

1981 ANNUAL REPORT



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

ABOUT EES

The Engineering Experiment Station (EES) is a Georgia Tech center for applied research and development which serves its sponsors on a non-profit basis. Administratively, EES reports to Georgia Tech's vice president for research. All research contracts are administered through the Georgia Tech Research Institute, a non-profit Georgia corporation which supports Tech's research program.

During 1981, EES continued its traditional missions, while extending its services to Georgia and a variety of clients throughout the nation and overseas. Its staff of engineers and scientists performs about two-thirds of all the research done at Georgia Tech, an institution which ranks second among all U.S. colleges and universities in engineering research and development expenditures. Academic units perform the other third of Tech's research work.

The Georgia state legislature created EES in 1919 to promote engineering and industrial research for the benefit of the state. In 1960, its mission broadened and the Station now:

- Participates in national programs of science, technology and preparedness;
- Promotes business and economic development in Georgia, the United States and overseas;
- Encourages the utilization of Georgia's natural resources; and
- Provides technological support to the state's industry and local governments.

EES has become an increasingly important national resource for applied research. In 1981, the Station continued to provide research leadership in areas such as alternate energy, industrial development, millimeter wave technology and electronic defense.

Cover Photograph:
This solar reflector is
being used in
radar antenna studies at EES.

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One year into the new decade, the Engineering Experiment Station is well-positioned to meet the unique technological needs of the 1980's. A half century of growth in applied engineering research has given the Station a broad base of expertise to address many of today's pressing problems.

On the national level, our leaders are paying closer attention to the quality of America's military defenses, and they are turning increasingly to EES for sophisticated electronics systems.

America's troubled economy requires innovation to revive itself and the Station has worked hard to stimulate high technology manufacturing, an industrial sector which is growing rapidly in Georgia and the U.S. today.

Pivotal to the quest for economic recovery is the effort to reduce fossil fuel consumption in this country. EES is a leader in alternate energy research, having developed new technologies to convert wood into synthetic fuels and to make solar energy a cost-effective option for industry.

The environment created by modern technology is also a concern of ever-growing importance, and EES is active in this area, whether its engineers are helping

employers to meet government safety regulations or designing computer systems to make nuclear power plants safer.

As this capsule description suggests, research at EES is highly diversified. A variety of new technical thrusts has begun at the Station in recent years and 1981 was a period when this rapid growth stabilized. While EES research programs grew less rapidly in 1981 than in the previous several years, actual funding still rose 14 percent during the year to a level of \$36.7 million.

That EES continued to grow at all during this time of national economic and political uncertainty is due in large measure to the Station's dedicated and highly motivated staff. I am deeply grateful for their contributions to the continuing research enterprise at Georgia Tech. This booklet is a summary of their accomplishments during the last year. □

Donald J. Grace

**Dr. Donald J. Grace, Director
Engineering Experiment Station**

Research and Development Growth

EES research income rose to \$36.7 million last year, an annual growth rate of 14 percent.

In 1981, the Station growth rate in sponsored personal services (salaries and wages) was 14 percent. Approximately 560 new research awards during the year boosted EES' overall income to \$36.7 million, an increase of \$4.5 million since FY 1980. Contracts and grants from private industries and government agencies accounted for \$31.3 million of the Station's total income. Interdepartmental services provided \$1.4 million and the State of Georgia's allocation rose \$400 thousand to \$4.2 million. This state money funded a variety of research and development projects.

Staff-generated proposals topped all previous records for the second consecutive year. EES staffers wrote more than 875 new contract proposals valued in excess of \$118 million.

Last year, 72 percent of EES' total research effort involved elec-

tronics programs, while staff research on the nation's natural, human and manufacturing resources accounted for 28 percent of the Station's activities. That ratio changed only slightly from FY 1980, when the breakdown was 70 percent electronics and 30 percent resources.

Program growth and losses were spread evenly over a number of areas in 1981. In the resources laboratories research expanded

moderately in solar and alternate energy; energy conservation and applications; and physical, chemical and materials sciences. Economic development and technical assistance programs comprised a smaller percentage of the Station's total work. In the electronics area, research grew slightly in antennas, electromagnetics and optics as well as computer technology and applications. Funding for electronic systems, electronic techniques and components as well as electronic defense remained proportionately the same as it was the previous year. □

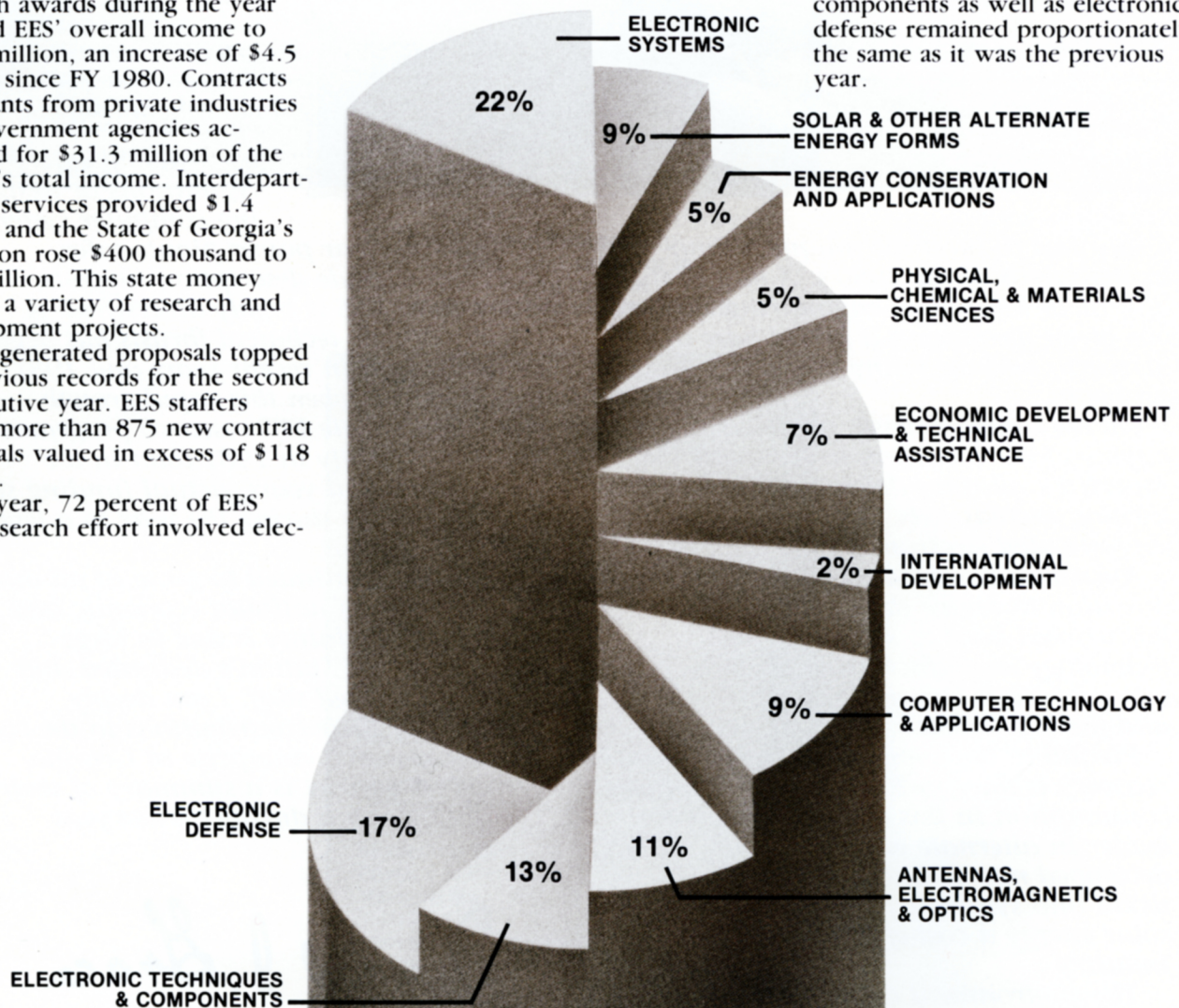


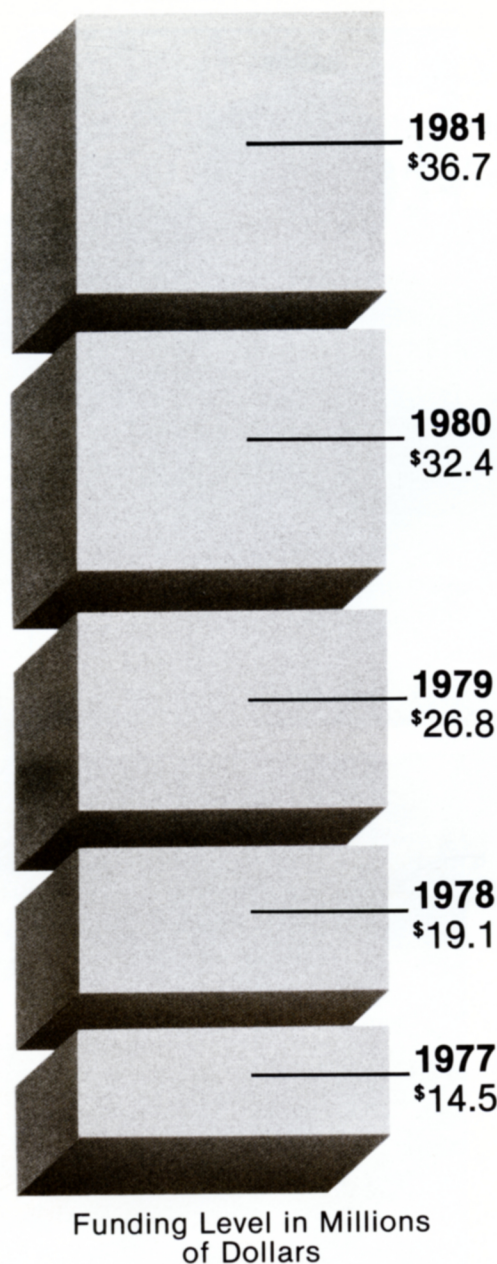
Figure 1
EES 1980-81 SPONSORED PERSONAL SERVICES
Distribution by Research Areas

New Technical Thrusts

1981 was a year when significant new research thrusts emerged at the Station.

In electronics, EES is a nationally recognized leader in radar systems, millimeter-wave technology, and near-field antenna research. It is perhaps the foremost university research center in electronic defense. Significant new capabilities are emerging in a variety of electronics specialties, including: digital image processing, high-temperature testing of materials for antenna windows and radomes, microwave imaging in biomedical research, nuclear safety, fiber optics, geoprocessing, computer modeling and analysis of complex mechanical structures, and man/machine interfaces. During the year, the electronics laboratories began gearing up for new and expanded thrusts in infrared devices, electronic defense simulation, very-large-scale integrated circuit design, defense mobilization, embedded computer systems, robotics, and molecular beam epitaxy. EES also established a field office to support the Tactical Air Warfare Center at Eglin Air Force Base. The Station already maintains a field operation in Huntsville, Alabama.

In 1981, EES enhanced its already prominent position in the energy field by initiating a new program in entrained pyrolysis and gasification of biomass, continuing development of the GIT wood-to-ethanol process, and planning for a major new solar thermal advanced research center on the Tech campus. The Station began a study of energy-integrated farming as a new thrust in its nationally recognized



Funding Level in Millions of Dollars

Figure 2

FIVE-YEAR FISCAL GROWTH IN EES RESEARCH VOLUME

program of R&D in energy conservation and alternate energy technology. Other significant programs focused on market penetration and impact studies of technologies with potentially large effects on future energy-use patterns. Important steps began to upgrade EES capabilities in materials research and chemical and environmental sciences. □

Sponsors

The Department of Defense was a major research sponsor at the Station last year.

In 1981, federal government contracts continued to fund more than three-quarters of EES' sponsored research. The level of funding was 77 percent, a decrease of 2 percent from the previous year. The Department of Defense provided the largest share of government contract work at the Station at 54 percent. The figure was 3 percent lower than it was in 1980. Within the Department of Defense, Army and Air Force contract volume declined slightly while Navy research, still comparatively small in total dollars, increased almost 40 percent. Contract funding from NASA and the Department of Energy continued to drop, and last year both sources together accounted for 3 percent of the Station's sponsored research.

The level of industrial support remained at 16 percent, while state and local government sponsored 7 percent of EES' research during the year, an increase of 2 percent. □

Services to Georgia

In 1981, the Station continued its legislatively mandated effort to improve economic productivity in Georgia. The most significant new milestone in this program was EES' continuing support of the state's new Advanced Technology Development Center (ATDC). The Center was organized to stimulate high technology industrial growth in Georgia. The ATDC was placed on the Georgia Tech campus so that client companies can take advantage of the Institute's many technological resources.

Part of the ATDC's program is to provide assistance and incubator facilities on the Tech campus for fledgling entrepreneurs with commercially promising ideas. EES is conducting technical reviews for each application for assistance and these evaluations are the basis for the ATDC staff's decisions to support an entrepreneur's product development.

EES backing of the Center includes other services. Station administrators are helping to guide the ATDC through its initial phases of growth. EES also has allowed the ATDC to use equipment for its entrepreneurial program and the Station's field offices have actively promoted the Center throughout the state.

Besides its help to ATDC, Station engineers provided important services for Georgia through existing programs of assistance to businesses and industries. Some of the accomplishments were as follows:

- Approximately 150 companies received assistance through EES' Southeastern Trade Adjustment Assistance Center to help them counter the adverse effects of foreign competition.
- Business eliminated around 270 serious hazards through the Station's voluntary Occupational Safety and Health Program. This service helps businesses and industries to comply successfully with government safety & health regulations.
- The Station helped 34 minority businesses and inventors with product ideas and assisted seven of that number in getting their products well on the way to commercialization. The Technology Utilization and Commercialization Center



Top left, Microcompatible Inc. uses Georgia Tech space through the Advanced Technology Development Center, an organization EES helped to begin in 1981. Top right, EES economic development specialists make a health and safety inspection. Below, visitors tour Southcon '81, a major electronics show in Atlanta which EES helped to promote.

was responsible for this work.

- The Station provided information or direct assistance to Georgia firms in 807 cases and made 735 industry visits through its network of field offices in Augusta, Gainesville, Savannah, Douglas, Rome, Macon, Albany and Carrollton.

- EES continued a \$300,000 state program of technical assistance to the Georgia poultry industry in the

areas of energy conservation, alternate energy technologies, noise control, wastewater treatment and computer applications. This program was funded by the Georgia legislature for this specific purpose and was directly responsible for EES attracting an additional \$135,000 in industrial grants and federal matching funds for poultry research. □

Major Activities

Last year, EES agreed to manage a major R&D center in Ireland.



Above, an Irish delegation tours EES research facilities before a news conference announcing the Station's affiliation with a new R&D center in Ireland. Below, Japanese visitors are given a demonstration of the Station's geoprocessing capabilities.

helped to host the largest electronics convention ever held in the Southeast. Southcon '81 attracted more than 10,000 persons to the World Congress Center in Atlanta and EES personnel offered extensive assistance in promoting the conference and carrying out its technical programs. Southcon will take place annually and organizers hope it will enhance an already-booming electronics industry in the Southeast.

EES engineers secured more than \$1 million in funding to develop an innovative system to produce syn-

thetic liquid fuel from biomass. This entrained pyrolysis unit shows promise for cost-effectively converting wood to synthetic gas in the large quantities needed by industry. The Station also enhanced its standing in the field of solar energy research by securing a contract from the federal government to conduct a wide range of solar thermal R&D work over the next five years.

The Station delivered to military sponsors two separate mobile radar systems whose combined budgets totalled more than \$9.5 million. Design work began on another radar system which ultimately is expected to involve a \$9.5 million effort. Additionally, EES received an \$8.2 million contract to develop several integrated special-purpose radars. This contract, signed shortly after year's end, is the largest in the Station's history. EES also received \$1.4 million as part of a continuing effort by the Air Force to develop an active radar disruption system.

Though the Station closed its field office in Manila, Philippines, during 1981, contacts with Asia continued to be strong. EES administrators visited Japan last year and groups from Japan and other Asian nations toured research facilities at Georgia Tech, too. □

During 1981, EES concluded lengthy negotiations with the Republic of Ireland, resulting in an agreement for Georgia Tech to organize and manage the new European Research Institute of Ireland (ERII) for ten years. ERII is jointly supported by the Irish government, industry and university organizations as well as by foreign industries operating in Ireland. ERII's main purpose is to complement and strengthen the high technology industrial thrust of Ireland while providing R&D services primarily to European clients. The Institute will be supported in accomplishing this objective by its direct access to the Georgia Tech research community. In turn, EES' participation in this new research institute will give Georgia Tech a valuable window on the Western European contract research market.

Another activity of major consequence was the establishment of the Advanced Technology Development Center (ATDC) on the Georgia Tech campus. The Center received extensive assistance from the Station in support of its mission to stimulate the growth of high technology industries in Georgia. More detailed information on the ATDC is contained in the "Services to Georgia" section of this report.

In January 1981, the Station

Challenges of 1981

Office and laboratory space for researchers continued to be critically short at the station.

One of EES' largest challenges in 1981 was maintaining a stable cadre of research professionals. Staff turnover of full-time professionals increased last year. The Station's administration undertook studies to understand the reasons for the trend and upgraded recruiting efforts. The net number of full-time EES employees — 528 research professionals and 221 support staff — rose by only one during the fiscal year. This is an important development to address since staff size and research volume are inextricably linked.

Space remained a critical issue during last year. At the close of FY 1981, EES occupied 372,976 square feet of office space, actually 1,780 square feet less than at the beginning of the year. During 1981, EES relinquished 21,810 square feet of off-campus leased space in the C&S Tower and the Atlantic Steel Building and gained 20,030 gross square feet of campus space in the newly renovated O'Keefe Building. Renovation of part of the Hinman Building enabled the Station to accommodate some of the personnel moved from Atlantic Steel. □

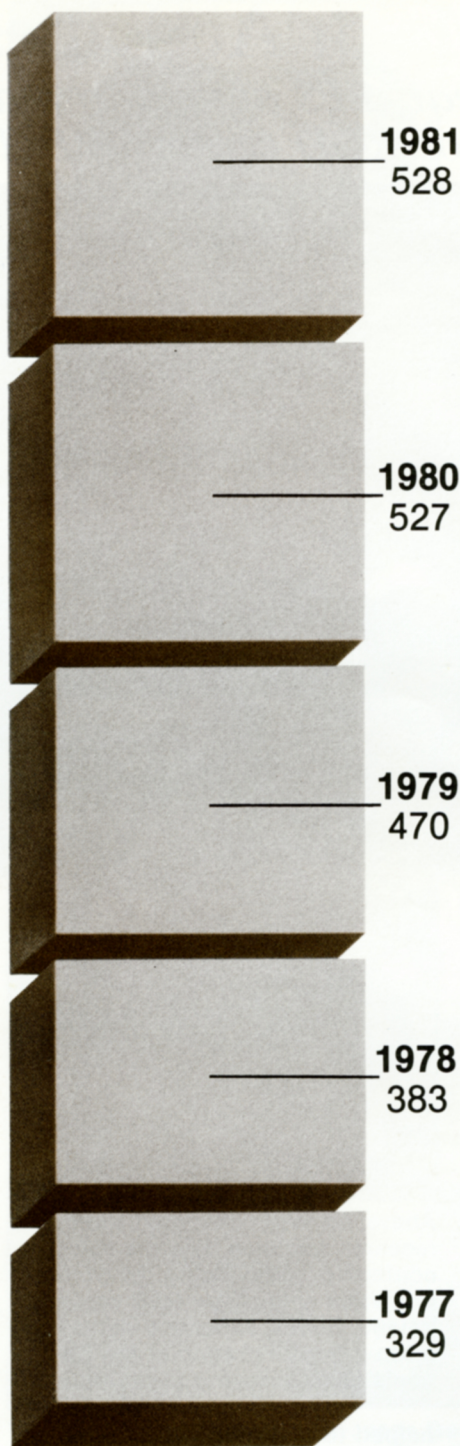


Figure 3
FIVE-YEAR FISCAL GROWTH
FULL-TIME
RESEARCH PROFESSIONALS

Future Outlook

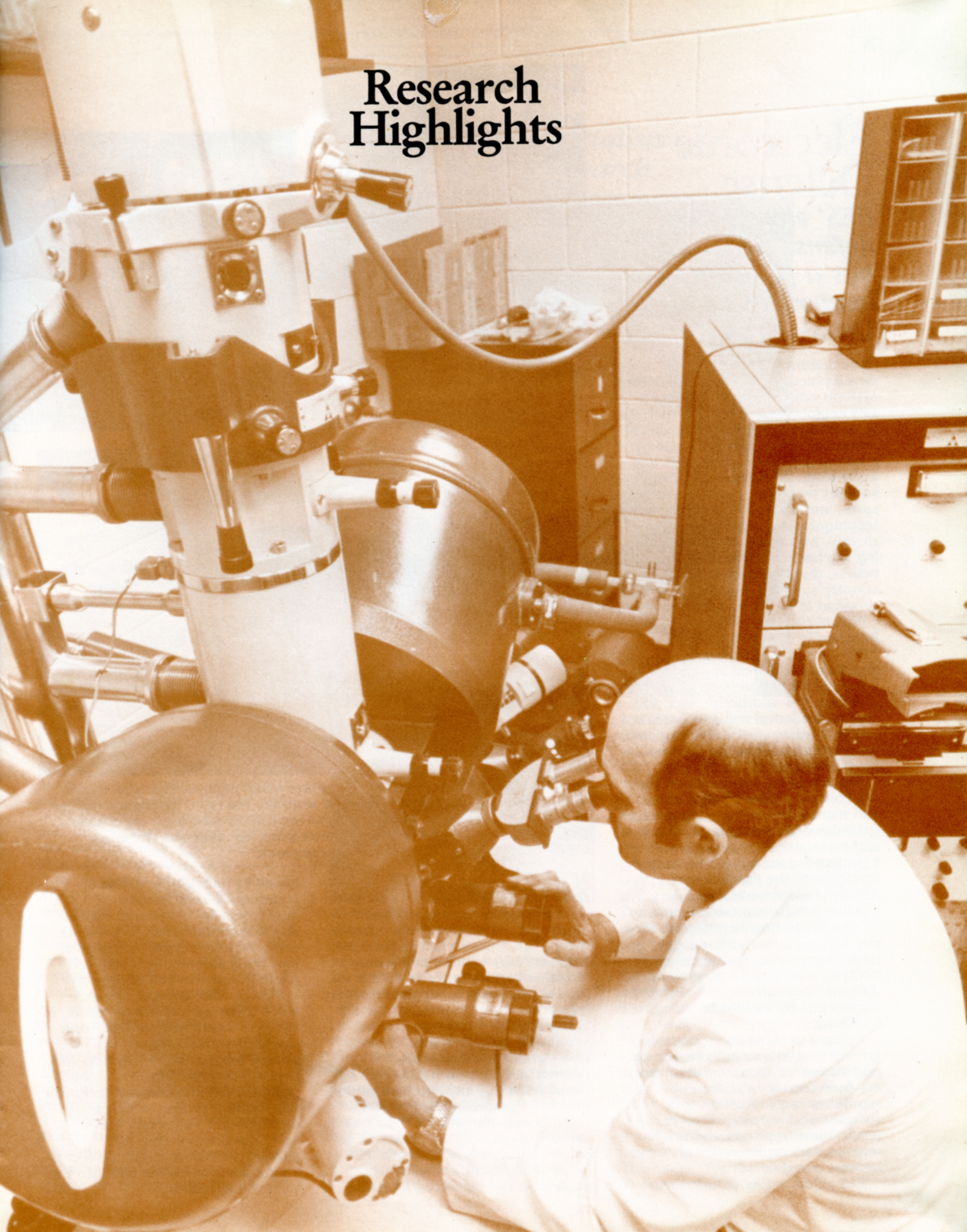
If real growth is to resume at previous rates, space will continue to be one of the Station's most pressing problems. EES will need about 50,000 square feet of additional high-quality R&D space every year to meet growth projections over the next five years. The current geographical dispersion of EES units and subunits hampers interaction, and leasing costs absorb dollars that could be spent more effectively on research. To meet the Station's long-range needs, a new building is necessary. EES is exploring innovative means for financing the development of additional long-term space with the Georgia Tech administration and the Chancellor's office.

A shortage of middle-level managers still exists, and the Station continues to seek ways to recruit top-flight researchers and provide management training for present staff. EES needs to hire an estimated 150 new professionals in FY 1982 to fill new positions and replace departing personnel.

EES must acquire sophisticated and expensive R&D equipment if it is to keep pace with the requirements of sponsors and remain competitive with other research institutes. The Station also needs to expand internal R&D efforts. As research activities continue to grow in number and complexity, the need becomes more urgent for a quick-response, semi-automated management information system.

With the increasing uncertainties in the Federal R&D programs, the need to elevate the state allocation above its present level is evident. Though the allocation has steadily risen in terms of actual dollars, its buying power has effectively declined. The ever-diminishing proportion of the state allocation to total volume prevents growth of services to Georgia and reduces the matching funds and seed money available for developing new programs. As a non-profit institution, EES does not generate reinvestment funds. For this reason, the Station needs outside investment monies from the state for improved facilities, equipment and space if it is to continue expanding. □

Research Highlights



Electronic Defense

EES' electronic defense program has a position of leadership in the United States.

The Station is a leader in the development of electronic defense systems which protect our nation. EES engineers have broad expertise in specialized radar systems which an enemy might use against our country. EES continually uses its knowledge to develop electronic support measures, countermeasures, and counter-countermeasures techniques to defend against these threats. As a result of its work during the last several years, many believe that the Station has this country's leading university-based program in electronic defense.

EES maintained a highly varied program in concepts analysis in 1981. In one major project, engineers developed and analyzed concepts for suppression of enemy defenses. For another project, EES applied analytical tools to predict cruise missile survivability, satellite vulnerability and future radar and missile trends.

EES researchers also helped the Air Force to optimize chaff, flare, and maneuver tactics which protect specialized aircraft from air-to-air and surface-to-air missile assault. In a project for the Navy, the Station investigated the feasibility of missile guidance and control systems which minimize exposure of missiles to hostile jammers. EES also formed a multidisciplinary team of psychologists and engineers to study tracking errors induced in manually operated tracking devices by various jamming techniques.

An area of significant program growth in 1981 was electronic support measures. One important project demonstrated the feasibility of significant improvements to a special radar warning receiver. As a result, quick reprogramming of mission data on aircraft will become possible.

EES enhanced its countermea-



Top left, EES maintains a transient digitizer which digitizes high speed radar pulses and formats them for computer analysis. Top right, the Station has the capability to construct computer graphic replicas to solve a variety of electronic defense problems. Below, EES now owns two airplanes which are available for a variety of airborne test programs.

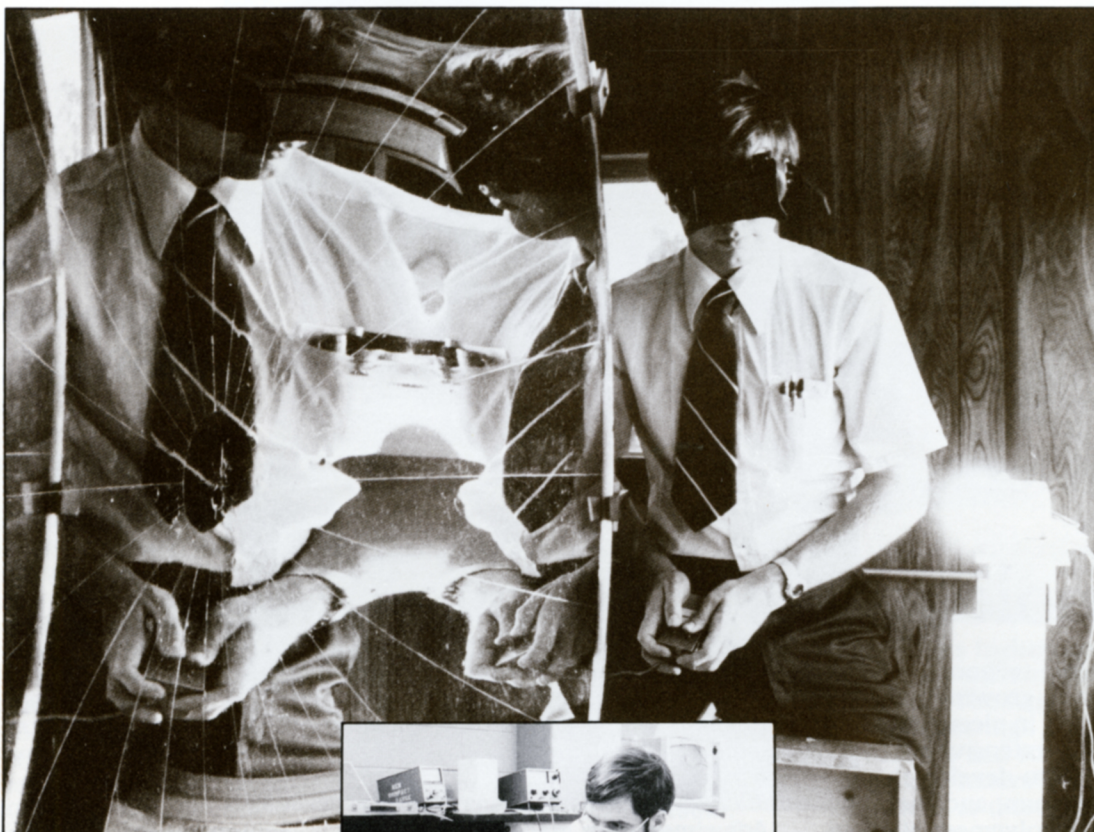
asures research capabilities by acquiring a second airplane for flight testing and system integration of electronic countermeasures equipment. This Convair C-131 joins a Convair T-29 which the Station already owns. At present, EES is using the airplanes in support of a long-term research program aimed at developing a radar disruption system for the Air Force. The Station's airborne electronics laboratories have shown exceptional reliability thus far: out of 85 missions comprising nearly 300 flight hours only one mission was cancelled and only one delayed. In other countermeasures work, EES helped the Navy determine the vulnerability of selected American

radars to potentially hostile countermeasures systems. Engineers also developed expendable countermeasures to protect Army helicopters and designed a lens array antenna for enhanced countermeasures jamming power.

Finally, EES' defense systems work involved a continuation of an effort to implement an Electronic Countermeasures Signal Analysis System for the Warner Robins Air Logistics Center. The Station also provided engineering and technical support in a project which is developing a VLSI (Very Large Scale Integration) chip for military application. The project is a significant move for EES into the VLSI research area. □

Antennas

NASA is using antenna specialists at EES in Space Shuttle research.



Last year, EES performed research projects involving design, analysis, fabrication, testing and siting of antennas. Antenna systems for adverse environments continued to be a Station specialty, but the variety of problems addressed in this area increased and greater emphasis was paid to design and development than in previous years.

In one major program for the Army Research Office, EES developed analytical methods for estimating interference problems which occur when antennas of different frequencies operate from common geographic sites. Related to this effort was a project which measured radiation characteristics of conventional parabolic antennas at several out-of-band frequencies. A specialized computer system developed for this research will allow antenna performance to be described statistically and modeled for correlation with actual antenna performance.

Another EES program for NASA is developing a measurement system for determining the elec-



At top, EES is conducting radar antenna studies in high temperature solar energy environments. Below is equipment for testing space shuttle tiles which protect antenna arrays.

trical performance of thermal protection tiles on the Space Shuttle. The tiles under investigation protect antennas on the orbiter which are used for telemetry and communications. EES is comparing the tiles' electrical characteristics before and after flight to determine if re-entry renders them ineffective in protecting Shuttle antenna systems. NASA hopes to develop an

instrument to determine whether tiles have been damaged in flight without having to detach them from the orbiter. The Station's work is part of this program.

In 1981, EES also began to evaluate the performance of a Luneburg lens antenna for an industrial sponsor. The Station will encapsulate the antenna, mount it, and provide it with receivers and a specialized feed network. The antenna will then be installed in an aircraft for use at a missile test range.

EES engineers also designed and built a new data logger system which permits antenna pattern data to be taken automatically for later processing. This system is the first EES has developed which is adaptable to general antenna pattern range measurements. It can also be used for broadband antenna and radar cross section measurements.

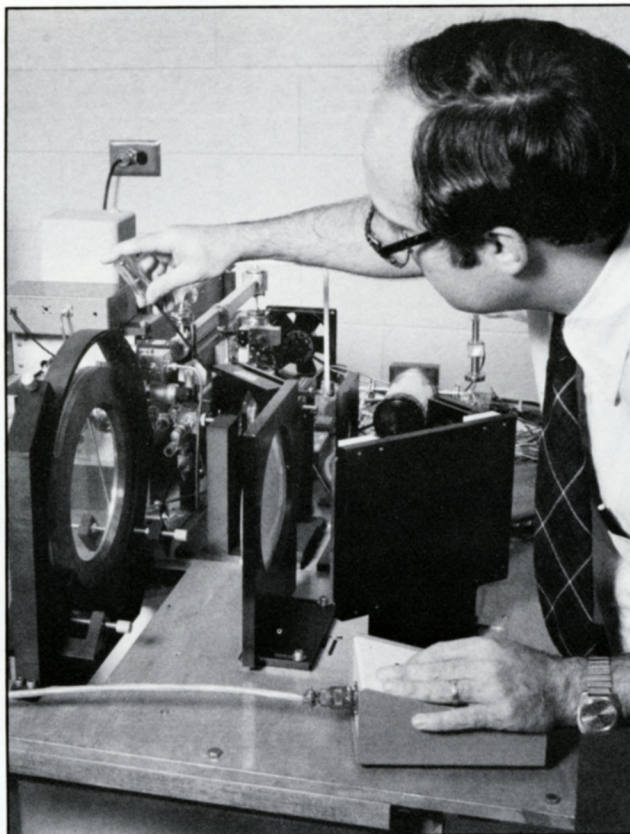
EES also delivered a large antenna that was designed and fabricated for an industrial sponsor. The budget for the program was more than \$1 million. □

EES has worked at the forefront in efforts to develop millimeter wave applications since the 1950's.

Millimeter Wave Technology

Millimeter wave technology is one of the fastest growing research specialties in electronics. EES has worked extensively since the 1950's to develop this part of the spectrum, and the Station's long involvement allowed it to perform a wide variety of applied and basic research in this field in 1981. Millimeter wave sensing devices lack the range of lower frequency instrumentation, however, they are highly effective at penetrating smoke and dust in poor propagation conditions common on battlefields and can identify targets with extremely high resolution. They also can be built in unusually small packages and manually carried. These characteristics make millimeter wave sensors advantageous in military applications such as missile guidance and detection.

Last year, EES was internationally recognized for millimeter wave modulator technology as well as



Adjustments are made to the world's highest frequency millimeter wave radar, operating at 225 GHz. The Station developed this radar and it will be used to test high frequency radar techniques and to obtain the first target and natural background signatures at these frequencies.

transmitter and receiver development. Work in these areas grew substantially, as Station engineers performed research programs for military clients in the U.S. and industrial companies overseas. EES also conducted a variety of studies of the reflectivity and propagation characteristics of millimeter waves. The Station delivered to the Army a Mobile Measurement Facility (MMF) which will be used to measure atmospheric propagation and target reflection parameters simultaneously at 94,140 and 220 GHz. In addition, EES worked on a

broad spectrum of millimeter wave antenna applications for radar, radiometry, direction finding and communications. The Station also designed and developed millimeter wave

equipment for the Army's use in investigating possible hazardous bioeffects. This research was deemed necessary because of the military's increasing reliance on electronics systems exploiting this area of the spectrum.

More detailed information on each of these program areas is presented in sections of this annual report which are dedicated to radar, radiometry and biomedical electronics.

EES also contributed to greater understanding of millimeter waves in the academic world. Researchers at the Station co-edited and authored several sections of a volume of the series, "Infrared and Millimeter Waves," on the topic, "Millimeter Systems." □

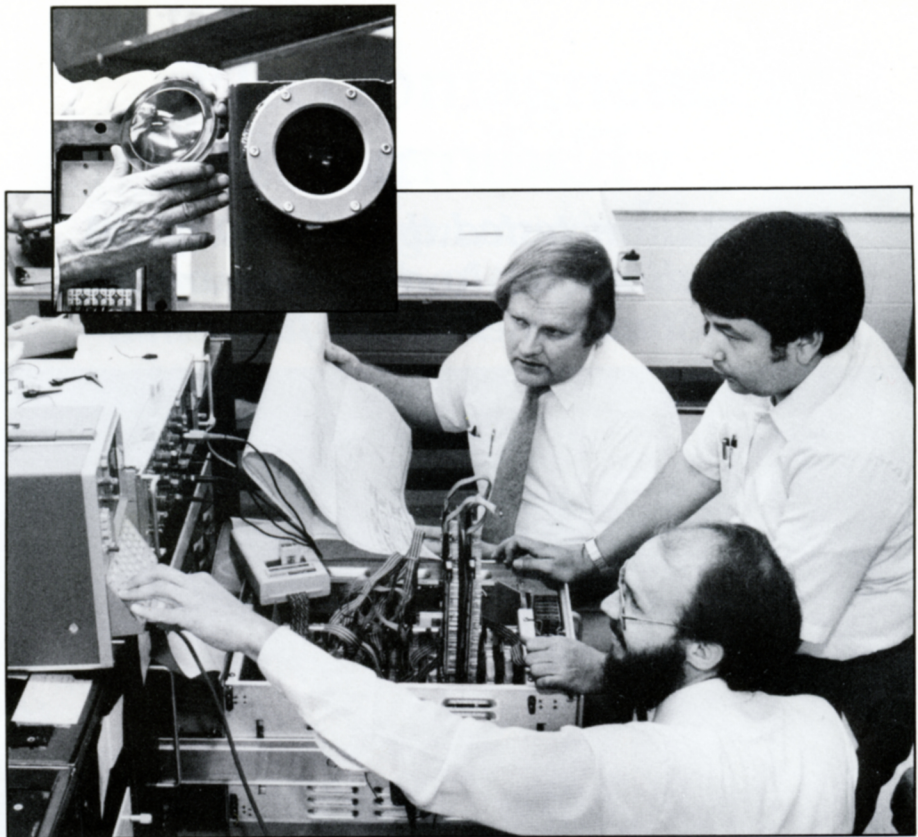
Radar

EES is developing one of the first coherent 95 GHz transmitters.

In 1981, EES radar specialists continued to stress millimeter wave technologies, radar signal processing techniques and experimental radar systems. The Station also worked in modeling, simulation, security system development, and law enforcement radar.

Investigations of high power transmitter technology highlighted EES's millimeter wave program. During the year, the Station continued development of one of the first coherent transmitters to operate in the 95 GHz range of the spectrum. Data reduction and analysis programs continued along with efforts to measure the propagation and reflectivity characteristics of millimeter waves in military environments. In one noteworthy project, EES performed target/background signature measurements with a Station-developed tracking radar and transponder. Another research project concluded with the delivery of millimeter guidance instrumentation to the Army Missile Command.

Research in radar signal processing techniques emphasized military applications. However, a number of large industrial companies sought EES help in this area during the year, and several contracts resulted from this interest. Engineers assessed the effects of extremely high speed logic technology on radar system performance and investigated fiber optics in several applications, including a fiber optical phase shifter network



Top, the Station developed an enclosure and antenna for a radar application to help miners excavate coal by remote control. Bottom, EES made progress in 1981 in the development of this Advanced Surveillance and Tracking Radar.

for use in phased array antennas. EES made progress in the development of the Advanced Surveillance and Tracking Radar (ASTAR), a fieldable radar system capable of demonstrating new concepts in signal processing and techniques for identification of friend or foe. The Station also used radar to detect non-metallic mines, highway voids and stationary targets. In another project, engineers developed a prototype radar sensor which coal mining operators may employ to guide excavating machinery by remote control.

EES maintained its national reputation for designing, developing and fabricating certain types of experimental radar systems. In 1981, the Station delivered two different mobile radar systems, one to the Air Force and the other to the Army. The budgets of these two programs totalled more than \$9.5 million. Design work began during the year on still another system for the Air Force, one which is expected to cost more than \$9 million. In addition, EES developed

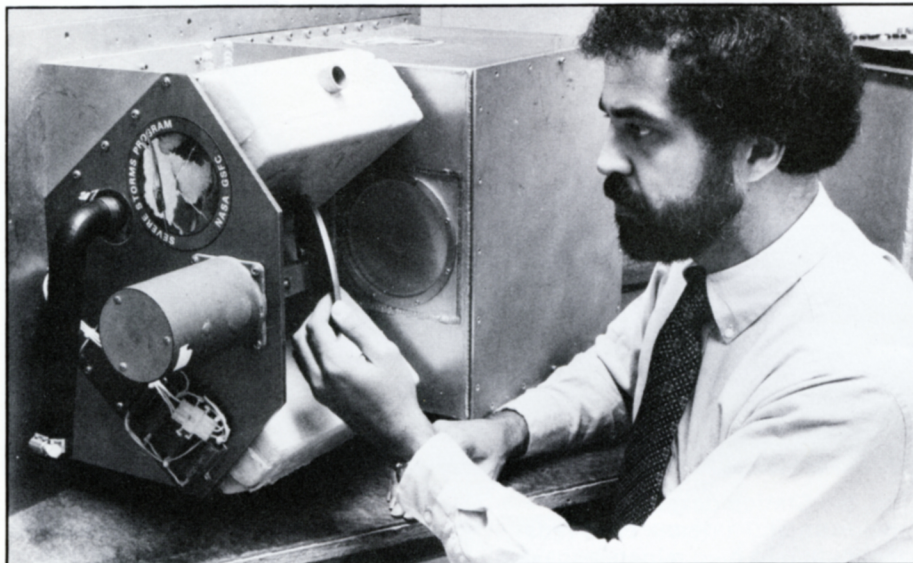
the world's highest frequency millimeter wave radar, operating at 225 GHz. The Army will use this radar to test high frequency radar techniques and to obtain the first target and natural background signatures at these high frequencies.

The Station also applied radar techniques to a variety of civilian and military security systems. Applications were under development in 1981 for protection of nuclear material processing plants from airborne terrorists, security at MX missile deployment sites, detection of potential waterborne invaders at nuclear plants and surveillance of airborne smugglers carrying contraband materials. In addition, EES worked on a national program to help train law enforcement officers to properly use speed-timing radar.

Applied research in modeling expanded, particularly in projects relating to the protection of naval ships. In the area of simulation, a major contract ended with the completion of a closed loop flight simulator which will enhance the capability of the military services to evaluate the effectiveness of electronic countermeasures against missiles. □

Radiometry

The Station tested the ability of an EES radiometer to detect ice on the Space Shuttle's external fuel tank.



The Station continued to develop radiometers to predict and track thunderstorms last year. This Advanced Microwave Moisture Sounder was used by NASA for several data-gathering missions.

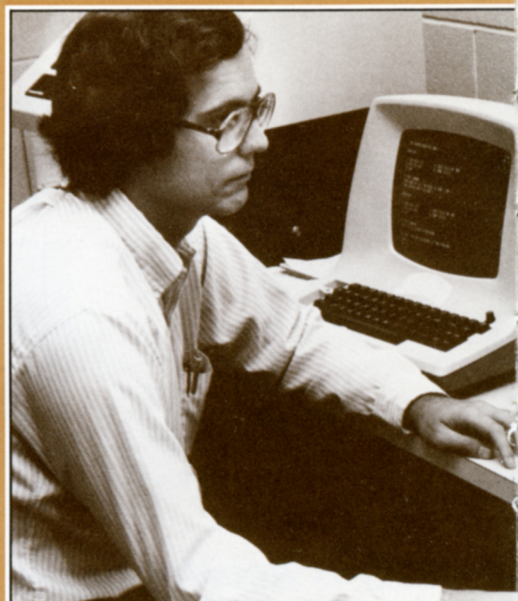
Only a few American research centers maintain programs with more activity in radiometry applications than the Station. EES engineers specialize in radiometric sensing devices which exploit the millimeter wave region of the spectrum. U.S. government agencies sponsor most of this work for defense-related and scientific purposes.

A 35-95 GHz instrumentation radiometer developed at the Station was used extensively last year. One program tested the ability of the radiometer for detecting ice formations on the Space Shuttle's external fuel tank. NASA currently uses computer models to predict weather conditions which allow such icing. The EES radiometer is one instrument under investigation to provide actual detection of ice accumulations. The tests took place at NASA's Space Technology Laboratory prior to the first Space Shuttle launch. The same radiometer was also used for passive detection of hidden targets at 35 GHz and for target location

measurements using the transmission window at 220 GHz.

Another radiometric project resulted in a 140 GHz radiometer for the Naval Research Laboratory. This device was successfully flown on the P-3 aircraft during sea surface measurements near Virginia and Hawaii. Ongoing work for this agency includes the integration of a 220 GHz front end into the existing radiometer in preparation for future P-3 flights.

One prominent meteorological application during the past year involved the use of the Advanced Microwave Moisture Sounder in NASA's WB-57F high-altitude research aircraft during two data missions. The Florida Area Cumulus Experiment from Cocoa Beach, Florida, and the Cooperative Convective Precipitation Experiment from Fargo, North Dakota also worked with the Sounder. EES delivered a complete set of data tapes for future data analysis to NASA/Goddard Space Flight Center following these experiments. □



Infrared/ Electro-Optics

Last year, EES' infrared/electro-optics research program served the needs of the military through projects involving modeling, simulation and systems analysis.

In one significant modeling study, EES engineers used electro-optical techniques for target acquisition. Modelers devised systems such as the IR Maverick and the Pave Tack as part of an Air Force effort to predict the performance of equipment in a variety of battlefield weather conditions. EES also modeled non-imaging missile seekers presently in use, particularly threat systems. The purpose of this research was to evaluate the survivability of U.S. aircraft in the face of attack by air-to-air or ground-to-air missiles.

One significant systems analysis program showed possible applications of advanced infrared focal plane arrays. This technology may be useful in air-to-air and air-to-ground missile seekers. EES helped General Electric to assess the effectiveness of focal plane array technology in its InSb detector. The Station also investigated electro-optics techniques for identifying friend or foe. The U.S. Missile Command is attempting to develop a system to determine whether incoming aircraft are hostile or friendly without cooperation from these planes. EES is studying the possible application of an infrared CO₂ laser for accomplishing this objective.

Electromagnetic Compatibility

EES' electromagnetic compatibility program is one of the few centered at a non-profit institution.



EES electromagnetic compatibility specialists are using this antenna to study radio signal penetration of buildings.



Above, an artificial geographic scene is produced by computer graphics. Below, a researcher uses this quasi optical network analyzer for reflectivity measurements.

Through one important simulation project, the Station developed a background clutter model with three-dimensional capability. This model generates synthetic scenes with statistical characteristics of real scenes, which may be viewed from any geometry and include concave or convex surfaces as well as hidden objects. The model may also incorporate multiple illuminating sources for diffuse reflection or self-emission modeling. Targets, buildings or other natural or manmade clutter objects may be inserted with an orientation anywhere in these scenes. This model allows full simulation of varying depression angles, range closure and fly over. □

Increasing levels of electromagnetic energy in the environment have made studies of electromagnetic compatibility more and more important. EES has been a forerunner in this discipline for many years and its research program grew significantly in fiscal 1981. Areas of major activity included program management consultation, device technique development and analytical assessments.

One highlight of EES' consultation activities was an assessment of the electromagnetic compatibility needs of future systems operating at millimeter wavelengths. Another program evaluated state-of-the-art measurement techniques for incorporation into existing military standards. Other consultation work determined the relative need for a test bed capability to investigate electromagnetic pulse effects on

communications systems. EES also critiqued Navy-wide capabilities and procedures for testing electromagnetic environmental effects.

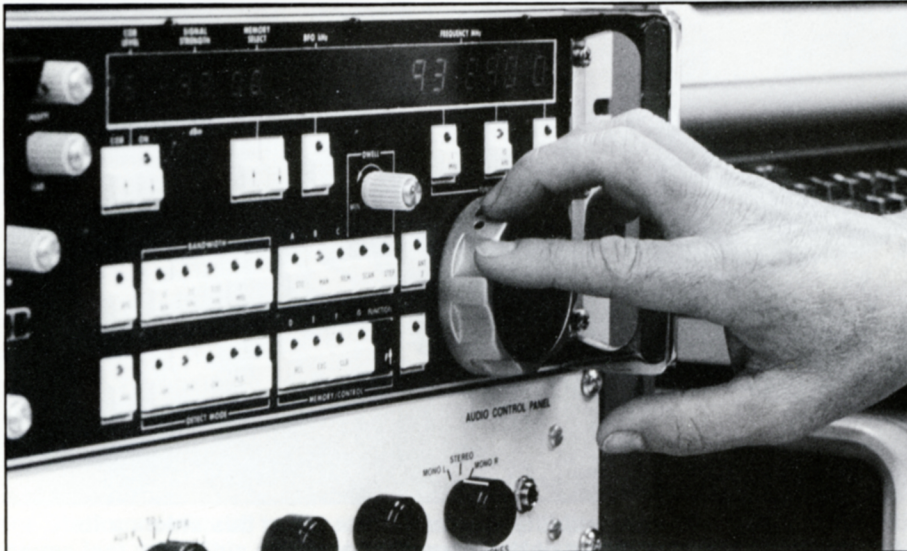
Engineers working in device and technique research developed devices and/or procedures for detecting, locating and suppressing potential interference-causing electromagnetic signals. Of particular interest in 1981 were active programs to develop an electronically variable time delay for the Air Force, investigate the location of RF arcs on ships and study the nonlinear properties of RF cables.

Last year, the Station performed an analytical assessment of the electromagnetic energy-gathering properties of long wires under various conditions of grounding. EES engineers also investigated the shielding properties of undersea cables for the Navy. □



Communications

EES is developing methods for the Army to select tactical communications architectures.



Basic program thrusts in communications research did not change last year. EES continued to specialize in the conveyance, disruption, location and interception of information. The Station provided assistance in systems applications; surveillance and disruption; communications technology, theory and policy; evaluation of command and control systems; test bed development; and creation of decision support systems. Most of EES' clients in this research were defense contractors.

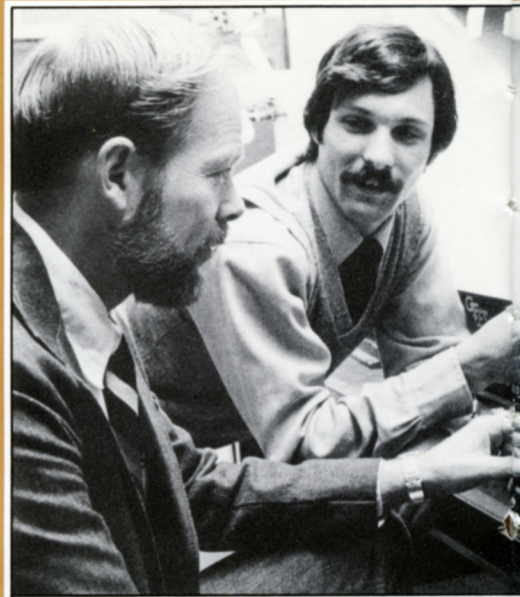
Significant military programs included the continuation of a three-year Basic Ordering Agreement with the U.S. Army Signal Center at Fort Gordon, Georgia. Another defense-related program evaluated the effectiveness and developed methodologies for selection of alternative tactical communications architectures. EES researchers also completed a project which provided the Army with a program guide for investigating research

EES has developed data acquisition equipment to help the Federal Communications Commission monitor radio stations for compliance with rules and regulations.

issues which will be critical in the development of information systems after 1985.

Non-defense research in communications included a program for the Tennessee Volunteer Electric Cooperative on problems such as land mobile radio communications, computer-to-computer links and data acquisition.

Studies also continued on atmospheric electricity and the electromagnetic characteristics of thunderstorms. This basic research, which included extended data collection at remote sites, is sponsored by NASA and will result in improved understanding of severe storms. □



Computer Applications

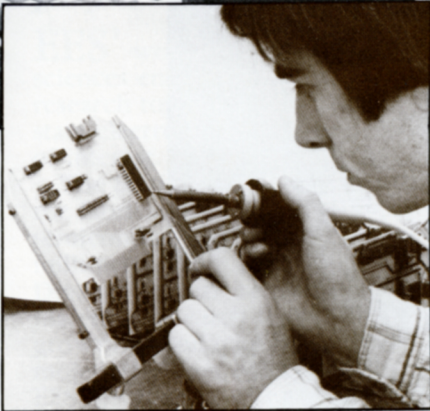
EES has expertise in devising new applications for existing computers as well as the capability to design and retrofit systems to meet special needs. In 1981, the Station reorganized its computer research program, and the most significant new thrust involved the application of existing military computer technology to the problem of nuclear safety. EES engineers developed a system concept for a nuclear plant control room as a prelude to a more extensive effort with nationwide implications. This system should simplify the work of control room operators and make accidents in nuclear plants less likely.

Microprocessor-based energy management systems also remained important at EES in 1981 as development and implementation of a campus energy management network continued. A major electronics firm has obtained rights from Georgia Tech to modify and market the network. The Station used its knowledge of multi-building energy control networks to assist in forming new specifications for military energy management systems. EES did related work for industrial sponsors such as General Electric and Burns International.

Security systems and reconnaissance were other areas for which the Station developed computer applications last year. The Station worked to design a Navy-sponsored Waterborne Intrusion Detection

Command & Control

The Station is helping sponsors keep abreast of rapid advances in computer technology.



Above, the Station has developed an innovative power line modem which allows computer information to be sent over power lines in two directions. Below, a printed circuitboard is fabricated at EES.

System which could protect nuclear power plants from attack by water. EES also provided a computer-based data collection and analysis system for a military security program. In addition, engineers at the Station wrote the software for a reconnaissance device on the U2 plane.

Through internally-sponsored research, EES developed its capabilities in geographic data base systems and image analysis, a computer technology which should be in heavy demand from military and civilian sponsors in the near future. To meet this need, the Station has established a research group which uses computer data bases to build displays of geographic information on an electronic video screen. Applications include almost any phase of land use planning. In one continuing program sponsored by NASA, EES and the University of Georgia work cooperatively to present two short courses per year on innovative techniques for earth resources data analysis using Landsat-generated information. □



Over the past decade, computers have come to play a significant role in improving the capability of our military commanders to make timely and more meaningful decisions. However, when the government attempts to secure current information management technology, it usually relies on the same process used to obtain large weapon systems. Ten years or more often pass from establishment of a command and control system requirement to attainment of a capability. Computer and information management technology is progressing so fast (in cycles of about five years), that systems being fielded are two generations behind what is in the laboratory and one generation behind what the general consumer is enjoying.

In 1981, command and control researchers at the Station took two steps to improve this acquisition problem. First, EES conceived and promoted Advanced Experiment Demonstrations (AED's) which bring the command and control system developer, user and researcher together early in system

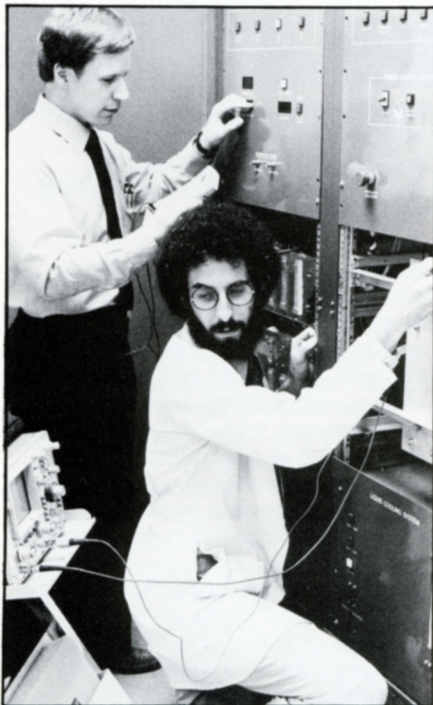
Command and control specialists at EES help sponsors make the appropriate use of computer technology for a wide spectrum of information systems.

conceptual development. Each party is encouraged to participate in an evolutionary cycle.

The Station also has undertaken projects with state-of-the-art commercial technology to show the military user how to apply available desk-top computers as command and control decision support systems. Examples include:

- Use of personal-type computers to support the Airborne Warning and Control System (AWACS) planner in tactical flight planning.
- Use of color graphics and friendly user interfaces (touch panel) for control of energy management control systems.
- The linking-up of micro-computers in a local network which disseminates information faster and allows decision makers who are physically separated to achieve a common understanding of a situation. □

EES is developing techniques and instrumentation to use radiation in medicine beneficially.



Above, EES is developing equipment to test rodents for the bioeffects of long-term exposure to low levels of radiation. Below, the Station has built hardware which measures the effect of neuro-chemical drugs used in medical treatment on brain enzymes.

Biomedical Electronics

Since World War Two, scientific and engineering breakthroughs have resulted in electromagnetic radiation of ever-increasing frequencies. EES is performing research to improve understanding of the effects of this radiation on organisms. Engineers at the Station also are developing techniques and instrumentation for beneficial application of radiation in medical treatment. EES has attained international recognition for its work in both of these areas of biomedical research.

In 1981, the Station investigated several possible bioeffects of radiation. One study explored the differential consequences which can occur when the blood-forming system is exposed to pulsed and CW non-ionizing radiation. Researchers also designed and developed a new illuminating technique for determining if low levels of non-ionizing radiation can adversely affect organisms over long periods of time. Each of these programs is yielding information to aid in setting improved personnel

safety standards. EES engineers in another project continued to analyze the electromagnetic performance of cardiac pacemakers last year. Their work should help industrial manufacturers to design improved heart pacemakers.

The Station's attempts to exploit radiation for beneficial medical purposes involved four programs. In one, engineers developed high-power equipment for enzyme inactivation studies. This research is potentially valuable in assessments of the effects of drugs on the brain. EES also developed and used computerized instrumentation to measure complex electrical properties of living tissues. Another program tested a technique for thawing frozen tissues safely. If successful, this work could make large organ transplants more feasible on a broad scale. The Station also investigated the varying dielectric properties of normal and cancerous tissues. This research may result in improved early diagnosis of certain types of cancer. □

Physical Sciences

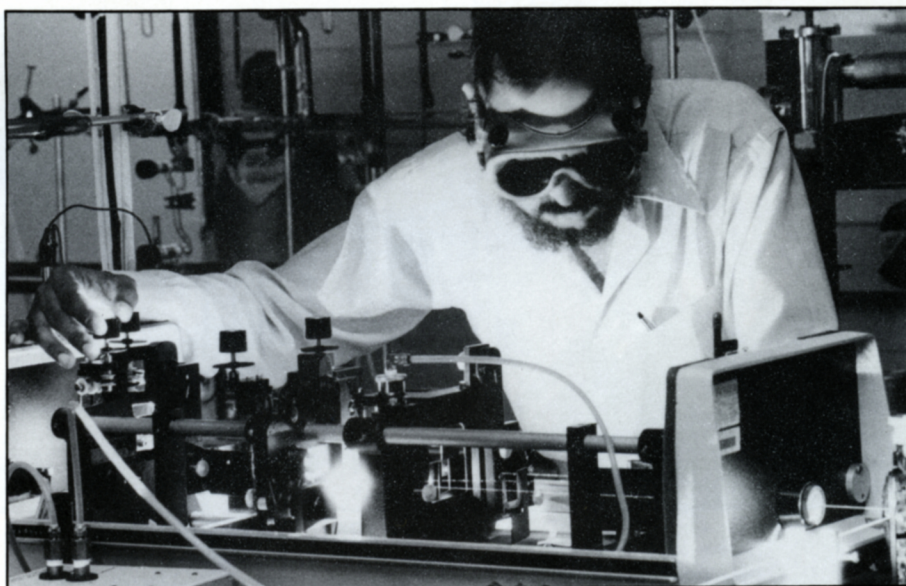
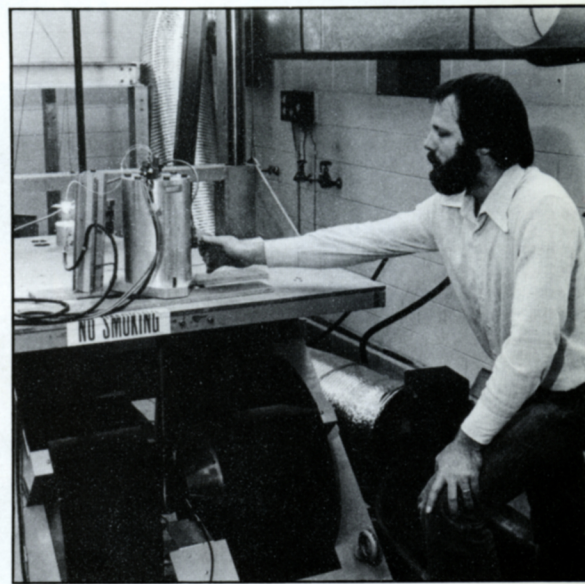
Solid state electronics is a major area of EES expertise in the physical sciences.

EES' work in the physical sciences encompassed a variety of research topics in 1981, with solid state electronics as the primary area of interest.

The Station is heavily involved in the fabrication of advanced semiconductors for microwave and millimeter wave solid state devices. During the year, semiconductor materials research focused on the growth of epitaxial layers by molecular beam epitaxy (MBE), and EES researchers investigated both III-V and II-VI compound semiconductors. A detailed study of InP epitaxial layers began, and researchers characterized electrical and structural properties of these epitaxial films for a wide range of growth conditions. Basic research continued for the fifth consecutive year in the development of new growth techniques for III-V compound semiconductor materials. This program emphasized the growth and characterization of ternary and quaternary materials and heterojunctions. A related project involved the development of millimeter wave gallium arsenide IMPATTs using the Station's MBE capability. IMPATT diode chip-level power combining, an area of established excellence at EES, continued at 40 GHz. The object of this research is to attain the high transmitter power levels required by military systems. Station engineers successfully combined two 40 GHz IMPATTs with a combining efficiency of 82 percent. EES now is working to achieve similar results consistently with beam-lead connected devices.

Other research thrusts in the physical sciences involved:

- **Reactor Neutrino Physics.** EES supported a National Science Foundation program to measure the neutrino spectrum at the nuclear reactor at the Savannah River Plant. The results of this experiment will



Top left, EES' solid state electronics program specializes in the fabrication of semi-conductor materials and devices. Top right, a Station engineer adjusts a magnetometer used in hydrogen energy studies. Below, lasers like this one are used at EES to provide basic data about the operations of atmospheric chemistry.

help to resolve the neutrino oscillation controversy.

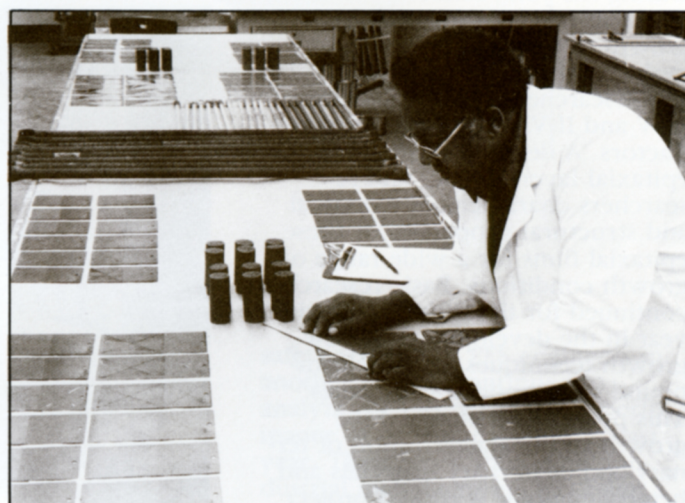
- **Tooth Enamel Studies.** The Station worked on a long-term effort to obtain new information about the atomic structure of human tooth enamel. EES is studying the effect on tooth decay of various atomic ionic species present in enamel.

- **Atmospheric Chemistry.** EES used spectroscopic and laser techniques to measure chemical reaction rates in the upper atmosphere. One outstanding result

of this work was a discovery which gave scientists more accurate information for calculating ozone depletion projections.

- **Hydrogen Energy Technology.** Hydrogen could be an important source of energy in the future if adequate storage media are developed. Last year, the Station studied a variety of metallic compounds which effectively store hydrogen. Findings at EES should help other researchers to develop cost-effective hydrogen energy applications.

EES has reorganized and expanded its research program in materials sciences R&D.



Materials Sciences

1981 was a period of reorganization for materials sciences research at EES. Well-established programs in high temperature materials R&D, materials characterization and protective coatings development grew, and the Station initiated a major expansion in chemical and environmental sciences.

High temperature materials R&D remained one of the Station's best known capabilities. EES engineers used solar furnaces and a high energy laser to develop hardened antennas which can withstand the thermal stress of a nuclear explosion.

In 1981, EES continued to use an extensive collection of advanced instruments for materials characterization. One highly significant program involved evaluations of schools and industries for asbestos pollution of air and water supplies. EES also studied sealants which may effectively contain decaying asbestos insulation and conducted short courses on sampling and analysis of asbestos and asbestos-containing materials.

The Station's protective coatings program continued to expand and diversify. EES analyzed new coatings which have been developed for bridges to satisfy health and environmental regulations. The Station also established a computerized data bank with performance information for a variety of highway bridge coatings. Another important program resulted in the

Above, EES is internationally known for radome development. Below left, closely coupled plasma emission spectrophotometry is an innovative new capability at EES. Below right, EES is expanding its protective coatings program.

formulation of anti-fouling coatings with a tin-based polymer for use on Navy ship bottoms.

Last year, EES' chemical and environmental sciences group developed new capabilities to perform a wide range of studies on toxic wastes, amorphous materials and properties of halocarbons. Work also continued on a program in waste recycling, using wet oxidation technology, so that wastes from food preparation and the human body can be employed as plant nutrients on long-term space missions. □

Solar Research

In 1981, EES enhanced its leadership position in the solar research field by establishing a major center for solar thermal R&D on the Georgia Tech campus. In early FY 1982, the Department of Energy designated the Station as a Solar Thermal Advanced Research Center. Research activities for this center will focus on established areas of excellence at EES: high temperature materials development, solar receiver/reactor design and thermochemical reactions.

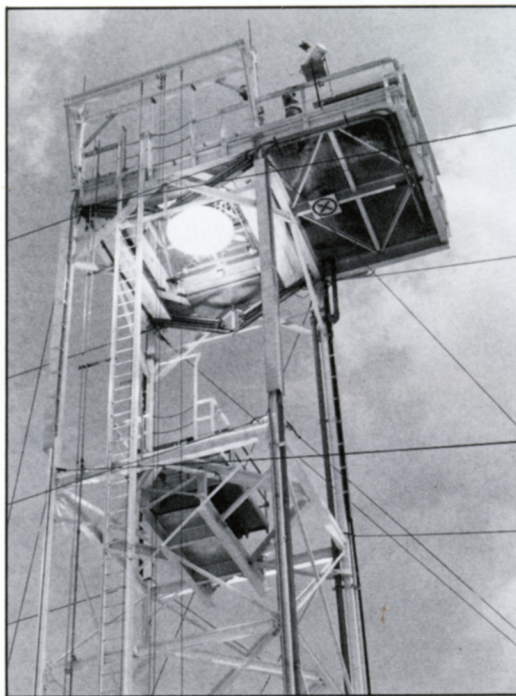
The Station's use of its central solar receiver, the Advanced Components Test Facility, changed

The Station began to put greater emphasis on R&D programs in solar energy last year.

significantly during the year. Prior to 1981, EES' principal function was to operate the facility as a test site for outside contractors. The Station de-emphasized this support role in 1981 and in-house R&D took precedence, with emphasis on production of chemicals and fuels using solar energy.

EES utilized its expertise in analytical modeling of solar hardware to develop a three-dimensional optical analysis program. This capability allows EES to develop and analyze a wide variety of concentrator designs. With EES' analytical modeling services, designers of solar equipment can easily modify and evaluate design changes at modest cost before actually fabricating components.

EES demonstrated solar energy technologies for the cooking and heating needs of several energy-



Top left is the solar thermal receiver EES operates on the Georgia Tech campus for the Department of Energy. Top right, the Station produced electricity when this engine developed by United Stirling of Sweden was exposed to solar energy. Below, a Station engineer works near the "hot spot" of the solar receiver.

poor African nations. Station engineers introduced to Mali and Somalia an easy-to-assemble and inexpensive solar concentrator invented by EES.

Plans began during the year to initiate systems development pro-

grams in solar photovoltaics, a technology which uses small silicon cells to convert sunlight into electricity. EES engineers concentrated on internally sponsored research to attain baseline knowledge necessary for future work in this area. □

Agricultural Research

Georgia's poultry industry has profited from EES' research program in agriculture.



In recent years, farms and agriculturally-based industries have grown increasingly dependent on modern technology. Since 1973, EES has conducted R&D projects which have focused on the particular problems of poultry processors and growers. This industry has a pressing need to upgrade efficiency but normally lacks internal R&D capability to tackle difficult technical problems. The State of Georgia gave the Station an appropriation of approximately \$300,000 in fiscal 1981 to conduct poultry industry research and the success of these programs attracted roughly \$135,000 more from federal and industrial funding sources. Last year, the Station conducted a varied program in energy conservation, alternate energy technologies, noise control, wastewater treatment, and computer applications.

The Station's noise control project was particularly notable. EES worked jointly with the Georgia Department of Agriculture and NASA to characterize the noise sources in two Georgia processing plants and devise a system of acoustical panels to reduce this noise to acceptable levels. In addition, the Station gave extensive at-

Above, the Station has designed and built innovative noise control panels for poultry plants. Below, an EES engineer takes a waste-water sample from a poultry processing plant.

tention to electronic systems which improve productivity on the farm and in the processing plant. Through one project, EES engineers developed a computer-based system so that broiler processing plants can monitor yields during the operations which remove inedible portions of poultry carcasses. This system gives plant supervisors a way to measure the efficiency of manual and automatic operations. The Station also continued to monitor four highly successful energy projects.

EES began to diversify its agricultural research program in 1981. The poultry industry continued to be its primary concern but engineers also began a four-year project to bring a Georgia dairy farm close to energy self-sufficiency. The Station is developing several alternate energy technologies for this effort, including anaerobic digestion, fuel alcohol production and an active solar energy system. □



Biomass Research

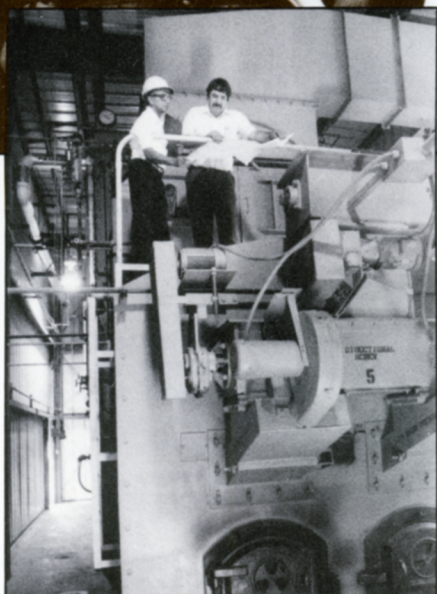
EES is a nationally-recognized center of excellence in biomass research and several major programs enhanced that reputation last year. The Station established the technical and economic feasibility of an advanced process for converting cellulose from biomass into ethanol and other chemicals. This technology could offer a method for producing ethanol-based fuels without reliance on food crops as feedstocks. Discussions are underway with private industry to construct a pilot plant for the "GIT Process" on the Tech campus and to commercialize the technology.

Supporting research and preliminary design work also began last year on a \$1.5 million research program to develop an entrained pyrolysis/gasification process unit for converting biomass feedstocks into liquid synthetic gases. This process has potential for use on a large industrial scale. It will convert biomass into syngas with high thermal efficiency, high material throughput and low emissions.

Work began in 1981 to make a north Georgia dairy farm energy self-sufficient, largely through on-site biomass energy systems. The first phases of this Department of Energy-sponsored program monitored farm energy consumption patterns to fix design parameters. In addition, EES engineers evaluated various technologies to determine their suitability for application on the farm.

Energy Conservation/ Applications

EES stepped up in-plant visits to industries in Georgia.



EES engineers helped a Georgia textile plant install a large, innovative wood boiler and wood handling system.

Station engineers worked intensively to show target industry groups the economic advantages of exploiting wood as fuel. During the past year, EES conducted joint feasibility studies with more than 15 industrial firms which wish to use wood fuels but lack access to expert analytical resources. The Station successfully developed a full-scale operating wood combustion system for use by two Georgia companies in 1981. It will allow firms to use wood residue fuels instead of oil. Other studies showed the technical and economic feasibility of large-scale, wood-fired cogeneration systems for an industrial authority and a military reservation. EES also began a major study of peat resources and conversion technologies available in Georgia. A different but related study is underway to assess the environmental effects of biomass-derived energy. □



The Station's program in energy conservation was wide-ranging in 1981 and served industries, homeowners, apartment managers, schools, poultry and dairy farms, poultry processors and electric utilities. These clients were primarily in Georgia, but EES also did work in the Tennessee Valley Authority region and other parts of the Southeast. The Station conducted conservation workshops, sponsored major energy conferences and published extensive educational materials. EES also addressed specific energy needs through computer applications, technical assistance, in-plant energy surveys, and energy demand modeling.

In 1981, EES stepped up in-plant visits to industries throughout the state. This change in emphasis allowed engineers to become better acquainted with special energy needs of industries. As a result of this effort, EES now is holding more workshops which address specialized energy problems.

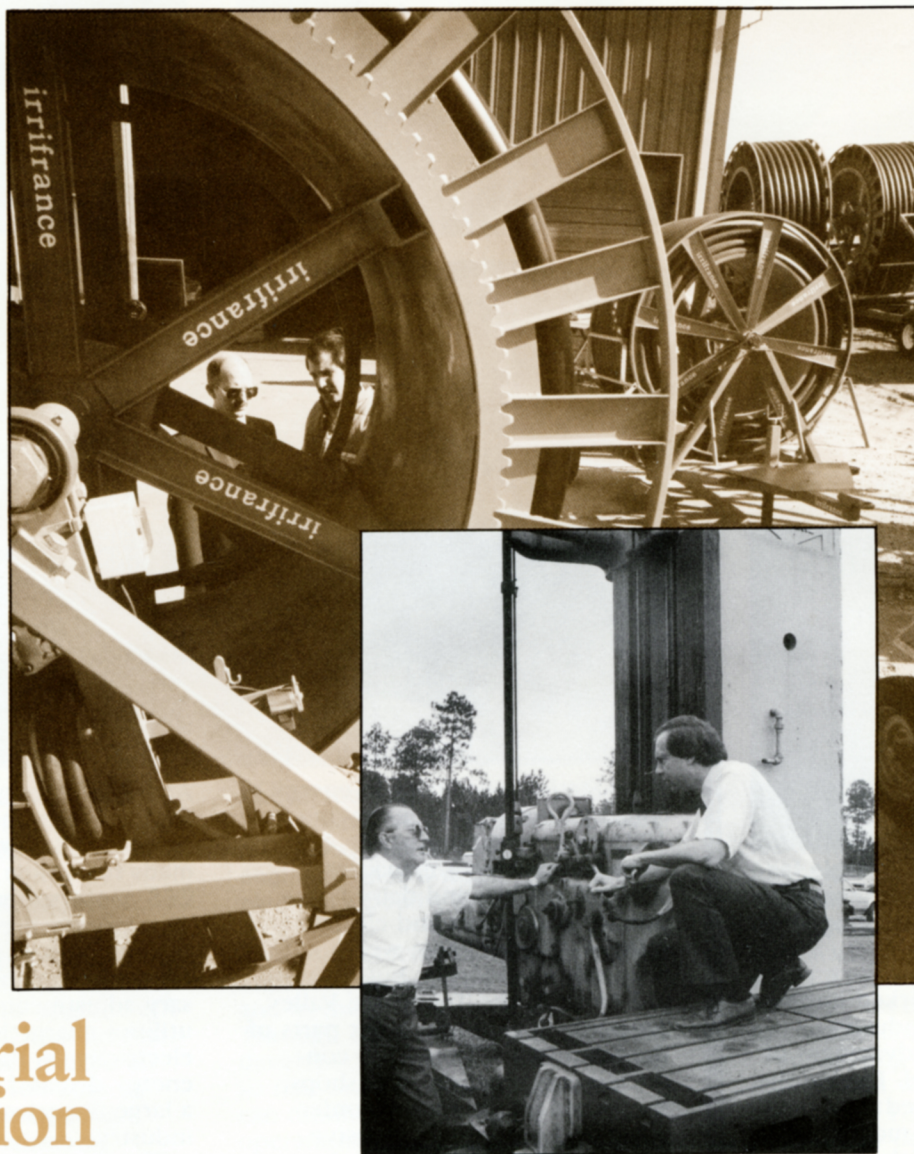
A growing area of energy conservation assistance at the Station last year was energy demand modeling, a technique which allows large energy users to

Above, an energy engineer from the Station measures electrical consumption. Below, preparations are made for a slide presentation at an EES conservation workshop.

document peak periods of power consumption and to make necessary adjustments. Since electric utilities charge industries for electricity on the basis of peak use, energy demand modeling can have a large impact on power costs in industry.

The Station continued to tap the potential of computer technology for helping to conserve energy. The best example of this work was continued development of an advanced facilities management system which monitors and controls electrical energy consumption in a number of buildings on the Tech campus. The most distinctive features of this three-tiered computer system are its easily reprogrammable software and its ability to monitor multi-building complexes. A major electronics manufacturer has contracted with Georgia Tech to commercialize this system. The technology is also available for other units of the University System of Georgia. □

The Station is Georgia's principal center for helping businesses and industry enhance productivity.



Industrial Extension

Small to medium-sized businesses and industries typically lack the staff to solve all of their technical and managerial problems. EES' industrial extension program offered valuable assistance to many of these firms, in 1981. Last year, the Station maintained field offices in eight Georgia cities: Augusta, Gainesville, Savannah, Douglas, Rome, Macon, Albany and Carrollton. Resident staff members at these offices were able to transfer technology to the state and to do so with a keen sensitivity to local needs. In 1981, these industrial extension engineers provided information or direct technical assistance to Georgia firms in 807 cases and made 735 industry visits.

In many instances, field office

personnel referred companies to sources of assistance at Tech. Industrial extension staff members also worked hard to introduce Georgia Tech's new Advanced Technology Development Center to the state. Through their efforts, companies learned how they can use this center to diversify into high technology product lines.

The field offices also served as the state's most visible advocate for productivity improvement. The state legislature has assigned to EES the role of helping businesses and industries to upgrade production and operating efficiency. To this end, the field office staff published regular newsletters with detailed information on methods and technologies to improve productivity.

Above, an EES industrial extension engineer consults with a Villa Rica manufacturer of irrigation systems. Inset, a Station representative inspects a boring machine which he helped a South Georgia firm to select.

Most important, though, were in-plant consultations which resulted in improvements in productivity.

The Station's industrial extension staff rendered effective help in areas such as energy outreach; noise measurement, analysis and control; production flow; and aid to inventors. In one especially noteworthy project, EES analyzed the business practices and production of work centers for the mentally handicapped.

Economic Analysis/ Business Development

In its first year, the new federal administration devoted much of its attention to the restoration of America's economic health. In this climate, EES continued to render valuable services, both in analyses of economic problems and direct assistance to business and industry.

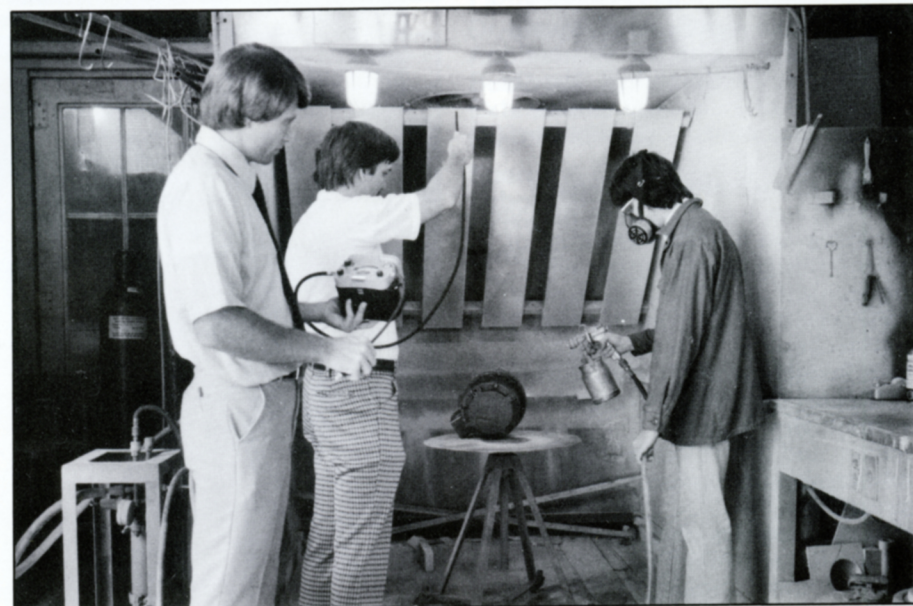
One important area of assistance at the Station involved the economics of energy. EES performed market penetration studies on technologies that may have a powerful impact on future energy use patterns in the country. One such study conducted for the Oak Ridge National Laboratory assessed the penetration of the heat pump into the residential housing market. Another project addressed the socioeconomic consequences of large power plant construction, such as the Vogtle nuclear facility now being built by Georgia Power Company. The Station also worked to develop an analytical model which could help utility companies forecast future energy demand. A program for The Electric Power Research Institute will generate an implementation guide to enable other utilities throughout the U.S. to upgrade their own forecasting methodologies. Other energy-related studies evaluated Georgia's intercity bus network and compiled information about auto use in the Atlanta metropolitan area.

Programs of assistance to specialized business and industry groups continued in several areas last year.

They included:

- *The Economic Development Administration's Management and Technical Assistance Program.* Last year, 35 projects were active, six of which supported enterprises owned by women or minorities. This program saved some 60 identifiable jobs and created 25 additional positions.

- *The Minority Business Development Agency's Technology Utilization and Commercialization Center (TUCC).* In its fourth year, TUCC evaluated 34 product/venture ideas, seven of which are well on their way to commercialization.



Top left, EES is commercializing this ornamental house plant manager through its minority business assistance program. Top right, economic development specialists meet to explore one of the many business and industrial problems the Station is capable of handling. Below, specialists in industrial health and safety from EES inspect a machine shop operation and offer suggestions for improvements.

TUCC successfully guided a device to commercialization which detects pinhole leaks in oil wells.

- *The Southeastern Trade Adjustment Assistance Center (TACC).* Last year, 147 companies completed various stages of TACC's five-tiered process for overcoming the problems of foreign business competition. An outside evaluation of the national TAAC program concluded that EES' regional center "is the most effective of all TAACs."

- *Occupational Safety and Health Program.* Under this program, the Station offered free, on-site occupational safety and health consultations to businesses and industries. In 1981, the program received 189 inquiries, conducted 157 plant visits and controlled or eliminated 273 serious hazards. An outside audit of the OSHA program concluded that its overall quality was "excellent . . . well organized and well managed." □

International Programs

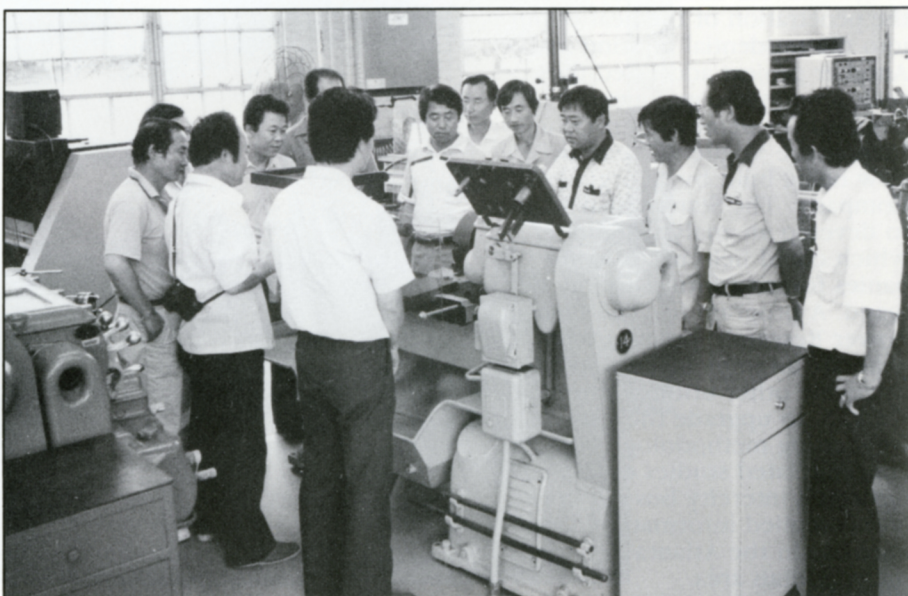
The Station is delivering technologies to help underdeveloped nations develop clean water, better industrial bases and alternate energy sources.

In 1981, EES continued its programs of assistance to developing nations while significantly expanding its contacts with the Western European research market. The Station's field office in Asia closed, but EES maintained a presence in the Far East.

EES's major initiative overseas last year was its decision to manage the European Research Institute of Ireland (ERII). The Institute will model itself after EES and provide R&D services on a contract basis to high-technology industries in the Irish Republic and Western Europe. ERII plans to export advanced technologies from the U.S. to its clients, and this effort will probably result in contracts with Station researchers.

In another area of work overseas, the Station expanded its effort to make sanitary drinking water more available in developing nations. Engineers from EES taught Third World countries to produce, install and efficiently maintain water pumps. They worked in Indonesia, Tunisia, Sri Lanka, Honduras, the Philippines and Ecuador. The Honduras project was the first phase of a major new contract which calls for EES to deliver sanitary water technology to underdeveloped countries.

EES engineers also gave Third World nations assistance in developing alternate energy sources. The Station trained technicians in Mali and Somalia to build an inexpensive solar cooker in-



Top left, the Station continued to transfer sanitary water technology to underdeveloped countries in Asia, South America and Africa last year. Top right, Irish cabinet minister Desmond O'Malley meets with Georgia Tech President Dr. J.M. Pettit to announce the participation of Georgia Tech and EES in the European Research Institute of Ireland. Below, this South Korean group took a six-week industrial training course at the Station in 1981.

vented at EES as a substitute for dwindling wood resources. The Station assisted the governments of Egypt and Jamaica in designing major programs to conserve energy and develop renewable fuel sources.

EES continued to advise the Korean Credit Guaranty Fund on ways to develop an effective pro-

gram of management and technical assistance for industries in South Korea. EES' International Division also consulted with the Asian Development Bank on several industrial development loan applications. In another program, EES helped to target technologies suitable for rural workers in Haiti. □

EES and Its Laboratories

The Engineering Experiment Station is organized into eight laboratories. Five conduct electronics research; three are concentrating on developing the nation's human, natural and manufacturing resources.

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