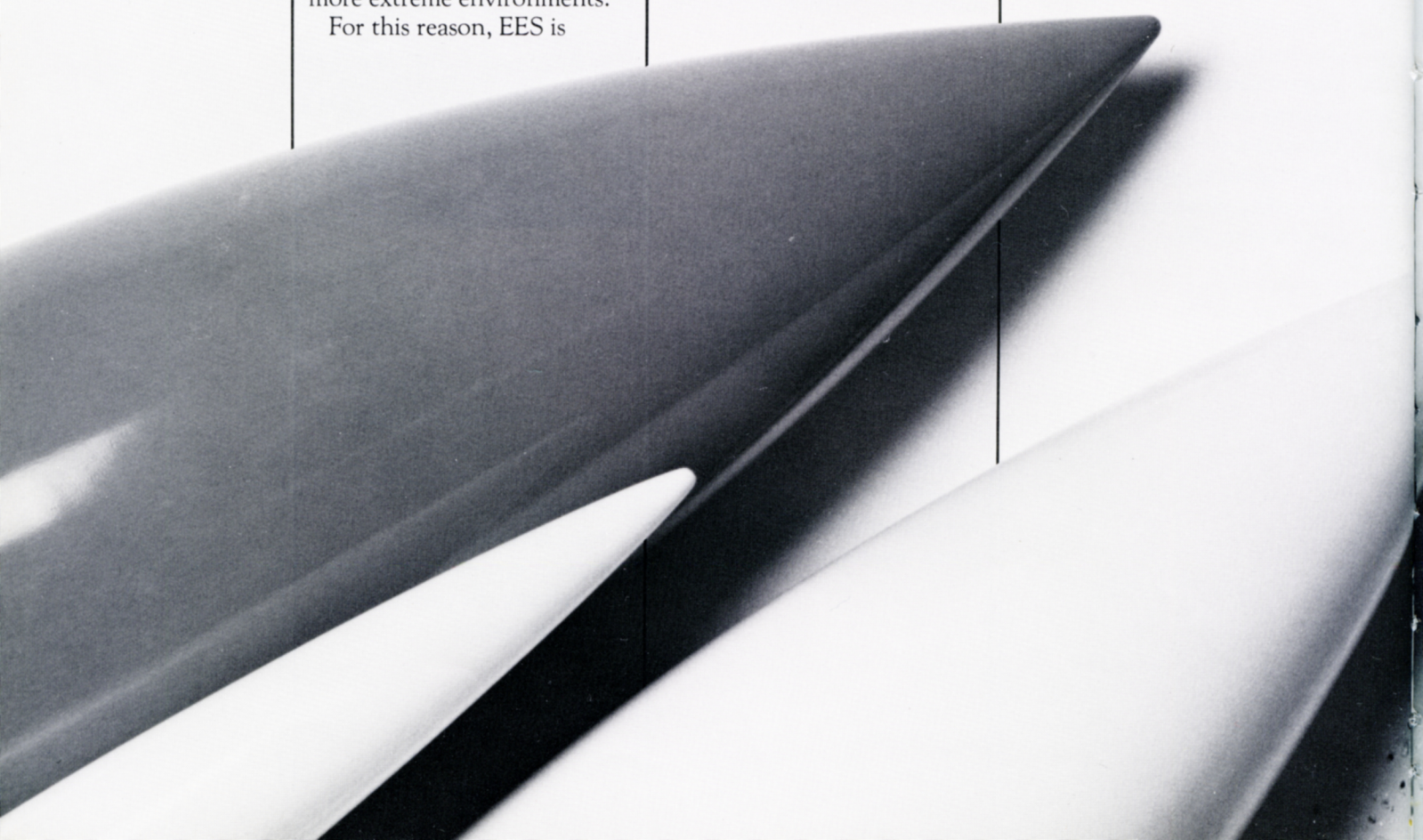
Fifteen years of development have gone into the Station's advanced radome materials fabrication program, and EES researchers have earned an international reputation for their work in this area. Because of their achievements, the Station is already well-equipped to accommodate the growing need for radomes in advanced radar applications, such as millimeter wave systems.

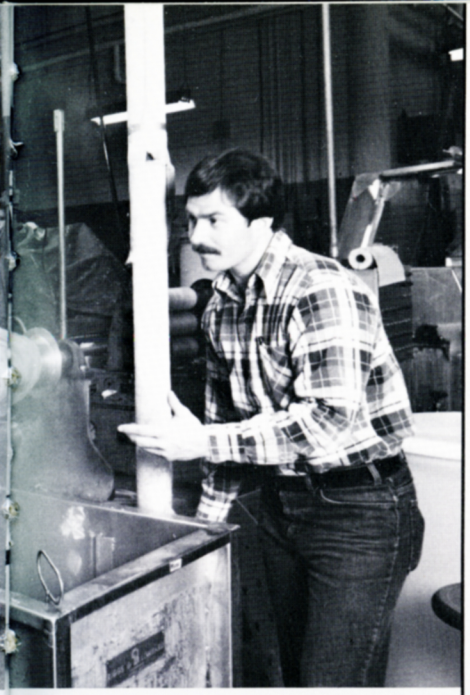
The missile radomes developed during 1982-83 were small enough so that a relatively fragile material such as fused silica could be used. Future millimeter wave radomes must be able to withstand stresses of more extreme environments.

For this reason, EES is investigating sturdier materials to meet this requirement. Fabrication techniques recently developed at the Station will allow researchers to make larger thin-wall radomes for millimeter wave applications using silicon nitride. An even stronger material under study at EES is a ceramic matrix composite, which has promise in high-temperature structural applications as well as radome fabrication.

A number of other interesting materials sciences programs were underway in 1982-83, including:

- Feasibility experiments using lasers to simulate the effects of nuclear thermal radiation on materials.
- Development of application criteria for performance coatings used to protect bridges from corrosion.
- Characterization of the electrical properties of selected ceramic materials for millimeter wave tubes.





Energy Conservation

Excessive energy consumption is one problem in textile plants which threatens the health of the industry in America. Last year, EES compiled a summary of several approaches which have been effective in reducing energy use in textile operations.

This information was disseminated to Georgia textile firms through the Industrial Energy Extension Service, a center operated by the Station to help manufacturers in the state conserve fuel. This extension service is sponsored by the Georgia Office of Energy Resources under a grant from the U.S. Department of Energy.

Each EES recommendation was implemented by at least one Georgia textile operation in 1982-83. Technologies suggested for use by manufacturers included:

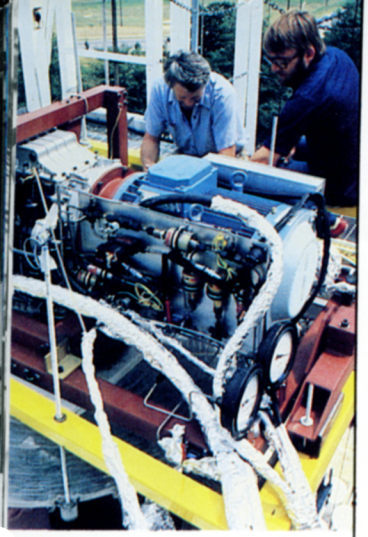
- Tandem dyeing. In this process, baths are not discharged after each dyeing cycle as in conventional processing. As a result, less heat is necessary.
- Better temperature control. EES researchers pointed out that most companies set temperature control monitors for dye becks higher than is necessary to maintain a properly heated bath.
- Installation of dye beck doors. As much as 50 percent of the energy used in a typical batch processing operation is lost through evaporation. One way to cut off vapor escape routes is by installing doors on becks.

Helping the textile industry is only one part of the total mission of the Industrial Energy Extension Service. This center assists manufacturers of all kinds in Georgia with energy conservation problems. Last year, Station engineers accomplished this objective in three ways: by conducting eight conservation workshops throughout the state on generic or industry-specific problems; by publishing technical briefing reports; and through 60 energy surveys in industrial plants.

Other important 1982-83 energy conservation programs included:

- A nationwide study to identify and recommend novel technologies for cost-effectively increasing water recycling and reuse in the pulp and paper industry by the year 2000.
- Identification of the most promising new electrification technologies in the textile industry for funding by the Electric Power Research Institute.
- Determination of steps to improve process controls and excess air controls in a metal recycling plant.
- Sixty free energy management surveys for small and medium-sized businesses by engineers in the Station's Energy Analysis & Diagnostic Center and Appalachian Regional Commission Energy Audit Program.

(Top Center) EES researchers measure heat loss from a textile dye bath. (Above) The Station conducts free energy surveys for small and medium-sized Georgia companies.



Solar Research

(Above) Last year, EES and United Stirling engineers demonstrated that a solar-heated engine could reliably supply electric power to a utility grid. (Below) EES tests new solar technologies at DOE's Advanced Components Test Facility on the Georgia Tech campus.

Last year, EES enhanced its reputation as a major solar testing center when a Stirling external combustion engine was mated successfully with the Station's 325 kW experimental solar thermal concentrator. In a program sponsored by United Stirling of Sweden, EES researchers demonstrated for the first time in history that a 20 kW Stirling engine could use a solar heating source to generate directly usable electric current.

During these experiments, the Stirling engine was placed at the focal point of a seven-story tower at Georgia Tech's Advanced Components Test Facility. A field of mirrors on the ground below reflected and concentrated sunlight onto a series of tubes running outside the engine. Helium passing through these tubes was heated to high temperatures. This hot gas then drove the engine's pistons and powered the generator.

The success of these tests attracted worldwide interest in technical and general interest publications. The Solar Energy Research Institute of the Department of Energy called the application the most economically promising solar-to-electric technology developed to date.

EES engineers estimate that, with further development, the Stirling application can be three times more efficient than present photovoltaic solar panels in converting sunlight to electricity. Photovoltaic arrays turn solar energy into low voltage direct current which must be modified for use in conventional power lines. The Stirling engine has the additional advantage of producing alternating current.

Other significant 1982-83 solar research programs centered on:

- Design, fabrication and testing of a direct solar flux entrainment reactor for efficient conversion of solar energy to storable fuels and chemicals.
- Development of surface temperature measurement techniques and hardware for use in high solar flux environments.
- Characterization and development of ceramic materials and high temperature windows for use in solar central receivers.
- Development of a facility for testing and configuring photovoltaic electric power systems for residential applications.
- Evaluation of the use of solar energy for the production of synthetic fuels.
- Testing of a small particle, solar thermal receiver at the Advanced Components Test Facility for the Lawrence Berkeley Laboratory.

Biomass Research

Engineers at the Station completed a prototype of a novel wood pyrolysis system in 1983. Traditional pyrolyzers use a fixed bed to process wood chips and other biomass materials. EES' experimental unit will produce synthetic fuels by pyrolyzing small wood particles in a moving stream of hot, inert gas. The process under development is known as "entrained flow pyrolysis."

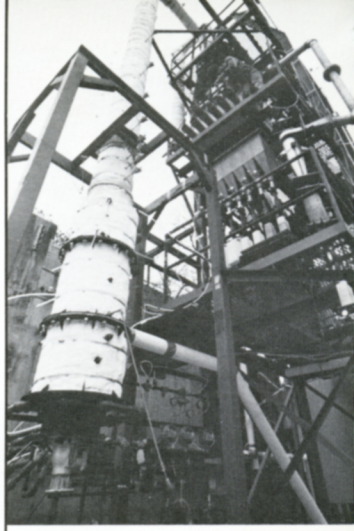
This EES technology is the fruit of many years of basic research in wood pyrolysis. Station engineers are conducting performance tests of the prototype unit. Based on current projections, the entrained flow method will greatly optimize conversion ratios of hard wood to pyrolytic oil and syngas. The oil is valuable as an alternate source of fuel for heating, and syngas can serve as a feedstock in other manufacturing processes, such as the production of ammonia and methanol.

The Department of Energy, which is sponsoring this multi-year R&D program, considers the entrained flow method to have strong potential for industries to produce cost-effective synthetic fuels from wood on a large scale. Many companies are located near large supplies of cheap, easily obtainable wood, and it would be advantageous to them to convert their energy systems to biomass fuels, if this were economically attractive.

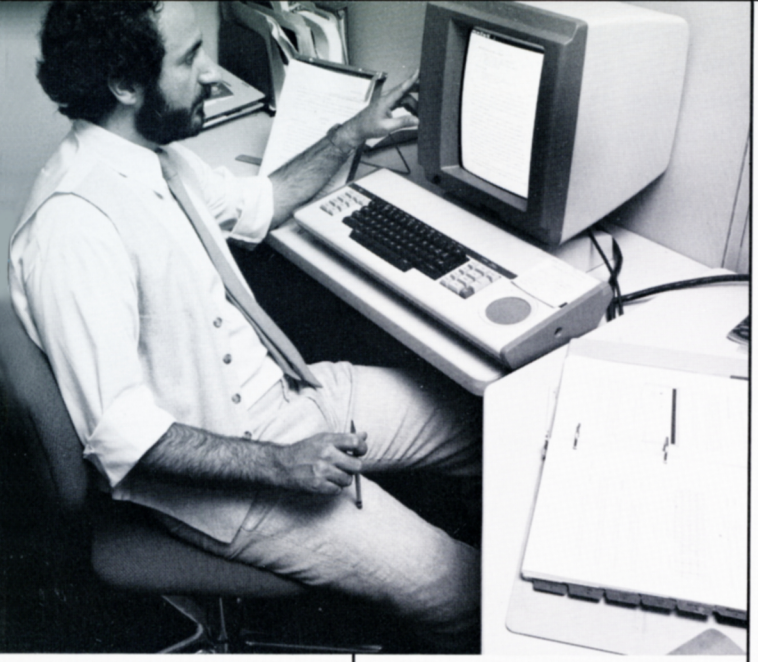
Entrained flow pyrolysis is promising enough that future research is likely to determine whether conversion ratios can be optimized when other types of biomass materials are used. There also is a strong possibility that the pyrolytic oil produced by such a system can be processed into a usable synthetic diesel fuel.

Other 1982-83 biomass research programs focused on:

- Pyrolysis of an African species of wood chips in a vertical bed pyrolysis plant to establish operating conditions for producing charcoal, pyrolytic oil and gases.
- Development of a testing facility for wood and other solid fuels to provide fuel characterization services to industries.
- Evaluation of biomass fuel supplies for Army ammunition boiler plants.
- Completion of a multi-year wood energy program involving 34 industrial feasibility studies and two on-site boiler installations to help industries convert to wood energy systems.
- Development of a thermochemical method for disposing of tars and other effluents produced during gasification of biomass feedstocks.



(Above) This EES entrained flow pyrolysis unit is being tested for its ability to produce synthetic fuels from wood on a large scale. (Left) The Station is developing a thermochemical method for effluent disposal during gasification of biomass.



Economic Analysis

(Above) Station economists have developed a computer model to help utility companies forecast energy consumption patterns in major cities (below) and residential areas.

Last year, economic analysts at the Station improved a computer model which makes detailed forecasts of long-term energy consumption patterns. The volatility of today's energy market makes a tool like this invaluable to utility companies in staying abreast of changing trends in electrical power demand.

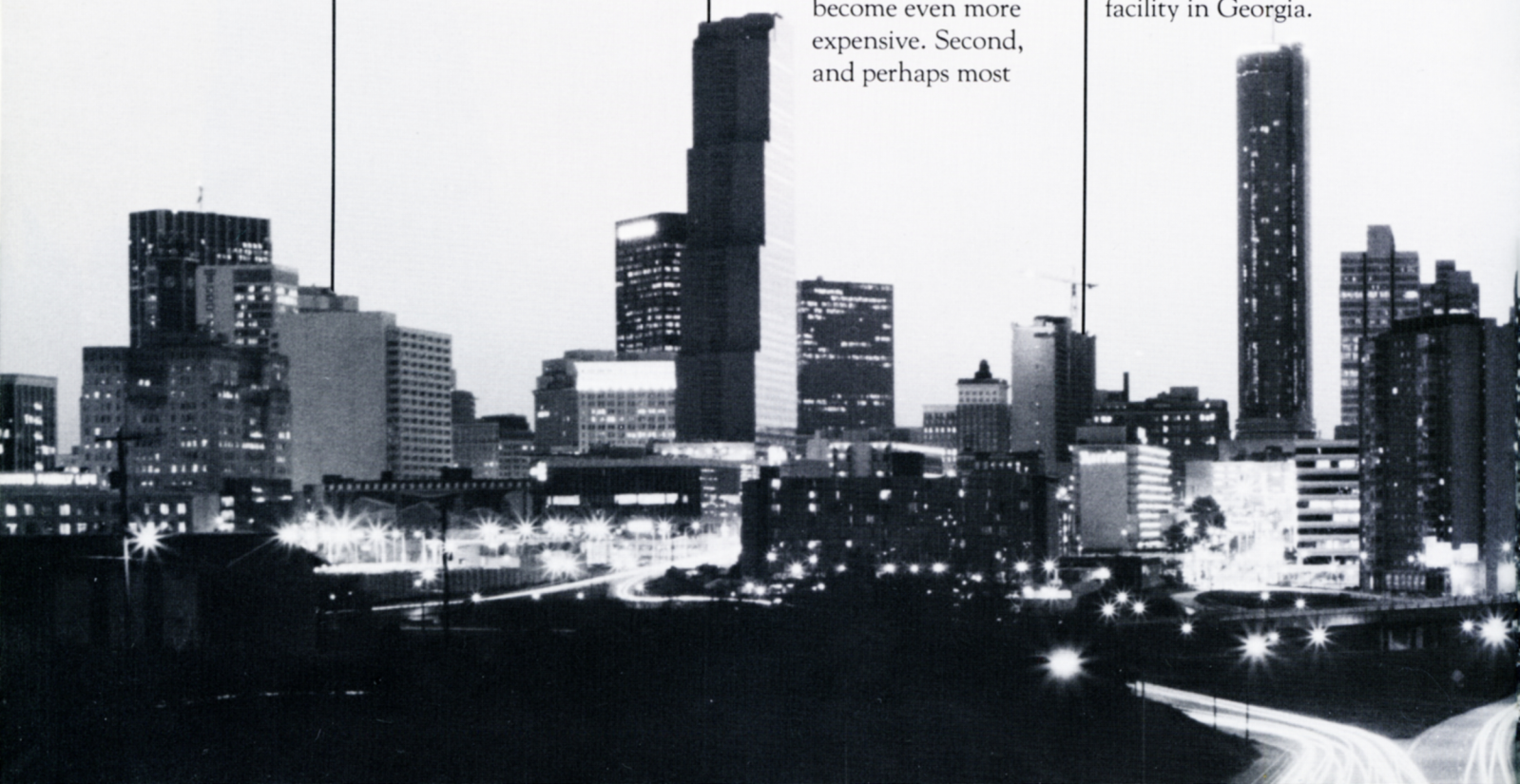
The model's most distinctive component is its ability to project the amount of electricity which consumers will need for a variety of purposes. In 1982-83, EES researchers developed a new feature which simulates the choices people make when buying electric space heating systems. Until recently, the demand for space heating was low enough not to figure significantly into overall projections of utility company load growth.

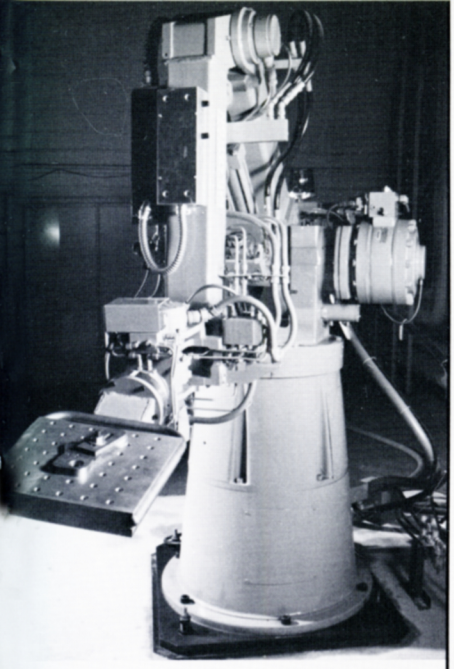
The EES forecasting model is aiding utilities in two very important ways. First, it is helping power companies to assess whether they must build new generating plants. This decision has become increasingly vital because the cost of building these facilities has become even more expensive. Second, and perhaps most significantly, the Station's model offers utilities good information for developing conservation strategies designed to forestall the need for new generating capacity.

Last year, EES readied this model for broad distribution to American utilities by making it easier for operators to use and more adaptable to a variety of computer systems. Current research is focusing on improvements in the data bases from which the model's predictions are derived.

In 1982-83, economic analysts at EES were also concerned with:

- An environmental impact study of increased use of biomass-derived energy in the southeastern United States.
- Project feasibility study and development of investment training materials for the United Nations Industrial Development Organization.
- Development of computer models to analyze the market penetration of coal technologies and heat pumps.
- Assessment of the socio-economic consequences of constructing a nuclear power facility in Georgia.





Industrial Extension

Most small companies lack the experience to guide them when they introduce high-technology processes into their operations. Such was the case when a South Georgia manufacturer of agricultural machinery decided to purchase an industrial robot in 1982.

EES field engineers helped this manufacturer survey the marketplace and select a robot best suited to its needs. After consulting with robotics experts on the Georgia Tech campus, these field engineers helped the company to design an efficient method for using its new robot.

In this developmental process, EES engineers helped the firm:

- Draw layouts for moving materials to and from the robot.
- Select a feed mechanism for the system.
- Obtain components for a gripper which holds materials being worked on by the robot.
- Locate a source for an analog control module which monitors the performance of the robot and orders it to stop work if there are deviations from acceptable standards of quality.

The robot is now installed at the company plant, where it feeds metal into a heat treating furnace and welds machine parts used in agricultural plows. For human operators, this work is fatiguing, repetitive and hazardous, but the robot's performance is not affected by these factors.

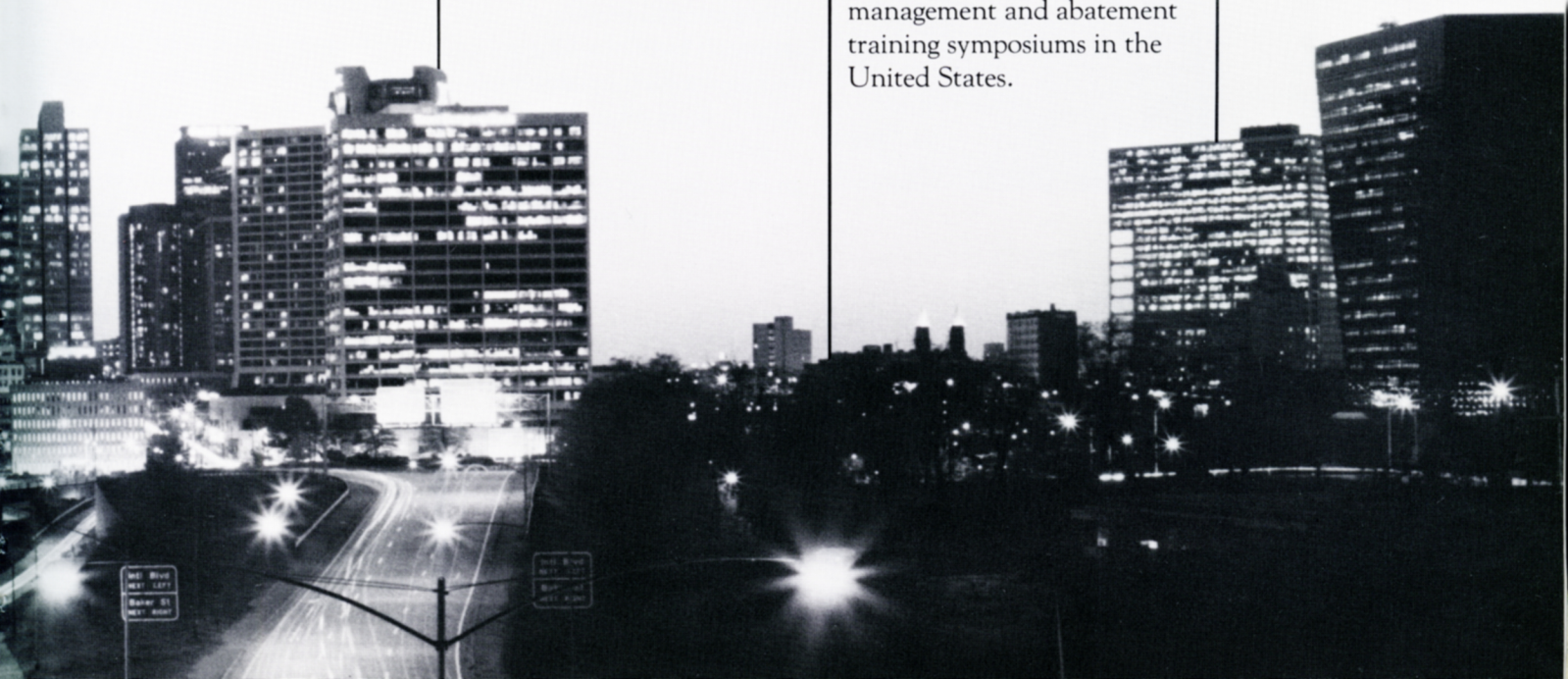
Work on this project continues, and it is already apparent that the developmental cycle is moving much faster because of EES' involvement.

This assistance was given free of charge by one of the Station's eight field offices in Georgia. Each of these centers is staffed by resident engineers whose mission is to help Georgia businesses and industries to solve productivity problems. In 1982-83, field engineers provided direct technical assistance 315 times and fulfilled 600 requests for technical information.

Examples of other notable 1982-83 industrial extension programs were:

- Design of preventive maintenance management programs for a heavy equipment manufacturer and the Marine Corps.
- Completion of a five-year technical and management assistance program which helped an apparel manufacturer to increase sales by $9 million.
- Engineering and technical assistance involving various aspects of manufacturing and product testing for Hayes Microcomputer Products, Inc.
- Presentation of one of the first multi-course asbestos management and abatement training symposiums in the United States.

Field office services range from (top center) selecting an industrial robot for a Georgia manufacturer to (above) consulting with a high technology firm on production and product testing. (Photo reprinted with the permission of Hayes Microcomputer Products, Inc.)



Agricultural Research

Last year, EES introduced two new technologies to the poultry industry. (Above) A home computer system for keeping better flock and financial records. (Top Center) The EES-designed electronic data processing system for tracking and reporting condemned birds.

Computer applications in agriculture have expanded significantly in recent years, but little has been done to give individual poultry farmers greater access to these technologies. EES took an important step in this direction last year, when poultry industry specialists set-up an inexpensive computer system on a Georgia poultry farm for demonstration and research. The project was done in cooperation with the Georgia Poultry Federation.

Engineers from the Station first interviewed poultry processors and farmers to determine the kinds of information which need to be computerized for growout houses to function more efficiently. This survey also focused on the best form for this information to be presented to farmers on a computer system.

Processing plant managers reported a need for computer systems which monitor feed bin levels in growout houses as well as environmental conditions such as ammonia concentration, temperature and moisture levels. Farmers indicated that computerized record-keeping would help them maintain flocks properly and keep better control of their finances.

EES researchers identified commercially available computer software programs which could help keep track of financial information and flock records. New software programs were developed to meet special requirements. The Station also identified inexpensive and commercially available computer hardware to meet these needs. Equipment was installed on a North Georgia poultry farm, and since the demonstration program began, a number of refinements, additions and improvements to the system have been made.

Work also began in 1982-83 to install and evaluate environmental sensors on a research farm of a large, Georgia-based cooperative.

Other significant agricultural engineering programs concentrated on:

- Development of an electronic data processing system for tracking and reporting condemned birds in poultry processing plants.
- Evaluation of a rotating biological contactor as a cost-effective technology for use in treating wastewater from poultry processing plants.
- Continued development of an energy integrated dairy farm employing anaerobic digestion of biomass for electric power and waste product utilization systems.

International Development

In 1982, EES began a $6.6 million program to establish an industrial extension service for Egypt. This organization will be modeled on the Station's field office network in Georgia, which is recognized widely for its effectiveness in bolstering industrial productivity through expert technical assistance.

Egypt is attempting to upgrade its industrial base, and one essential building block in this process is providing companies with quality technical information and assistance. In the industrialized world, these resources have built up gradually over several centuries and are now taken for granted. But in developing nations, technical data and guidance are often severely lacking.

In early 1983, EES sent three industrial engineers and an information specialist to live in Egypt for the next several years. The team of researchers is guiding the Egyptians in setting up their industrial extension service, which will be known as the Industrial Technology Applications Project (ITAP).

ITAP will seek improvements in industrial practices currently in use in Egypt, and introduce new technologies deemed adaptable to the country's economic climate. Georgia Tech's researchers are arranging for consultants in Egypt and the United States to work on industrial problems which are troublesome to a broad range of Egyptian companies. They also are organizing training programs in Egypt and America for industrial managers and Egyptian staff members of ITAP.

The EES information specialist is developing ITAP's inventory of technical information. This phase of the project is crucially important because economic development specialists have discovered an empirical correlation between ease of access to technical information and a nation's level of industrial productivity.

Other highlights of the Station's international development efforts in 1982-83 included:

- Obtaining a $2.6 million contract to introduce alternate energy technologies to villages in Sudan, Africa. Other objectives are to reduce the nation's dependence on oil imports and excessive use of trees, which promotes desert encroachment.
- Training local laborers to install and maintain water pumps for safer drinking water in Tunisia, Ecuador, the Philippines, Honduras, Haiti and Indonesia.
- Construction of a testing facility for water pumps which are distributed by the Agency for International Development to help Third World countries obtain safer drinking water.
- Continued technical assistance and training in industrial extension for the Korean Credit Guarantee Fund.

(Left) An EES technical assistance team is helping Egypt to set up an industrial extension program similar to the Station's field office system. (Above) An EES engineer trains Haitians to install the U.S. AID hand pump for safer drinking water.

Dr. Donald J. Grace
EES Director

EES & ITS LABORATORIES

EES is organized into eight laboratories. Five conduct electronics research. Three laboratories focus on alternate energy, energy conservation, economic analysis and development, industrial assistance and chemical and materials sciences. For more information on specific programs, contact:

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