

The GTRI Connector

Vol. 7 • No. 6

Published Monthly for the Georgia Tech Research Institute Family

May 1991

Researchers discover chip failure mechanism

By Martha Ann Stegar, RCO

As circuits are packed more and more densely on microchips, the risk of premature failure looms ever larger. With tiny components of sub-micron size (a human hair is about 50 microns in diameter), the chemical, electrical, thermal and mechanical stresses of the operational environment become significant considerations.

Although improvements have been made by empirical methods (finding out what "works" by trial and error), in order to devise the best materials combinations for circuit reliability, it is important to understand the failure mechanisms going on. What is actually happening—physically and chemically—to cause microcircuits to fail?

GTRI team tackles electromigration

A research team led by Bill Livesay of the Physical Sciences Laboratory is investigating one such phenomenon—solid-state electromigration.

"Electromigration has long been recognized as a primary wear-out process in microelectronic materials where thin metal films are used extensively," Dr. Livesay explains. "When even a small electric current is run through these minuscule metal conductors,

high current densities are built up within their narrow confines. This causes atoms within the metal films to move out of place or migrate, causing degradation and ultimate failure of the device."

The researchers observed the following effects of electromigration:

- When atoms move, they create voids within the metal. These voids begin to coalesce and get bigger. Finally, the current densities around the voids increase, accelerating the process until melting occurs.
- The displaced atoms migrate through the metal film and stack up as hillocks somewhere else. Occasionally, they grow into long, thin whiskers. Hillock growth can pierce insulating layers, causing shorts or other problems prior to catastrophic burnout.

Electromigration/dislocation correlation?

"What we're trying to understand," Livesay says, "is what goes on when atoms move. My supposition, based on a lot of evidence, is that electromigration closely corresponds with mechanical deformation. Malleable metals like aluminum, copper, gold and silver are easily deformed under mechanical stress, such as stretching, bending or hammering, which causes enormous displacement of the atoms via activation of dislocation dynamics. With these thin films, primarily aluminum, the high current density moves the atoms around. So we decided to look for a correlation between electromigration and dislocation mechanisms." This approach to the problem came naturally to Dr. Livesay, with his thin-film mechanics background, as opposed to the usual electrical engineer's approach.

After performing several crucial experiments, they did indeed find such correlations

Continued on page 2

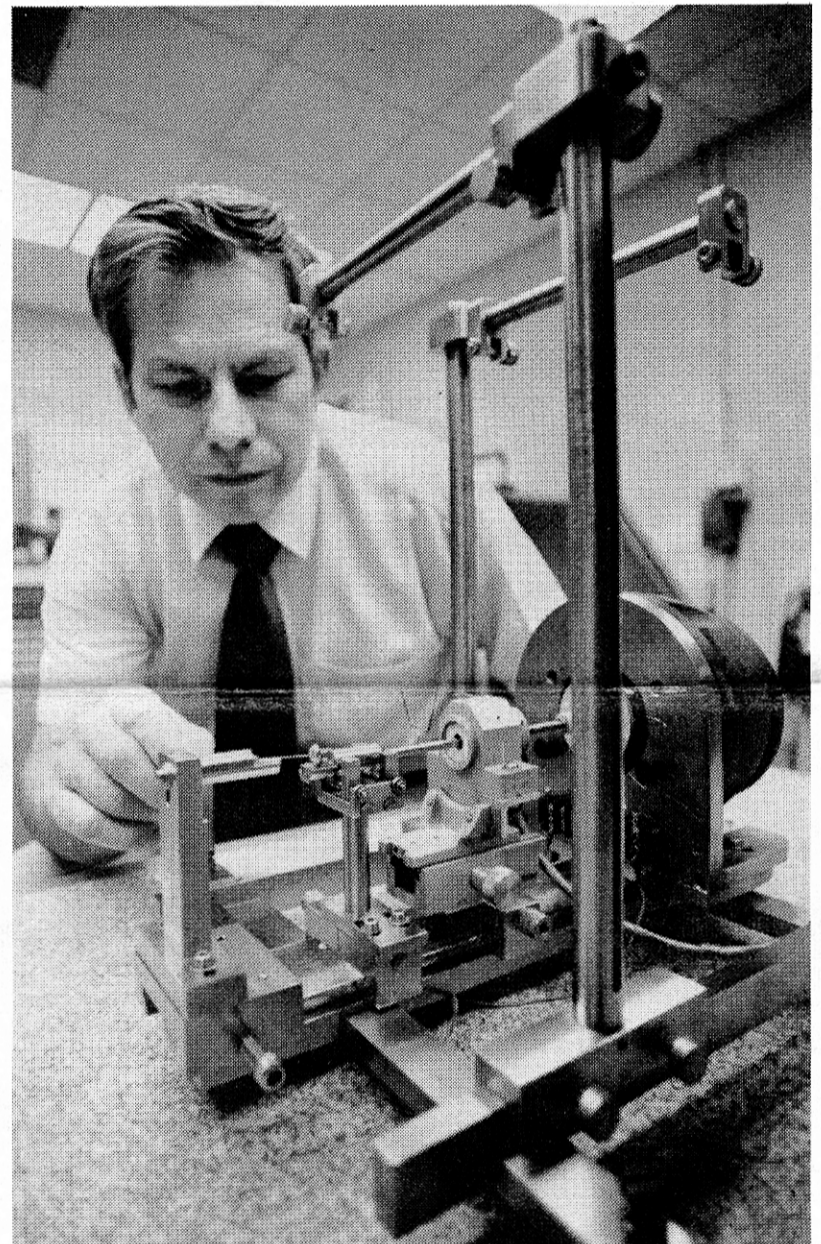
Jones' Law:

The man who can smile when things go wrong has thought of someone he can blame it on.

Flip Wilson's Law:

You can't expect to hit the jackpot if you don't put a few nickels in the machine.

(Courtesy of Barry Rosenberg)



As part of his microcircuit reliability studies, Bill Livesay performs tensile strength studies using an advanced, computer-controlled apparatus he designed for his micromechanics lab.

Observed & Noted

There's a lot more to high-definition systems than HDTV, and a task force at Georgia Tech is working to get Tech researchers more involved. See page 2 for details.

Scientific-Atlanta has donated its new \$115,000 state-of-the-art microwave receiver to the

School of Electrical Engineering's Antenna Laboratory. Read about it on page 3.

Nine GTRI retirees are profiled on pages 4 and 5, and 31 employees receiving 25-year Gold-T's and 10-year certificates are listed on page 5.

Also on page 5, learn about the computer graphics and visualization capabilities available free to all campus researchers at the Scientific Visualization Lab.

On page 6, Pat O'Hare answers the first question sub-

mitted to the DIA-LOGUE BOX.

GTRI is offering business development services to Middle Georgia businesses and contract liaison with Robins Air Force Base at the newly opened Middle Georgia Technology Devel-

opment Center in Warner Robins. ATDC administers the facility, which is described on page 6.

A myriad of GTRIers made research presentations at two recent technical meetings. See page 7.

Congratulations to Sam Piper, who has been elected a Senior Member of IEEE. In other page 8 "people" news, stork delivery ran to daughters in April and May.

**News
&
Notes**

**"We want to hear from people on this campus who have enabling technologies in the high-definition systems area they want to promote. We can help them sell their ideas to sponsors."
—Gene Greneker**

Electromigration From page 1

between electromigration and dislocation dynamics. "We basically wanted to answer two questions," Livesay says. "First, how were the atoms moving? The common supposition was that they were moving along the grain boundaries of the metal. This does happen, but we felt this was not the primary cause of electromigration. The activation of dislocation dynamics is a far more effective mechanism for the significant atomic displacements taking place during electromigration.

"The second question was what can be done to inhibit or slow down the migration? People had learned empirically that the addition of copper slows down the movement, as does building up multiple-layer structures. But nobody knew what was really going on."

Living proof

The next step was to decide how to prove that dislocations are a major factor in electromigration. Dr. Livesay's reasoning went like this. "Metals are crystalline, composed of tiny crystals or grains. By definition, a dislocation is a linear lattice defect of a single crystal. We know that high-density electrons will be scattered from such a linear defect, such that we can use the resistivity of the crystal to determine the density of the dislocations."

It is hard to get direct verification on an atomic scale, but the researchers were able to establish several convincing pieces of circumstantial evidence. Dr. Livesay explains:

"We first looked for an electroplastic effect. We applied high-density current pulses to thin aluminum films while under mechanical stress to see if they caused the material to plastically deform. We had to separate out the thermal effect in our experiments, which was accomplished through time-dependent analysis.

"Next, we looked at the growth mechanism of the hillocks and whiskers. If the dislocation mechanism was operating, the layers would be built up by a rotational effect, creating each whisker as a single crystal. We verified in the electron microscope that this was the case.

"If dislocations truly were involved in electromigration damage, we should be able to observe this phenomenon directly in the transmission electron microscope. We laid down thin aluminum films and thinned single crystals of aluminum; then we saw the dislocations move during the high-current pulses."

To additionally confirm their findings, they discovered, during literature searches, that Russian scientists had recently seen the same thing happen with a single crystal of copper. Also, some scientists had reported that, as the hillocks grew, they heard noises (acoustical pulses), suggesting that dislocation sources were caused to operate.

Thus all the pieces fit together to make a strong case for the relationship between electromigration damage and mechanical dislocation dynamics. The practical value of this breakthrough in understanding, according to Livesay, is that the very things that one would do to inhibit electromigration are what people have been doing all along to increase the mechanical strength of a metal, such as selective alloying, interface strengthening, and the like.

Dr. Livesay, with other staff, presented the team's findings orally in April at a special U.S. Army Missile Command symposium in Huntsville. He will present them in a formal paper at the ASM International Electronic Materials Congress in Montreal in August.

Persons assisting Dr. Livesay in this research are:

- Materials Science and Technology Lab—Garth Freeman, Jim Hubbard, John Sparrow
 - Physical Sciences Lab—Stan Halpern, Mike Harris
 - Electro-Optics Lab—Tarrison
- Several students have made significant contributions. They include Hollinger, Paul Quesenberry, Matthias Iig, and Wolfgang Mantke.

Dr. Livesay feels the team's significant accomplishments were made possible by the combination of advanced processing and sample preparation techniques at GTRI, the unique measurement capabilities of Materials Physics' Micromechanics Laboratory, and MSTL's materials characterization facilities. He forecasts: "During the next decade, these capabilities will be applied to a wide range of electronic reliability problems in the evolution of new materials combinations to enhance the manufacturability and durability of microelectronic systems." □

High-Definition Systems Task Force seeks ideas

By Martha Ann Stegar, RCO

Hear the words "high-definition systems" and the home television of the future immediately comes to mind—with a picture nearly as large and sharp as that of a neighborhood mall theater and sound as flawless as that of a compact disk.

We've all heard about the race among consortia in Europe, Japan and the United States to come up with technologically acceptable and commercially viable television flat-panel displays with screen definition at least twice as crisp as in present-day TV sets. But that's only a part—albeit the sexiest part—of the picture. The new technologies now being developed will have broad applications in military and medical imaging, in computer-aided design, and a wide variety of electronic products. In fact, they promise to revolutionize the computing, communications and entertainment industries.

Contrary to popular belief, the United States no longer lags in the worldwide high-definition television (HDTV) competition, according to reports in *The New York Times* and *The Atlanta Journal and Constitution*. Although both Japan and Europe have beaten us in introducing the first operational HDTV systems, their systems "transmit only by satellites, which are unwieldy for local broadcasts." In contrast, "American companies have developed systems that will be able to transmit high-definition programming over ordinary television frequencies." The advance

that makes this possible is transmission entirely in digital computer code. At least four all-digital HD systems have been developed by U.S. companies, and testing will start this fall at the Advanced Television Test Center in Alexandria, Virginia.

This digital broadcasting breakthrough not only boosts the U.S. back to the cutting edge of HD technology, it also (according to the *Times*) "would set the stage for the development of televisions that function like computer work stations capable of storing, retrieving and manipulating video material."

HD-related efforts at Georgia Tech

Georgia Tech has strong capabilities in several high-definition technology areas and is making a concerted effort to offer its services to some of the principal players. A High-Definition Systems Task Force has been created to serve as:

- The Georgia Tech/GTRI center of expertise for high-definition technology
- The marketing initiation and coordination body for all high-definition systems (HDS) research conducted at Georgia Tech/GTRI
- A funding source for deserving proposals and white papers on HDS
- The official point of contact to follow up on all HDS-related inquiries received by Georgia Tech
- A clearinghouse to match campus research capability to industry and government needs and requirements

Task Force Chairman Gene Greneker says the research that the group is promoting includes high-definition television and other communication systems that require extremely high resolution and wide bandwidth signals. The Task Force also supports the activities of the Georgia Center for Advanced Telecommunications Technology recently established by the State of Georgia.

The Task Force is working on military applications of HDS with the Defense Advanced Research Projects Agency (DARPA), on technical policy considerations with governmental agencies like the Federal Communications Commission (FCC), and through its connection with the Georgia Center for Advanced Telecommunications Technology it will be a technical resource for industry in the state of Georgia.

A recent survey of the Tech campus by Orlando Feorene, Director of Tech's Office for Technology Integration, uncovered approximately 60 researchers representing 17 academic units and 11 of the 22 GTRI laboratories who are working in the high-definition technology area. The Task Force would like to work with these and other researchers to match their expertise with governmental and industry needs.

"We want to hear from people on this campus who have enabling technologies in the HDS area they want to promote," Greneker says. "We can help them sell their ideas to sponsors. DARPA already has agreed to fund a project on high-resolution camera technology led by Chris Summers and Bill Hunt, and the agency has asked Marc Berger of the School of Mathematics to submit a detailed proposal on a technique for image and data compression. Randy Case (GTRI/CSIT) is proposing to develop a HD frequency management program for the FCC.

"We also have held discussions with the Center for Advanced Television Studies (CATS) in Alexandria, Virginia, on the possibility of assuming some research responsibilities for them. This center is governed and

supported by its member companies—industry giants like ABC, NBC, PBS, HBO, Ampex, Eastman Kodak, Tektronix, and Zenith—and a major goal is to provide research support for domestic companies in their effort to regain the initiative in determining the future of television in the United States. Their research is performed by independent academic institutions, and we would like to offer our services as a 'captive expert,' Greneker adds.

Enabling technology needs

"This is a broad and rich technology area," comments Greneker. "The HDTV field includes cameras, storage media, wide-bandwidth transmission systems, frequency allocation and management, broadcast formats compatible with current analog technology ("it looks like we're going all-digital, so this is an issue"), and transmission standards that will apply to both technologies. "From this probably will come a U.S. standard that may well be different from the European and Japanese standards," Greneker adds.

One of the biggest technical challenges of HDTV is compatibility with conventional TV. The compatibility issue will be decided when all technical issues have been addressed. Transmission standards will dictate final system configuration.

For the home receiver industry, Greneker lists research needs in the areas of high-definition camera systems, bulk HD recording systems (20 megahertz bandwidth), decoding of compressed signals, large-screen HD displays, high-bandwidth audio (very high-quality stereo), satellite channel compatibility, and the networking problems to be faced by cable companies.

Military requirements include high-resolution flat-panel displays on aircraft, submarines and tanks; innovative data compression techniques; low-weight, high-capacity batteries; multi-circuit chips to serve as the memory and engine to drive HD systems; and communications policy studies.

Medical imagery is another prominent application. "The technology has great promise as an educational tool for hospital staffs," Greneker points out. "It can be used for high-resolution lifelike presentations of surgical procedures, for example."

Greneker urges researchers interested in any aspect of HDS to contact him or any member of the HDS Task Force. "We're an active group with many contacts and leads on opportunities. And we have some discretionary funds to assist researchers with proposal writing and visits to prospective sponsors," he says. The money comes from a legislative grant to the Georgia Center for Advanced Telecommunications Technology and from GTRI program development funds.

Members of the HDS Task Force include the following:

GTRI—Gene Greneker, RIDL; Chris Barnes, MAL; Randy Case, CSITL; Eric Barnhart, COML; Hugh Denny, EEEL; Chris Summers, PSL

Electrical Engineering—Kevin Brennan, William Hunt, Russell Mersereau, Ronald Schafer, Mark Smith

College of Computing—Philip Enslow, James Foley

Ivan Allen College—Richard Barke, Willie Belton, John Endicott

Microelectronics Research Center—Richard Higgins

ATDC—Wayne Hodges

Others working with the group include OIP Director Gary Poehlein, Vice President

for Research Demetrius Paris, Orlando Feorene, GTRI Director Don Grace, Don Wilmot of GTRI's Program Development Office, and William Read of the Georgia Center for Advanced Telecommunications Technology, who holds the new Southern Bell professorship in telecommunications policy at Georgia Tech. Patty Bartlett is the Congressional liaison. The Task Force also will be cooperating with Tech's economic development field offices on support issues germane to state industry, Greneker says. □

Scientific-Atlanta donates microwave receiver

Scientific-Atlanta, Inc. has donated one of its newest and most successful products, the Model 1795 Microwave Receiver, to the School of Electrical Engineering. The receiver will be used in the school's Antenna Laboratory, headed by Dr. Ed Joy.

The Model 1795 Microwave Receiver, introduced last year by Scientific-Atlanta's Microwave Instrumentation business, is the only multi-channel phase/amplitude measurement system available today that can measure 5,000 data points per second and simultaneously perform measurements on up to four channels of data. Microwave receivers are used to record and measure the amplitude and phase of microwave signals emanating from antennas, signal generators or other components.

According to Dr. Joy, the receiver will be used to support graduate and undergraduate research and education in antenna engineering and antenna, radar cross-section, and radome measurement techniques. Currently, three PhD, two master's, and two undergraduate students are working on research projects in the laboratory. Each year, approximately 30 graduate and 40 undergradu-

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To submit your Special Interest Ad, write GTRI CONNECTOR, RCO/GTRI 0800 or PROFS MSTEGAR.

ate students take courses involving the Antenna Laboratory.

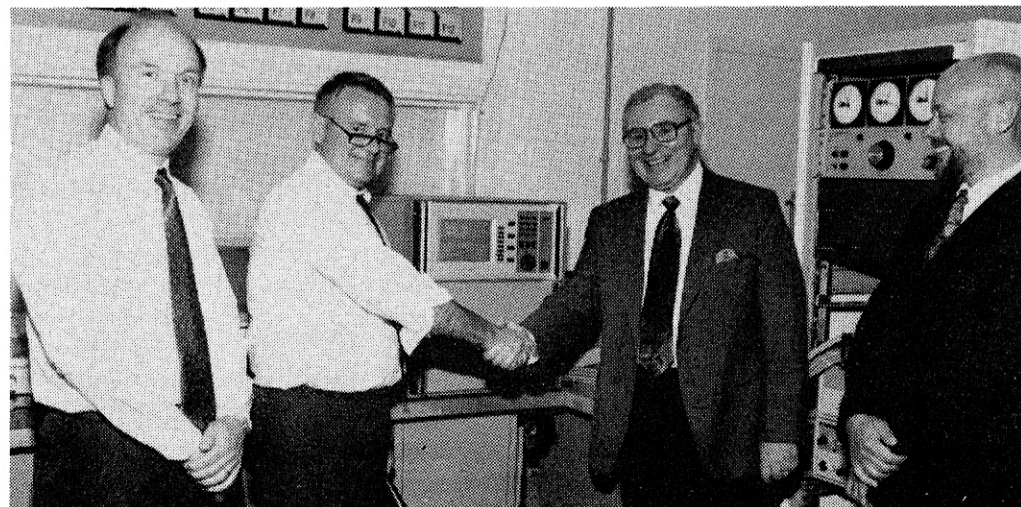
Georgia Tech and GTRI have been major contributors of new antenna, radar cross-section, and radome measurements techniques, including the development of the compact antenna range and planar and cylindrical near-field measurement techniques. Current efforts include a new range reflection compensation technique, and development of spherical near-field microwave holography techniques for antenna and radome diagnostics.

Scientific-Atlanta is a world leader in cable television electronics and satellite-based communications networks, and is a prominent supplier of instrumentation for industrial, telecommunications and government applications. It was started in the early 1950s by several former employees of Tech's Engineering Experiment Station (now called GTRI).

At the informal presentation of the equipment to the school, James D. Huff, general manager of Scientific-Atlanta's Microwave Instrumentation business area, said, "For more than a quarter of a century, Scientific-Atlanta's microwave receivers have been the benchmark against which all others have been measured. The Model 1795 is the latest generation of Scientific-Atlanta receivers that have set measurement and performance standards throughout the industry."

John E. Breyer, president of Scientific-Atlanta's Instrumentation Group, added: "Industry has a vested interest in the quality of our community's schools and graduates. By donating high-quality equipment, we are taking an active role in helping ensure our technical graduates enter the work force with necessary skills and laboratory experience to keep our industries competitive." □

"By donating high-quality equipment, we are taking an active role in helping ensure our technical graduates enter the work force with necessary skills and laboratory experience to keep our industries competitive."
—John E. Breyer
Scientific-Atlanta



Scientific-Atlanta, Inc. recently presented a state-of-the-art microwave receiver to the School of Electrical Engineering's Antenna Laboratory. Left to right: Dr. Ed Joy, Head of the Antenna Laboratory; Dr. Roger Webb, Director of the School of Electrical Engineering; John Breyer, President of Scientific-Atlanta's Instrumentation Group; James Huff, General Manager of Scientific-Atlanta's Microwave Instrumentation Business. The donated Model 1795 Microwave Receiver has a market value of \$115,000 and is visible between Dr. Webb and Mr. Breyer. (Photo—Dayton Funk)

**Profile
&
Insight**

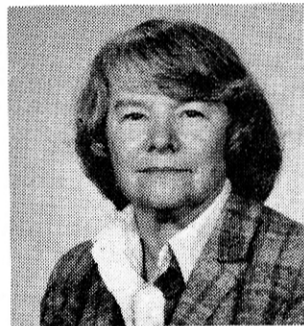
Nine GTRI retirees are honored in these columns. Their length of service ranges from 12 years (Dean Spencer and Lee Stillman) to 36 years (Joe Harris). Bruce Warren was the first to arrive here (in 1953), but he strayed off campus a couple of times, bringing his total years of service to 23.

Eleven retire from GTRI in FY 1991

Nine GTRI retirees were among those honored at Georgia Tech's Annual Retirement Dinner May 15, a festive Hawaiian luau affair. They included Steve Bomar, Bob Collier, Barry Cown, Jerry Eaves, Joe Harris, John Lockwood, Dave Plummer, Bruce Warren, and Leon Stillman. The other two retirees—Helen Blum and Dean Spencer—did not attend.

GTRI's long-term employees have made important contributions to its success, and it is appropriate to take a grateful look back at their careers in these columns. Bob Collier and Jerry Eaves were profiled in the April CONNECTOR. Sketches on the other retirees are given below.

Helen Blum



Helen is retiring after 21 years at GTRI. She joined the Basic Data Branch of the Economic Development Lab May 18, 1970, serving as Dr. Mary Edna

Anders' secretary for 9 1/2 years. When her husband, Fred, accepted a job with Gulfstream Aerospace in Savannah, she became the administrative secretary for EDL's Savannah Regional Office, where she has worked ever since. Their daughter, Kathy, is a Tech graduate, majoring in physics. Helen's retirement plans include studying at Armstrong College, taking karate lessons from her daughter (who owns a karate school), and watching C-Span.

Steve Bomar

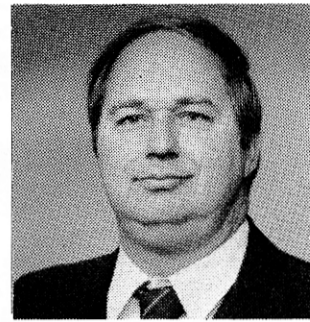


Steve started work for the Materials Science Lab in February 1958 as a student assistant, graduating from Tech in 1959 with a BS in ChE. He

worked as a full-time research assistant while earning his Ms ChE, which he received in 1962. He moved steadily up the promotion ladder, taking two years off in 1965-67 for active duty with the Chemical Corps, and received his PhD in ChE in 1967. In 1968, he was promoted to SRE and was appointed Head of the Fundamentals Branch of the High Temperature Materials Division. He worked many years as a PRE in the Energy and Materials Sciences Lab, and was affiliated with the new Aerospace Lab at the time of his retirement. Steve's professional activities were technically diverse, covering the areas of radomes, high-temperature materials, solar energy, chemistry, structures and thermodynamics. His research was conducted not only in the more traditional laboratory settings, but also on the solar "power tower" on

the Tech campus and at the solar furnace in the French Pyrenees. He plans to inspire students by teaching in junior or senior high schools in his retirement years.

Barry Cown



Barry worked for GTRI from the time he came to Tech in 1967 as an undergraduate, working as a senior electronics technician, until his retire-

ment this year as a PRE in the Electromagnetic Science and Technology Lab. He received his BS, MS and PhD degrees in physics from Georgia Tech. His PhD thesis, based upon research supported by the U.S. Army CECOM, developed a near-field theory for wideband radiating systems at in-band and out-of-band frequencies. He later made significant contributions in the area of rapid near-field measurements using the Modulated Scattering Technique (MST). He developed several MST measurement systems and demonstrated that this technique results in a two-order-of-magnitude reduction in the required measurement time. He also was instrumental in developing both coupling and performance models for predicting antenna performance which are in current use by the Navy. In particular, his development of the Spherical Angular Function (SAF) scattering analysis and the GMULT series of computer codes resulted in a significant advance in ship antenna analysis.

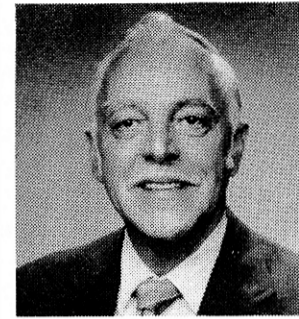
Joe Harris



Joe worked at GTRI for 36 years, beginning as a research assistant in 1955. Through the years, he became best known for his pioneering

work in slip casting fused silica. He is a coauthor of the *Fused Silica Design Manual*, and was instrumental in developing the nose cone for the Patriot missile of Gulf War fame. Later research involved developing a process for slip-casting complex shapes in reaction-sintered silicon nitride and sinterable silicon carbide. Most recently, he has conducted research on ceramic matrix-ceramic fiber composite materials and evaluated materials for future electromagnetic window requirements. He received his MS in Ceramic Engineering in 1982. Starting out in the old High Temperature Materials Division, he is retiring this year as an SRE in the Materials Science and Technology Lab. Retirement plans include working part time for a local industrial ceramics company and spending time with two new grandchildren and a new 40-pound puppy.

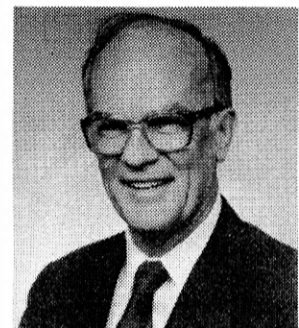
John Lockwood



An SRE, John has been at GTRI since 1977, working on many different radar programs and for several different laboratories, and retiring as a mem-

ber of the Threat Systems Development Lab. He served as the critical link between the electronics and the mechanics on radar research programs, including the XM-42 radar, the Low Probability Phased Array radar, the ASTAR program, and the "C" Band radar. His contributions to the Sierra Program, a 3600-element phased-array antenna research effort, were cited as outstanding. Always the perfect gentleman, when asked what he would do in retirement, John replied, "Enjoy it."

Dave Plummer



Dave came to GTRI in 1976 as a PRE in the Electromagnetics Lab, soon moving to RAIL, where he became head of the Electro-magnetic Surveillance

Branch. He moved to the new Systems Engineering Lab in 1979 and headed the Surveillance Technology Branch of the Electronic Support Measures Division (now Laboratory). His branch prospered and grew so much during the nine years of his leadership that, after his retirement last July, it was divided into three new branches. He and his wife, Betty, also a Tech retiree, plan to spend more time at their cabin in the woods near Dave's home town, St. John, New Brunswick, Canada.

Dean Spencer



Dean came to GTRI in 1979 as an SRE to head the Concepts and Requirements Branch of the Systems Engineering Lab. As head of the Simulation and

Instrumentation Branch from 1984-91, he led development of advanced instrumentation and one-of-a-kind simulation systems in the electronic warfare area. As a mathematician, his technical expertise was in requirements engineering, and he was a well-respected project director known for planning his jobs in great detail. He was project director and systems engineer for the Electromagnetic Compatibility Analysis and Testing project. He also developed cybernetic concepts for an intelligent real-time reconfigurable electronic counter-countermeasures system. Several years ago, he was tapped by OOD to lead the initial GTIMS (Georgia Tech Information Management System) effort. Dean also was a principal author and lecturer for the Electronic Warfare Software Principles

The Scientific Visualization Lab is available, free-of-charge, to Tech researchers needing access to computer hardware and software for graphics, modeling and animation purposes.

short course and a lecturer for the Fundamentals of Electronic Defense short course. At the time of his retirement, he was a member of the Engineering Sciences Lab.

Irving L. (Lee) Stillman



When Lee joined the Systems and Techniques Lab in February 1979, his first assignments were in the areas of technical documentation and program development.

This led to work on the design, development and documentation of the XM-04 radar receiver. He then was made a task leader for the design, development and documentation of a new video signal processor and scan-motor speed controller for the previously delivered XM-04 simulator's target tracking radar. His next assignment was as principal investigator in evaluating intelligence information. He was responsible for the receiver/signal processor portion of a design study that led to the award of the current TAS simulator development project. Until his retirement this month, he was the task leader for the development, implementation and acceptance testing of the TAS simulator's receiver and signal processor subsystems. He retires as an SRE in the Threat Systems Development Lab, but will continue to assist on the TAS program in a part-time capacity.

Bruce Warren



Bruce joined GTRI immediately upon receiving his BSEE from Georgia Tech in 1953. He was awarded his MSEE in 1955 and was assigned to the

Communications Branch, where he made significant contributions in active and passive filters, precision oscillators, and VLF and UHF receivers. He strayed to Bell Labs in 1957-58, but returned to work at Tech as a research engineer until he joined TRW in 1967. When the Electronics and Computer Systems Lab was created in 1981, Bruce was lured back to GTRI to serve as associate lab director, playing important managerial and technical consultant roles in building it into a successful laboratory. Immediately prior to his retirement, he was acting director of the Communications Lab. A PRE, he will be available hourly as needed, particularly to stimulate innovative technical thinking among the researchers in the Signature Technology Lab. □

Scientific Visualization Lab open to GTRI staff

By Carolyn Kanagy, Client Services Office of Information Technology

Many of you may have heard of the Scientific Visualization Lab, run by the High Performance Computing Group in Client Services, but may be unaware that it is open, free-of-charge, to all researchers on campus and, in particular, to the staff of GTRI. The lab is located in Room 259 of the College of Computing, not too far from the Baker Building and CRB. It houses several SGI machines and full videotaping/image processing facilities (including an image scanner and matrix camera). The staff of the Lab is on hand to help you get started and to guide you in using the software available or connect you with someone who can.

Over the past few years, the fields of computer graphics research and computer visualization of scientific information have been among Georgia Tech's most rapidly expanding areas of activity. The creation of the College of Computing and the addition of numerous new faculty working in the area of computer graphics research has resulted in the appearance of a plethora of video and graphics hardware on campus. In addition, the High Performance Computing Group makes continuing efforts to introduce and support much of the new software for scientific visualization which is rapidly being generated by both commercial and academic sources.

Last September, the Computer Graphics Research Lab, the Scientific Visualization Lab, the Image Understanding Lab, the Medical Informatics Lab, and the Animation Lab merged their facilities in the College of Computing. The hiring in January of Professor Jim Foley, an expert in the field of computer graphics, has resulted in further consolidation of activities and the subsequent creation of the Visualization, Graphics and Usability (VGU) Center, of which Professor Foley is director. This new facility is presently housed in Room 259 CoC and will soon expand to include more space on the same floor.

The Scivis workstations and, in fact, all but a very limited number of VGU Center machines are available to the entire university community. In addition to the hardware, considerable support is provided for the software available, in the form of basic instructional seminars, commercial manuals, and consulting by individual members of the High Performance Computing Group. An excellent brochure entitled *Scientific Visualization Laboratory User's Guide* is available outside Room 284 of the Rich Building. This brochure explains the working of the Scientific Visualization Lab and lists software and hardware available, as well as describing procedures for getting onto and around on the graphics workstations.

A brief listing of the software packages available and their functions is provided below:

- PLOT3D: a graphics program for displaying computational fluid dynamics grids and flow solutions
- RIP: interactive post-processor for PLOT3D
- GEMM: an interactive molecular graphics package for observing and manipulating biological macromolecules in real time

- BRL-CAD: a solid modeling system with ray-tracer, framebuffer library, solid geometric editor, lighting modeler, and image tools

- PERSONAL VISUALIZER: a modeling/rendering package created by Wavefront Technologies

- ADVANCED VISUALIZER: an advanced version of the Wavefront Personal Visualizer offering a much richer environment for 3-D modeling, rendering and animation

- MOLDYN: depicts the motion and properties of groups of atoms or molecules such as might come from molecular dynamics or molecular modeling simulations

- apE: a highly versatile graphics program for conversion of information into images and viewed as plots, color images, and three-dimensional objects

- PV WAVE: a package for visual data analysis which may be used either interactively or by writing PV WAVE programs

- UTAH RASTER TOOLKIT, IM RASTER TOOLKIT: collections of programs for manipulating and composing raster images

The above packages may be accessed from the four Silicon Graphics workstations. There are, in addition, four Sun Sparcstations and the hardware necessary to produce animations and process or capture images.

The facility is at times heavily used, but time and space are generally available for new users. Use of the lab permits interaction with computer graphics experts as well as an opportunity to utilize their state-of-the-art equipment. Time may be scheduled on the individual machines via a scheduler located on hydra.

Seminars on software are given by the High Performance Computing Group during the fall, winter and spring quarters. The easiest way to get acquainted with the facility and to get an application for access to the lab is to call the High Performance Computing Group in the Office of Information Technology (894-6866 or ccsupck@hydra). □

Georgia Tech RESEARCH INSTITUTE

31 GTRIers get longevity awards

The Faculty/Staff Honors Luncheon was held Wednesday, May 29, in the Student Center Ballroom. Receiving awards for their years of service were the following GTRI personnel:

25-year Gold-T: William C. Howard, Ben E. James, Jr., Edward E. Martin.

10-year certificate: Darrell W. Acree, Julie A. Blankenship, Charles E. Brown, Jerry M. Brown, Mary Ann Burke, Gerald J. Carey, Jr., Fred L. Cox III, Scott R. Crowgey, Gwyneth J. Dalton, Donald A. Esper, Lewis C. Garrett, W. Lee Hughey, Joanna King, Teddy L. Lane, James W. Larsen, Jacob T. Leverett, Douglas W. Martin, E. Archer Nelson, Carolyn C. Olive, Phillip G. Pflueger, Nicholas A. Pomponio, Katharine L. Schlag, Robert N. Seitz, Steven M. Sharpe, Charles B. Sheets, Christopher Summers, Donald J. Swank, Jr., Walter B. Warren, Jr. □

Queries & Quotes

Here is the first question submitted to the DIALOGUE BOX, together with the answer. We're looking forward to hearing from many more of you in the months to come.

The new Middle Georgia Technology Development Center offers "one-stop" shopping to businesses that need the services of ATDC, GTRI, Macon College, and the Houston County Development Authority.

Dialogue Box

By Patrick J. O'Hare, OOD

For a number of years, there has been talk of some kind of formal PhD support program for GTRI members wishing to advance their education. Over a year ago, Don Grace mentioned a forgivable loan concept which OOD was considering but had placed on hold because of reorganization. Is there any concrete plan to revive this concept? I am aware of the support for the last year of study/research; however, I was more interested in a longer-term program. A PhD is very difficult to obtain on a part-time basis; it can be done, but everything suffers, including studies, job performance, and home life. No one wants a free ride, only a more feasible avenue. Thanks.

There are many ways I would wish to respond to the first person who cares enough to get a DIALOGUE going... Thank you comes to mind first! I hope this is the start of a program that many people will feel free to participate in. We will all be better for it.

The question that you pose regarding a type of support for PhD candidates that would allow them to go to school on a full-time basis while not giving up their livelihood is a subject often discussed within the Executive Council. It becomes the "Catch 22" that we all dread because it often suggests that we are talking out of both sides of our mouth.

With that said, we promised straight answers in DIALOGUE BOX and we intend to live up to that. We do not have a program at this time that would allow a person to be supported on a longer-term basis than that which is already in place. Even the loan proposition that Dr. Grace has considered must be done within the constraints of current financial resources and dealt with in the context of priorities that call on those very scarce resources.

The value of a PhD is fully recognized, and the heightened contributions that our current team members make when they add to their knowledge and credential base are fully appreciated. However, although we will continue to ask you to make every effort to achieve this goal, there is not the ability to further relieve the time and/or financial difficulties this presents to individuals at this time. The Executive Council pledges to continue to look for ways to deal with this concern and will genuinely appreciate constructive ideas that might produce a more immediate and positive outcome. While it is certainly clear that a person willing to pursue this lofty goal is not looking for a free ride, I hope you will accept with equal candor that the Executive Council really would like to find a means to make this and many other—very worthwhile—investments in the people who are GTRI.

Editor's Note: How about it, folks? Send us your questions, suggestions and comments. Write GTRI CONNECTOR, RCO/GTRI 0800 or PROFS MSTEGER, and we'll get back to you—either in print or privately. □



The Middle Georgia Technology Development Center in Warner Robins was dedicated May 16. ATDC manages the facility, which also houses offices for GTRI's economic development and Robins Air Force Base contract liaison personnel. (Photo by Tedd Stafford)

GTRI opens offices in Warner Robins

By Martha Ann Stegar, RCO

The Middle Georgia Technology Development Center in Warner Robins was dedicated May 16, with Tech President John P. Crecine, Macon College President Aaron Hyatt, and numerous local dignitaries in attendance. Other Georgia Tech attendees included Jim Langley, Wayne Hodges, Bob Shackelford, Dave Swanson, Sherman Dudley, and several staff members of the Economic Development Laboratory.

The Middle Georgia Technology Development Center is designed to provide the Middle Georgia region with access to a full range of business assistance services at a single location. Among the tenants of the 34,000-square-foot building are ATDC and GTRI. Others are Macon College and the Houston County Development Authority.

GTRI is occupying 1,500 square feet of space which includes a large open area and a secure storage/meeting room plus four offices. The Macon Regional Office of the Economic Development Laboratory is using one office as an adjunct facility, and the other three will be used by Bob Mobley, Harry Siemen, and other GTRI representatives working with Robins Air Force Base. A procurement assistance officer will be added in July to help businesses bid on government contracts.

Macon Office Director George Lee says EDL's Industrial Extension Service has moved its 4.5-meter Scientific-Atlanta satellite downlink to the new facility. The office is a center that attracts attendees for remote classes offering noncredit coursework, principally from the National Technological University (NTU), but also from such sources as FEMA or NASA. They also can receive any courses uplinked from the Georgia Tech campus.

"Continuing Education has put in an interactive video line which we inaugurated during the open house, with two-way communication between our people in Warner Robins and others on campus," Lee says. This link will allow Middle Georgia residents to consult with Tech researchers, attend continuing edu-

cation and graduate education classes, and participate in live presentations from the Tech campus. Other activities during the open house included demonstrations of the Olympic video, the ATDC multimedia interactive video, and the intrusion radar developed at GTRI.

GTRI already has conducted two seminars at the new facility. Lee's office coordinated a seminar on pollution prevention for the Environmental Science and Technology Lab April 25, and facilitated a live satellite conference on small business innovation research (procurement assistance) April 29. "The Warner Robins facility is very convenient for us to service, as it's only a 20-minute drive from our Macon office," Lee says.

The other Tech connection is ATDC (the Advanced Technology Development Center), which is occupying 6,300 square feet, including core support areas for all tenants. Some 13,700 square feet of incubator space for start-up companies also is available. ATDC manages the facility and coordinates business assistance services available from organizations housed in the MGTDC. Jerry Wilson is the manager, and Donna Vandersall is the administrative secretary.

Two high-tech companies already have moved into incubator space. They are Simulation Systems and Support, which does radar and communications signal simulation, and Middle Georgia Logistics Specialists, which



Jerry Wilson and Donna Vandersall are the manager and administrative secretary, respectively, of the Middle Georgia Technology Development Center, a new "one-stop shopping" center that provides a full range of business assistance services to the counties surrounding Warner Robins. (Photo by Tedd Stafford)

performs logistical and technical program documentation analysis.

Other tenants are Macon College, with 12,000 square feet of instructional space, and the Houston County Development Authority. The college offers freshman and sophomore core courses for students who intend to participate in the Regents Engineering Transfer Program, transferring to Georgia Tech. The Warner Robins Small Business Development Center plans to move in at a later date.

The idea of the Technology Development Center was born 11 years ago, when State Rep. Sonny Watson (D-Warner Robins) approached then Georgia Tech President Joseph Pettit about creating a technology park. Watson later secured \$300,000 from the state legislature to plan the park and the center. The building is owned by the City of Warner Robins. The city's mayor, Ed Martin, was an invaluable participant in making the center a reality. □

Many GTRlers participate in EW Program Review

The 13th Annual Electronic Warfare Techniques Analysis Program Review (EWPR) was convened March 26 at Georgia Tech by Lloyd Lilly, chairman. The EW Techniques Analysis contract is sponsored by the EW Division of the Avionics Directorate at Wright Laboratory, Wright-Patterson Air Force Base, Ohio. The Electronic Warfare Program Review is a yearly review of all the tasks that have recently ended or are currently ongoing on the contract, as well as high-profile efforts in EW sponsored by other U.S. government agencies.

This year, GTRI personnel made the following presentations:

Session I (March 26)

Session IA, EW Analysis, Harry Andrews, chairman:

"Semiactive Monopulse Missile CM Chamber Tests" by Tom Pratt

"Adaptive Null Steering CM Analysis" by Lou Fertig

"B-1B ALQ-161 Memory System Design" by Tim Strike

"X-POL Effectiveness Against Phased Array Radars" by Armand Masse

"ECM Functional Requirements Analysis" by Harry Andrews

Andrews also presented a brief description of other programs in this area.

Session IB, EW Processing, Larry Holland, chairman:

"Analysis of Superconductors in Microwave Receivers" by O. Rausch

"Intrapulse Data Analysis Results with Expanded Libraries" by Katharine Schlag

"Intrapulse Data Collection and Analysis—Eglin Test Site" by Katharine Schlag

"Simultaneous Air/Ground Collections" by Bob Willoughby

"Neural Nets for Adaptive Intrapulse" by Katharine Schlag

"Analysis of Conventional and Fiber Optic Microwave Transmission Lines" by O. Rausch

"ECCM with Pattern Recognition Techniques" by O. Rausch

Other programs in this area were described in a presentation by Larry Holland.

Session II (March 27)

Session IIA, EW Analysis, Harold Engler, chairman:

"Digital RF Memory and Ground-Based

Radar Analysis" by Phil West

"Probability of Intercept Analysis for Frequency Agile Radar" by Ben Slocumb

"Digital EW Receiver Techniques" by Harold Engler

"High-Power Countermeasures Analysis" by David Erickson

"HPCM Video Tape" by D. Misk

"REED Data Base" by Jeffrey Smart

"Precision Jammer Location" by James Byrum

"Radar Environment Generator Design" by Harold Engler

"ECCM EVADE Data Base" by Molly Gary

Other programs were described in a presentation by Harold Engler.

Session IIB, Passive EW, Bill Youngblood, chairman:

"PAVE LOW Threat Response Language" by Brian Miller

"Conformal DF Antenna" by Victor Tripp

"DRFM Laboratory" by Mark Smith

"Broadband ELINT Antenna Array" by Victor Tripp

"Automated RWR Resource Management Tool" by Michael Cooper

"IRCM Flight Test Support" by Charles Carstensen

"Anti-Cross Eye" by James Byrum

Bill Youngblood described other programs in this area.

Session III (March 28)

Session IIIA, Technology, David Flowers, chairman:

"Cepstral Techniques" by Guy Morris

"Investigation of Receiver Coloration" by John Bordelon

"Clutter Attenuation Limits in Threat Radar Systems" by George Ewell

"PC Based Reprogramming and Test Systems for EW Systems" by David Fentem

"High Altitude Airborne Remote Sensing Using the Advanced Microwave Precipitation Radiometer" by Joe Galliano

"Reliability and Maintainability through Manufacturing Technology Research" by Ron Bohlander

Other programs in this area were described by David Flowers.

Session IIIB, EW Testing and Evaluation, Bud Sears, chairman:

"Improved EC System Acquisition" by Bud Sears

"Disciplined Test Process for EW Receivers" by Michael Cooper

"EW Testing with Integrated Facilities" by George McDougal

"Instrumentation for EW Testing" by Tom Miller

This year, 73 government personnel from all branches of the military attended the review. Those in attendance included Col. Stan Lewantowicz, Deputy Director of the Avionics Directorate; James Thomas and Nicholas Toomer from the Office of the Secretary of Defense; and Jack Tehan, EW Division Chief of the Avionics Directorate at Wright Laboratory. □

GTRI helps lead Telesystems Conference

At the 1991 National Telesystems Conference, held March 26-27 at the Georgia World Congress Center, GTRI and Georgia Tech were strongly represented. Sponsors of the conference, held in conjunction with Southcon, were the IEEE, Aerospace and Electronics Systems Society, and the IEEE Atlanta Section.

Roger Webb (EE) was vice chairman of the Conference Committee. From GTRI, Mark Richards (MAL) was Technical Program chairman, Linda Harkness (RSAL) head of Registration, and Jim Wiltse (OOD) senior advisor. Dr. Wiltse also is on the NTC Board of Directors.

GTRI researchers also chaired and presented papers at six technical sessions. Details follow.

• *Session 1a, Aerospace Guidance & Control, Jeff Holder and Brian Stevens (both MAL), chairmen:* Brian Stevens made a presentation, and Harold Stalford (AE) gave a paper on "Mu Control of Aircraft in Windshear."

• *Session 3, Radar Discrimination Technology, Bill Holm (MAL), chairman:* Jill Butterfield (MAL) gave a paper on "Fractal Interpolation of Radar Signatures for Detecting Stationary Targets in Ground Clutter."

• *Session 5, Wideband Waveforms & Coding, Marvin Cohen (MAL) and Mel Belcher (RSAL), chairmen:* Papers were given by Marvin Cohen, "An Overview of High Range Resolution Radar Techniques"; Mel Belcher, Robert Howard (MATDL) and Mark Mitchell (MATDL), "Wideband Waveform Distortion and Compensation Techniques"; and Harold Engler (CAL), "Systems Considerations for Large Percent-Bandwidth Radar."

• *Session 10, Radar Technology, Guy Morris (RSAL), chairman:* Linda Harkness and Jill Bach (both RSAL) presented a paper on "Modern Digital Simulation of Airborne Sensor Performance and Vulnerability," and Guy Morris gave a paper on "Trends in Electronic Counter-Countermeasures."

• *Session 11, Remote Sensing Technology:* A.J. Gasiewski (EE) gave a paper on "Technology for Spaceborne Passive Microwave Earth Remote Sensing."

• *Session 12, Battlefield Telerobotics, Rob Michelson (ASTL), chairman:* Papers were given by Ron Arkin (Computing), "Reactive Control as a Substrate for Telerobotic Systems"; Steve Dickerson (ME) and Brett Lapin (EE student), "Control of an Omni-Directional Robotic Vehicle with Mecanum Wheels"; and Rob Michelson, "Telerobotic Control Issues for NLOS, NOE Rotary Wing Target Drones."

• *Session 13, MMW Sensors & Phenomenology, Jim Wiltse (OOD), chairman:* Bob Trebits, Benjamin Perry, and Jill Bach (all of RSAL) presented a paper entitled "Effects of Obscurant Materials on Millimeter Wave Radar Seekers." □

Do you sometimes fail to get your Connector?

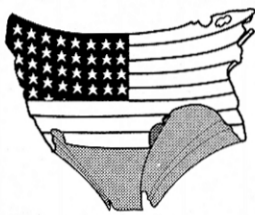
Every once in a while, people call up and tell us they didn't get their Connector that month. This is puzzling to us, as each month, Payroll and Records Services (PARS) supplies us with an updated set of address labels for every GTRI employee, as well as Georgia Tech general faculty. The only solutions we can come up with are (a) maybe it got lost in the campus mail, (b) the sophisticated labeling machine at the printer chewed up a label or two, or (c) someone coveted an extra copy so much that they stole your copy!

If you fail to receive your personal copy of the Connector, just let us know, and we'll send you one in the campus mail right away. Call RCO at 894-3444 or PROFS MSTEGAR. □

**Focus
on
Folks**

Some 73 military personnel heard 32 GTRI researchers make presentations at GTRI's Annual EW Program Review this year. And Georgia Tech had strong representation at the National Telesystems Conference recently held in Atlanta.

Focus on Folks



We are grateful to our loved ones who risked their lives in the Gulf War. See some of the names on the right.

The GTRI Connector
Vol. 7 No. 6 May 1991

Published by the Research Communications Office, Centennial Research Building, Georgia Institute of Technology, Atlanta, GA 30332. Georgia Tech is a unit of the University System of Georgia. The deadline for submission of copy is the first Tuesday of each month.

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Professional Activities

Aerospace Science & Technology Lab

At the request of the Vertical Special Program Office of the National Headquarters of the Federal Aviation Administration, **Krish Ahuja** organized a technical workshop on Noise from Tiltrotor Aircraft, held March 28-29. Attendees included a number of representatives from government, industry and academia, from both the U.S. and abroad. Dr. Ahuja chaired the workshop and made two related presentations.

Economic Development Lab

EDL conducted the 24th annual Basic Economic Development Course on campus in mid-April. Co-directed by Bob Cassell and **Claudia Huff**, the week-long offering for economic development practitioners had 83 enrolled. This year, the course gave an increased emphasis to the role of environmental issues in economic development, with ESTL's **John Nemeth** as one of the lecturers. **David Clifton** and **David Swanson** hosted the event. In all, a dozen EDL staff members and four from ESTL contributed to the course, which is certified by the American Economic Development Council.

John Adams presented a paper, "Horizons in Apparel Manufacturing: Computer Simulation of the Apparel Plant," at the annual conference of the Clothing Manufacturers Association in New York City in early May.

On April 15, **Sherman Dudley** taught a session on prospect targeting for the Economic Development Institute at the Indiana University-Purdue University joint campus in Indianapolis. Some 55 economic development professionals from across the country participated.

David Chatham went on the road this spring, traveling to Indianapolis to attend the Economic Development Institute in mid-April, then going to Omaha in early May for the third annual Business Retention/Expansion Workshop.

On April 18, the Albany Regional Office hosted a "Showcase," an event designed to acquaint local community and business leaders with Georgia Tech. President Creine spoke to the Rotary Club as part of the occasion.

Environmental Science & Technology Lab

On April 30, **Claudia Huff**, with **Elliot Price** of EDL's Augusta Regional Office, facilitated a retreat for the management team of the National Science Center in Augusta. She also served on a panel, "Women in the Workplace," April 18 at West Georgia College.

Chris Downing gave a presentation, "Indoor Air in the '90s," to Leadership Atlanta April 16 at the Georgia Power Environmental Center.

Materials Science & Technology Lab

Jack Lackey and **John Hanigofsky** co-authored a paper with GE Aircraft Engines personnel which won an honorable mention in the Best Papers Contest at the American Ceramic Society meeting in January. The paper, "Continuous Fiber Coating System," described the design and operation of the equipment as well as use of the system to coat fibers.

Microwave & Antenna Technology Development Lab

A paper by **Dayton Adams, Larry Corey, Robert Howard, and Armand Masse** (Countermeasures Development Lab) will be presented at the 37th Annual Tri-Service Radar Symposium in Colorado Springs. The paper is entitled "Analysis of Cross-Polarization Jamming of Phased-Array Radars."

Modeling & Analysis Lab

At the IEEE National Radar Conference in Los Angeles March 12-13, **Sam Piper** presented a paper entitled "FMCW Linearizer Bandwidth Requirements." He has been elected a Senior Member of IEEE.

Office of Director

Ed Reedy received his IEEE Fellow certificate at the National Radar Conference held in Los Angeles March 12-13.

Physical Sciences Lab

Chris Summers gave an invited seminar entitled "Chemical Beam Epitaxy for New Quantum Device Structures" at the Physics Department of Ohio University in April.

At the Integrated Photonics Research Topical Meeting in Monterey (CA) last month, **Kenny Chiang** presented a paper entitled "A New Technique to Measure the Effective Refractive Indices of Semiconductor Slab Waveguides"; coauthors were **Chris Summers** and **Richard Kenan** (EE).

Raj Rajavel attended the spring meeting of the Materials Research Society in Anaheim (CA) in May. He presented a paper entitled "Gas Source Doping of Molecular Beam Epitaxially Grown CdTe," coauthored by **Brent Wagner, K. Maruyama, Rudy Benz, A. Conte,** and **Chris Summers.**

Service Groups

Bob Lang, Director, Research Security, has been elected to the METROPOL Board of Directors. METROPOL is an organization of senior management police officers (chiefs, sheriffs, and FBI special agents), along with senior managers or directors of corporate security. It provides advice and guidance on matters relating to law enforcement and security issues to the Governor's Office, legislature and other Georgia government officials.

Ron Creswell (MAPS) has received his MBA (with a concentration in information systems) from Georgia State University. □

Personnel News

Aerospace Science & Technology Lab

John Bright is a new RE I in the System Development Branch.

Sherry Travis has been promoted to senior secretary in the Acoustics Branch.

Frances Shiflett has transferred to MAPS/Cobb II with a promotion to staff assistant.

William Hood, Dave Schuster, and **Jennifer Seckinger** (GRA) have terminated their employment.

Economic Development Lab

Rick Tate resigned at the end of April, and **Erma Hightower** departed in mid-May.

Modeling & Analysis Lab

John Andrews has transferred to the Radar and Instrumentation Development Lab.

Radar Systems Applications Lab

George Aboutanos left in May to further his education.

Service Groups

Congratulations to **Dennis Crain** on his promotion to assistant manager, Research Operations Analysis and Modeling Group; **Paulette Clark** on her promotion to staff assistant, MAPS/O'Keefe; and **Frances Shiflett** on her promotion to staff assistant, MAPS/Cobb II.

Richard Tofani, Research Security/Cobb County, has been promoted from project coordinator to assistant department manager, effective May 17. He now heads the CCRF branch of Research Security. Congratulations!

Threat Systems Development Lab

SRE Calvin Jameson has transferred from ESTL to TSDL. The lab also welcomes RE I **Bruce E. Kerkemeyer.** □

Personal Notes

Wedding Bells

David Asbell (MATDL) and **Michele McNichols** were married April 27.

Cradle Roll

Congratulations to **Pat and John Marshall** (ASTL) on the birth of their daughter, **Sarah Ellen**, April 22.

MAL staff also welcomed daughters: **Katie Elizabeth**, born April 22 to **Kelly and Byron Keel**, and **Lauren Cassandra**, born to **Jodi and Keith Aberegg.**

On May 1, **Pat and Jim Page** (RIDL) became proud parents of a daughter, **Anna Leigh.**

Congratulations to **Evan Chastain** on the birth of a grandson. The parents are Mr. and Mrs. **John Edward Chastain**, presently stationed in Japan.

Our Sympathy

Christie Belcher (MAL) lost her father March 30.

Ron Creswell's (MAPS) brother-in-law passed away May 7.

Sick Bay

Get-well wishes to **Bill Howard** (OOD), who had emergency surgery May 15. □

Honor roll of Gulf War veterans

Here are the first responses to a request for names of relatives of GTRI employees who served in the Gulf War:

- Warrant Officer II **Barry A. Cranfill**
Army helicopter pilot (Medivac)
Son of **Barbara Cranfill** (ASTL)
- Lt. **Richard Lee Hughey**
Navy fighter pilot
Son of **Lee Hughey** (RCO)
- SMSgt. **David Manchester**
190th Air Refueling Group
Air National Guard ("Kansas Coyotes")
Brother of **Sharon Tabor** (MATDL)

If you or your coworker have a relative who served in the Gulf War, send us the details. We'll publish an updated list in the June Connector. Respond to **Martha Ann Stegar**, RCO/GTRI 0800, or **PROFS MSTEGAR.** □