



There's No Place Like

HOME

Future computing technologies will allow senior adults to live independently longer.

by JANE M. SANDERS

A

Arthur was in great condition for a man of 91 years, but age had begun to take its toll on his short-term memory.

Arthur would start to cook a meal in his farm home, and the phone would ring. Forgetting he had something on the stove, he would start watching television. Then the smoke alarm would go off, alerting Arthur to a burning saucepan of food. This scenario

repeated itself enough times that Arthur's son, Bill, became concerned for his father's safety.

Bill carefully suggested the idea of moving to an assisted living facility, realizing the expense, but trading it off for peace of mind and safety. There, Arthur would have his own apartment, but not have the responsibilities of cooking and cleaning. He would have people nearby to help in an emergency and to socialize with every day. Arthur agreed and now seems happy in his new home. Bill is relieved that his father is close by and that Arthur is eating nutritious meals prepared by a professional cook.

Arthur is one of more than 35 million Americans over age 65. Many of them are facing or will soon face the same issue



PHOTO ILLUSTRATION BY GARY MEEK



PHOTO BY STANLEY LEARY

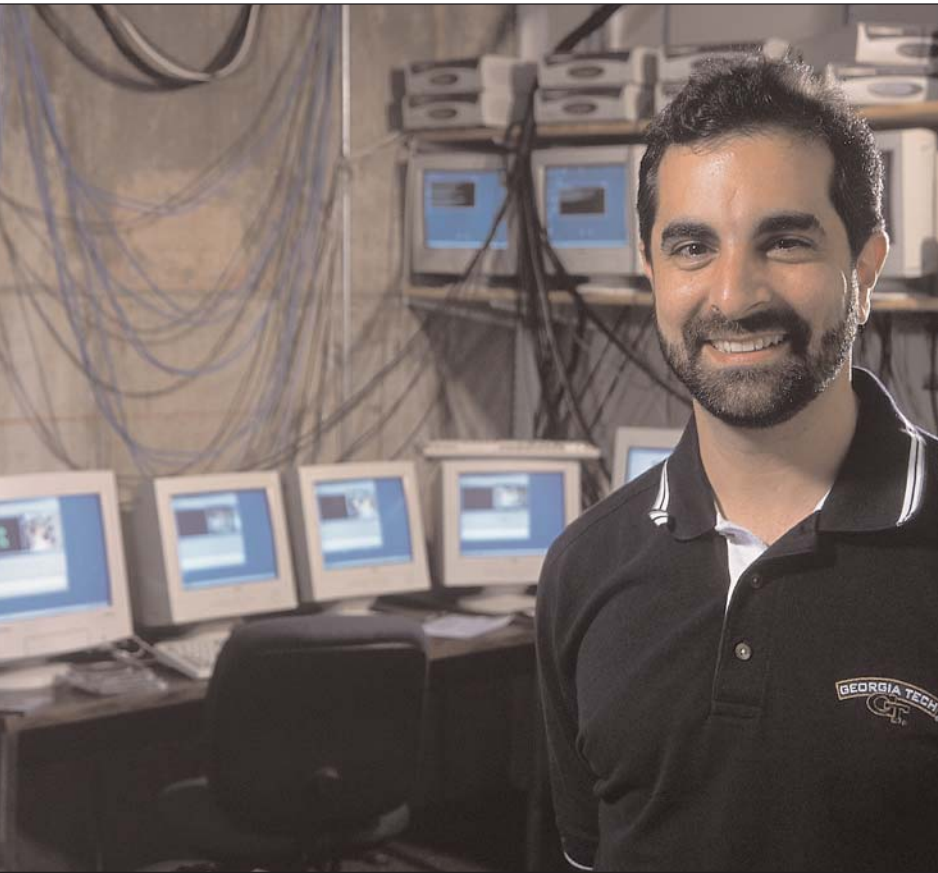


PHOTO BY STANLEY LEARY

An interdisciplinary research team led by Associate Professor of Computing Gregory Abowd is conducting a project called the Aware Home Research Initiative with a specific focus on using computing technology to allow seniors to live independently longer. The project is based in the unique 5,040-square-foot Broadband Institute Residential Laboratory, a three-story home adjacent to the Georgia Tech campus.

Arthur and Bill confronted. Will they be able to continue living in their own homes as memory and physical abilities decline? In five to 10 years, the answer may be more hopeful.

Researchers at the Georgia Institute of Technology believe they can lengthen older adults' independence, perhaps even for several years, with computer-based "aware home" technologies. Sensors can feed information to computers, giving a home an awareness of the residents' activities so it can support their needs — in this case, ways to combat the common impairments of aging.

"This is a well-grounded, pragmatic problem to be looking at," says computer scientist Beth Mynatt, an associate professor in the College of Computing and member of an interdisciplinary research team conducting a project called the Aware Home Research Initiative, with a specific focus on the issue of aging in place. "It's feasible that the technology will be affordable and socially acceptable in the broader context of other options available to senior adults."

The Aware Home project is based in the unique 5,040-square-foot Broadband Institute Residential Laboratory, a three-story home adjacent to the Georgia Tech campus. Construction of the residential lab, which opened in May 2000, was funded by a \$700,000 grant from the Georgia

Research Alliance (GRA). Additional GRA funds are supporting the maintenance and upgrade of the facility.

"With this project, we are trying to determine how one might design a home to enable older adults to be functionally independent longer and to minimize the transition into an assisted living center," explains Wendy Rogers, a professor in the School of Psychology and another team member. "... What kind of technology supports do they need to live in their own home longer? At the same time, we'll be designing those supports.

"For example, what is the best way to present information to a senior adult on their medication regimen?" Rogers adds. "You could present visual display reminders and instructions on how to take the medication. You might also track whether they took the medication and then remind them. So we want to design the best interface so they can process the information and benefit from it."

"Economically, it provides a tremendous savings if older adults can stay in their own homes rather than move to an institutional setting..."

Research funded by the National Science Foundation, corporate sponsors and the GRA centers around three themes: 1) development of technological building blocks that promote awareness of occupants and activities in a home setting; 2) gaining an understanding of the needs of an aging population and creating applications to meet those needs; and 3) development of software infrastructure to engineer robust applications using the technological building blocks, explains Gregory Abowd, director of the Aware Home project, associate director of the Broadband Institute at Georgia Tech and an associate professor in the College of Computing.

Researchers bring various areas of expertise to the project, and their collaboration in the residential lab is vital to the project's success. For example, applications will be driven by the capabilities of sensing and computer perception technologies that are designed and tested in the Residential Laboratory, researchers say.

The technologies developed from this research will benefit not only older adults, but other groups with cognitive impairments and eventually, as the technology becomes pervasive, the general public. "As we develop the technology, we find the value



PHOTO BY GARY MEEK

of it for a larger group of people," Abowd says. "This is referred to as universal design, and from my perspective it is a goal."

There will be other benefits to the general public, as well. Economically, it provides a tremendous savings if older adults can stay in their own homes rather than move to an institutional setting, says research team member Aaron Bobick, an associate professor in the College of Computing and director of the Graphics, Visualization and Usability Center, with which all research team members are affiliated. Not only is the expense of elder care facilities an issue, so is the availability of them, adds researcher Irfan Essa, an associate professor in the College of Computing.

Bobick cites another impact of Georgia Tech's research: "The Georgia taxpayer also has the benefit of the residential lab and our research being here, making the state grow in national reputation regarding elder care and technology. That means companies will locate significant facilities here and increase the range of technical expertise associated with Georgia."

Though they have not located new facilities in Georgia, companies such as Intel and Motorola have already taken an interest in research at the residential lab. Along with four other companies – Mitsubishi Electric Research Lab (MERL), Hewlett-Packard (HP), Accenture and Visteon – they sponsor research in the form of annual gifts to the Aware Home Research Initiative. These companies support the research, hoping to apply its findings about the future of personal computing, the future of connecting broadband communications to all homes and the interaction between these two issues, says Nikil Jayant, director of the Broadband Institute and a professor in the School of Electrical and Computer Engineering.

Intel has the most interest in aging in place applications, Abowd says. Meanwhile, MERL is interested in smart environments, as are Accenture and HP. Motorola wants research results on wireless communications, and Visteon is seeking

Researchers...believe they can lengthen older adults' independence, perhaps even for several years...

applications that will connect the home and the car, he explains.

"Although research at the Residential Laboratory is industry guided, we have to date not created a platform that is compelling enough for industry to be physically close to the lab," Jayant adds. "Its impact will be at a fundamental-knowledge-creating level. On the other hand, most companies that are attracted to Atlanta and Georgia Tech are attracted even more when they discover the Residential Laboratory as part of our research infrastructure. We'd love to see start-up companies make some use, even if it is indirect, of our research and the intellectual property resulting from it."

While companies are taking notice, Essa expects that retirees will also be attracted to Georgia's advances in elder care and aware home technologies.

In the broadest sense, the Aware Home project "brings to bear what technology should be doing in our homes," Essa says. "... We are asking questions like, 'What is computing technology good for except Web surfing?' We should start thinking about computing having the same impact on society as mechanical engineers have had on cars." **RH**

■ For more information, you may contact Gregory Abowd, College of Computing, Georgia Institute of Technology, Atlanta, GA 30332-0280. (Telephone: 404-894-7512) (E-mail: gregory.abowd@cc.gatech.edu)

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Researchers are creating technologies to address memory problems associated with aging.

Top left: The "Aware Home" at dawn.

Below: Associate Professor of Computing Irfan Essa, left, and his students are focusing on sensing technology, with the Residential Laboratory serving as the test bed. "The goal is to build an infrastructure so an aware home can see and hear its inhabitants and interact with them like a normal person would," Essa explains.

PHOTO BY GARY MEEK



Jogging the Memory with Information from Sensors

Researchers make progress in aware home applications and infrastructure.

PHOTO BY GARY MEEK



To promote social interaction between seniors and their grandchildren, Associate Professor Beth Mynatt, visiting researcher Itiro Sii and graduate student Jim Rowan have developed an application called Peek-A-Drawer. It provides virtual shared drawers for grandparents who want to share a part of their living space with grandchildren who live far away.

Gorgia Tech researchers involved with the Aware Home project are making progress in several areas, including age-related applications and the infrastructure of computer awareness technology.

The Digital Family Portrait, developed in prototype form by Associate Professor of Computing Beth Mynatt, is one application that is forging ahead. Its goal is to give adult children a virtual awareness of the condition and activity level of their independently living parent, who often resides in another town.

The portrait — actually a computer screen with the older adult's picture displayed in a digital frame — might hang on a mantel over a fireplace in the adult child's home. Sensing data from the parent's home feeds the portrait's frame with 28 butterfly icons that change in size, indicating the parent's daily activity levels for a 28-day period.

If the adult child wants more information about a particular day, she touches that icon and gets a more detailed visualization for that day. In this screen, information indicates the weather and temperature at the older adult's home, and a bar graph reflects the person's room-to-room activity.

Sensors in the Broadband Institute Residential Laboratory can already track movement of people from room to room, giving researchers a broad sense of activity based on an inhabitant's motion. Mynatt has experimented with using this data in the portrait application. In addition, she has conducted studies involving actual families in their own homes using information from interviews with the senior adult to supply data for the portrait. Mynatt plans more experiments like these, both in the Residential Laboratory with actual human subjects and in the field with additional families whose houses will be instrumented with simple sensing systems.

"The sensing information will provide a visualization for a unique footprint of a person's daily life," Mynatt explains. "We might find out that the older adult got up during the night a couple of times to go to the bathroom. Then they got up and had breakfast, and then there was a lull of activity followed by another burst of activity around dinner

PHOTO BY STANLEY LEARY



The Digital Family Portrait, developed in prototype form by Associate Professor of Computing Beth Mynatt, will give adult children a virtual awareness of the condition and activity level of their independently living parent, who often resides in another town.

and bedtime. So without breaching the privacy boundary, you can still get a good sense of a person's overall activity level using the Digital Family Portrait. If you know that person well, you gain a sense over time about whether today looks like a normal day."

With the Digital Family Portrait well under way, Mynatt and colleague Wendy Rogers, a professor of psychology, want to develop technologies to address memory declines in older adults. So they are investigating interfaces that make up for short-term memory impairments, as well as systems to provide near-term reminders. If an older adult is interrupted or distracted from a task, he might forget what he was doing. An aware computing system could continuously gather information and visually present information back to the resident to jog his memory.

Mynatt, Rogers and Gregory Abowd, an associate professor of computing and research director of the Aware Home project, developed a prototype interface called "What was I cooking?" In a demonstration of the technology, cameras under the kitchen cabinets record a person putting white ingredients into a bowl. For the prototype only, containers are also instrumented with sensors.

PHOTO BY GARY MEEK

Researchers use the sensing information to create a cartoon-strip-format display of the person's recent actions. Then when the person's activity is interrupted and they forget what ingredients were added to the bowl, the display provides a reminder.

A similar visual reminder system could prompt recall when older adults start a task in one room, then must go to another room to complete it. When they get to the other room, they often forget why they needed to go there. Rogers also wants to develop interfaces for prospective memory – memory to do something in the future (e.g., remembering to take medication). "So the house could become a surrogate memory system," Mynatt adds.

To promote social interaction between seniors and their grandchildren, Mynatt and visiting researcher Itiro Siio and graduate student Jim Rowan have developed an application called Peek-A-Drawer. It provides virtual shared drawers for grandparents who want to share a part of their living space with grandchildren who live far away. When a user puts something in an upper drawer of a chest and closes it, a photograph is taken automatically. Then the image appears on a monitor in the lower drawer of a chest in the relative's house. "The operation is so simple that even children can communicate with their grandparents," the researchers report. "Also, as the camera only takes pictures of objects inside the drawer, privacy is assured."

"...the house could become a surrogate memory system..."

Meanwhile, Associate Professors Irfan Essa and Aaron Bobick are focusing on sensing technology, with the Residential Laboratory serving as the test bed. "The goal is to build an infrastructure so an aware home can see and hear its inhabitants and interact with them like a normal person would," Essa explains.

Two prototype sensing systems exist in the Residential Laboratory, though neither is continuously operating for now. In the kitchen, optical sensors in the ceiling can locate a person in the room and approximately track where they are headed (e.g., toward the refrigerator or oven). In another room, cameras and microphones are embedded in the walls. Researchers are primarily concerned with data collection for now, rather than data processing, Essa says. But they can interpret audio data with commercial speech recognition software.

Later, researchers want the system to recognize a person's location when they speak. Then if



the person is speaking in the dark, the cameras can move where the person is located. Next, researchers will instrument the Residential Laboratory with sensors focused on specific areas, like the sink in the kitchen to gather data on when an inhabitant is washing the dishes, for example.

Altogether, the video sensing systems in the Residential Laboratory will provide generic location information — where people are and when — and then add basic activity recognition capabilities to the system, Bobick says. "One simple example is sitting on the sofa," he explains. "To assess your cognitive engagement, it matters a lot whether you are watching TV, reading the newspaper or sleeping. So once the tracking system identifies a person on the couch, I want to have more computer vision to tell me which level of activity they are engaged in."

Though prototype sensing systems may be apparent to users, future versions will not be. "We don't want people to feel tracked without giving any value back to the individual," Abowd says. "We have a desire to make sensing invisible in the house. We want to leave it to the house to be aware, and that is primarily a sensing challenge. But we also want people to be comfortable about what is being known about them.... We have found that people are willing to give up some privacy to have the ability to maintain their quality of life and stay in their own home."

It is in these issues where technology and real life intersect. Aware Home researchers have anticipated this intersection and are crossing it in advance of technology design.

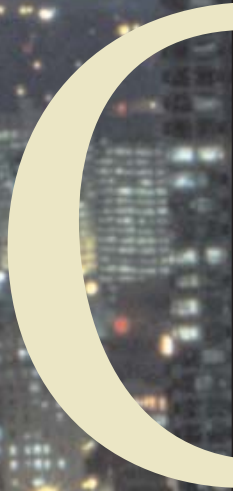
– Jane M. Sanders

PHOTO BY GARY MEEK



In a prototype technology demonstration called "What was I cooking?", cameras under the kitchen cabinets record a computer science student, Mahmudul Jilani, putting white ingredients into a bowl.

Eye *in the* Sky



by JANE M. SANDERS

IMAGES COURTESY OF THE GEORGIA DEPARTMENT OF INDUSTRY, TRADE AND TOURISM



Next generation ozone-monitoring technology expected to improve smog forecasting.

On a calm summer night, the air above Atlanta can be saturated with ozone and particulate matter while the pollutants at ground level plummet to near zero. It may appear, even to experts, that tomorrow's air quality will not merit a smog alert.

But the sun rises, and the heat begins to cook chemicals suspended in the air, forming more ozone. Soon, the winds mix pollutants into the air at ground level.

By noon, haze mutes the Atlanta skyline, contaminating the air metro residents breathe. By then, it's too late to issue a smog alert that might divert some motorists from the city's clogged highways and encourage mothers to limit the time their children play outdoors.

Had the experts known the concentration of ozone in the air above the city, they would have had a vital piece of information in making the next day's ozone forecast. And, over time, researchers could use this information to help determine the "sources and sinks" (i.e., where it is created and where it goes) of air pollutants. In turn, metro area planners could devise effective strategies to address air quality issues.

With these ultimate goals in mind, a team of engineers at the Georgia Tech Research Institute (GTRI) is designing the next generation of ozone-monitoring technology. Based on light detection and ranging (LIDAR) technology developed by the National Oceanic and Atmospheric Administration, the updated version will make ozone monitoring continuous and affordable, and results will be

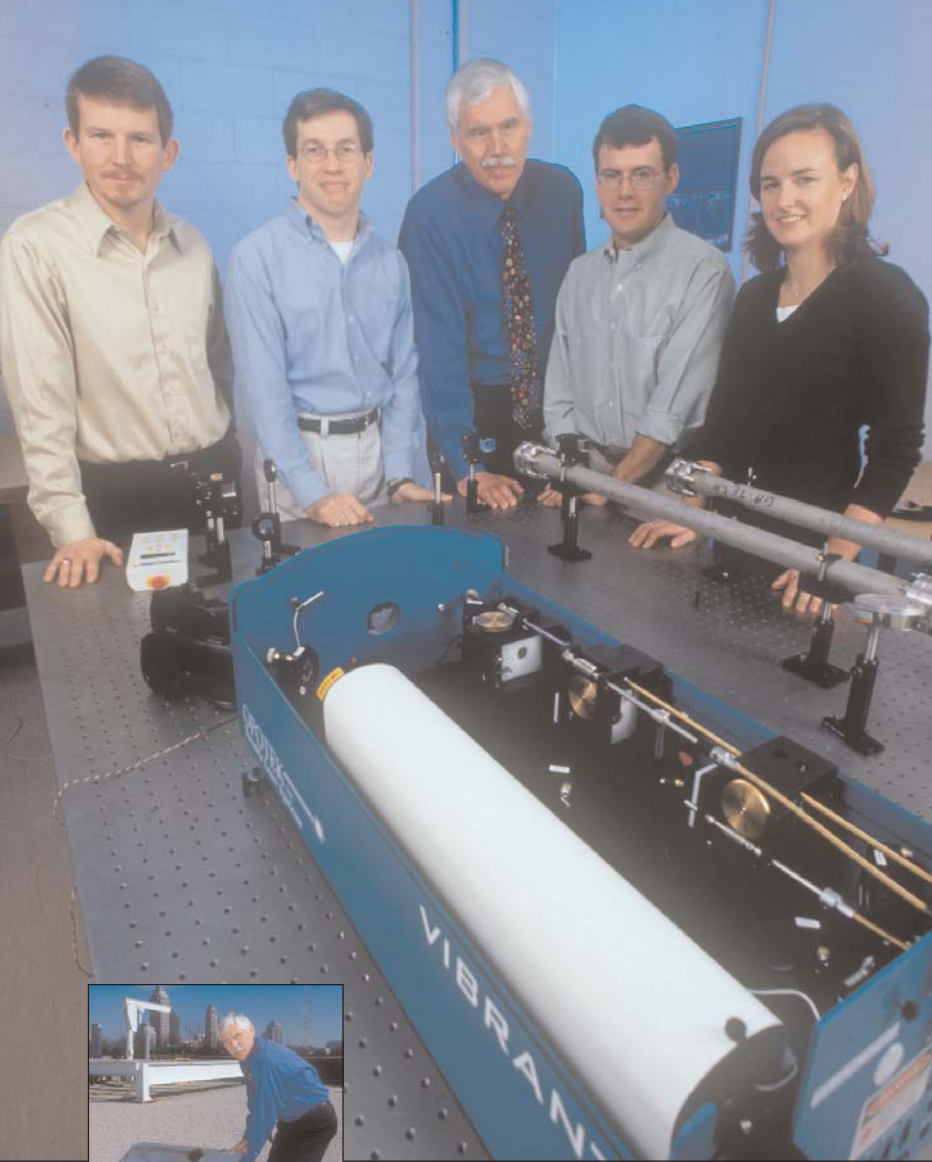
available via the Internet in real time. Funded by a Technology Development Partnership through the Georgia Research Alliance and LaserCraft Inc. of Norcross, Ga., the device has been dubbed NEXLASER for NEXt Generation Laser Air Sensor for the Southeastern Region (though the technology could be applied anywhere in the world, researchers explain).

"NEXLASER will be great for ozone forecasting, and it should enable people to do new kinds of research projects in city planning, environmental engineering and atmospheric chemistry," says GTRI project director Gary Gimmetad. "... Right now, it's hard to correlate anything like traffic patterns with ozone. It's just not accurate yet because there's not enough information."

NEXLASER will adapt and automate the operation of LIDAR, which in the past has been suitable only for short-term pollution studies because it requires numerous personnel to operate it. LIDAR works like this: 1) A laser emits pulses of light that scatter into the atmosphere. 2) Then a telescope receives that scattered light. 3) A detector converts the light to electronic signals. 4) A data system digitizes and stores those signals. 5) Finally, researchers determine the distance the light scattered by multiplying the speed of light by the flight time it took the pulse to travel up and back.

This information reveals the ozone concentration at periodic measured distances because ozone absorbs one color of light emitted from the laser,

Ground-level ozone pollution in Atlanta has prompted a technology development to improve ozone forecasting.



Above: Researcher Gary Gimmestad and his colleagues will field test the first NEXLASER ozone monitor through a hatch atop a Georgia Tech building later this summer.

“NEXLASER could be the single greatest improvement to our ozone forecasting at this time... We're looking forward to it with great anticipation.”

“Vertical profiles of air quality are the great unknown. All of the air quality monitoring we do now is essentially at the surface. But what's above the surface is extremely critical in terms of the air quality at the surface, particularly in the late afternoon. NEXLASER could be the single greatest improvement to our ozone forecasting at this time.... We're looking forward to it with great anticipation,” Chang adds.

Researchers have completed a laboratory version of NEXLASER and a prototype of software to automate data analysis. They recently began operating, testing and evaluating the system in their lab. The next phase, which may begin this summer, will be field-testing. After that, researchers would work with LaserCraft engineers in developing a commercial version of NEXLASER, which would cost about \$250,000 per unit. Gimmestad hopes a network of five to six NEXLASER units will be deployed within two years at Georgia Environmental Protection Division field sites around metro Atlanta.

“Atlanta is the perfect test case for a NEXLASER network,” Gimmestad says. “It has the third-worst air quality in the nation after Los Angeles and Houston.... We hope the NEXLASER technology would be adopted by other cities within five years.”

Meanwhile, much work must be done in the lab, the field and the commercial arena. Because LaserCraft is funding part of the NEXLASER research, it has the rights to license the technology. Georgia Tech would grant an actual license to LaserCraft after Gimmestad's team completes field-testing.

“LaserCraft is very pleased to sponsor this project for a number of reasons,” says Glen P. Robinson Jr., CEO of LaserCraft and a Georgia Tech alumnus. “It fits into our long-range plans to develop new products around laser technology. The NEXLASER will help solve a serious air pollution problem, and it will provide many new, high-tech

but not another. So a dense concentration of ozone would lessen the distance light scatters.

While LIDAR provides significant data, it is usually not automated. It takes a crew of operators to make adjustments, maintain the system, and collect and analyze data. NEXLASER will automate this process, making data collection continuous and data analysis occur in real time.

“NEXLASER's three-dimensional data — altitude up to 3 kilometers, ozone concentration and geographic distribution from a network of units — will represent a significant technological improvement,” Gimmestad says. “We hope that knowing the ozone concentration in all of these places can improve researchers' understanding of ozone sources and sinks.”

Senior research scientist Michael Chang in the Georgia Tech School of Earth and Atmospheric Sciences is hopeful about the potential of NEXLASER. “If they can pull this off and get a unit that is affordable, it would be great,” Chang says. “We can do this type of monitoring now, but it requires a \$2 million investment. If they can get the cost down to about a quarter of a million, it's still costly, but we can handle that.”

employment opportunities for Georgia citizens." LaserCraft engineers have experience in developing laser-based sensing and monitoring systems for military and commercial applications. The company's major products are laser speed guns used for traffic speed control, monitoring violations at traffic lights and stop signs, and identifying speeders in school zones and residential areas, and a line of laser-based surveying instruments.

The Georgia Research Alliance is also hopeful about the prospects for NEXLASER. "The NEXLASER system is an exemplary project for the Georgia Research Alliance Technology Development Partnership program," says Kathleen K. Robichaud, program manager for GRA. "It brings together Georgia Tech's research and development strengths with

LaserCraft's success in marketing and selling laser-based technology. And it has real potential for helping to address very serious air quality problems."

In addition to Gimmestad, the GTRI researchers involved with the study are project lead engineer Dave Roberts, and engineers John Stewart, Leanne Little West and Jack Wood. RH

■ For more information, contact Gary Gimmestad, Electro-Optics, Environment and Materials Laboratory, Georgia Tech Research Institute, Atlanta, GA 30332-0834. (Telephone: 404-894-3419) (E-mail: gary.gimmestad@gtri.gatech.edu)



Above: NEXLASER is expected to improve ozone forecasting and enable researchers to do new kinds of projects in city planning, environmental engineering and atmospheric chemistry.

Below: Leanne West and Jack Wood are part of the research team.

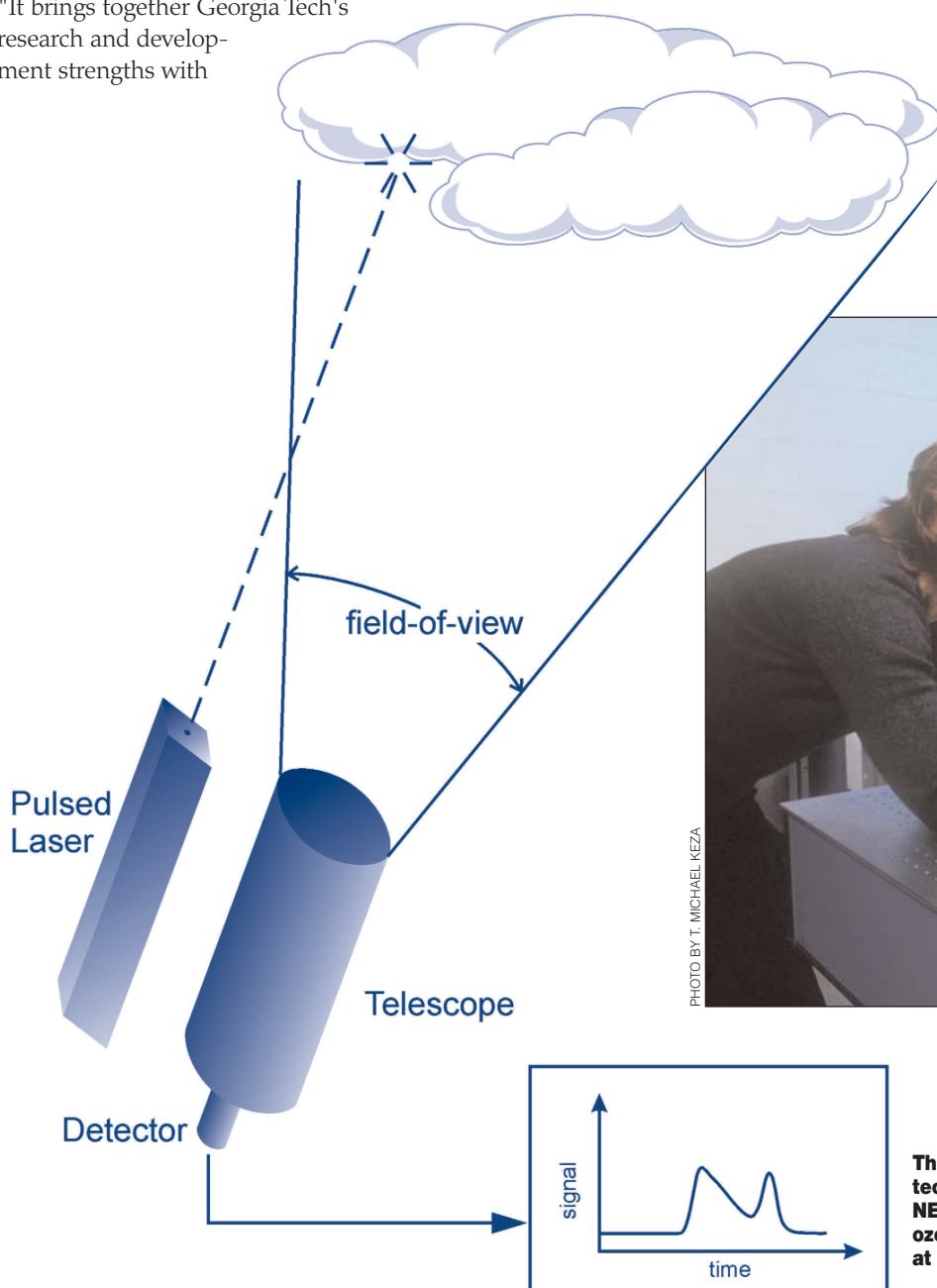


PHOTO BY T. MICHAEL KEZA



This graphic depicts the LIDAR technology that forms the basis for NEXLASER, the next-generation ozone monitor under development at GTRI.

ILLUSTRATION COURTESY OF GARY GIMMESTAD



Fresh Air, Weather Fair

Air quality researchers note cleaner air last summer, but expect return to normal pollution levels this season.

by JANE M. SANDERS

Though air quality in Atlanta last summer was the best on record since 1989, the state's air pollution problems have not been solved. So researchers at the Georgia Institute of Technology are already busy this season collecting air quality data around the state, hoping to advise cities on pollution control strategies, and alert metro Atlantans daily of ozone levels that could be harmful to their health.

"Last year was one of those rare annual events that occurs when the weather cooperates and you hit the cycle just right," explains Michael Chang, a senior research scientist at the Georgia Institute of Technology's School of Earth and Atmospheric Sciences and director of the Center for Urban and Regional Ecology. "Though it was good to have cleaner air, unfortunately, it happened when we were conducting an air pollution study."

Chang leads the Fall Line Air Quality Study (FAQS), which is assessing urban and regional air pollution in the Georgia metropolitan areas of Augusta, Columbus and Macon. Researchers are identifying the sources of pollutants and pollutant precursors and will later recommend strategies for air quality improvement.

The four-year study, which began in the summer of 2000, involves a team of researchers from the Georgia Tech schools of Earth and Atmospheric Sciences and Civil and Environmental Engineering. The team is conducting field studies from both mobile

Left: Atmospheric scientists at Georgia Tech are studying the ozone levels in three Georgia cities – Augusta, Columbus and Macon. They use a mobile air quality monitoring unit to gather air quality measurements.

PHOTO BY STANLEY LEARY

and stationary monitoring sites during smog season from May 1 through Sept. 30, and then using the data to feed models that can predict the impact of various air quality control strategies.

"This summer is critical for us," Chang explains. "We need to decide on the factors that are contributing to air quality. But last year we didn't see the pollution episodes we needed to diagnose the causes. We are beginning to analyze a couple of pollution events from last year, but preliminary results suggest that last year was not an ideal year to study air pollution. There were no violations of the current federal air quality standard in Columbus, six in Macon and three in Augusta. In Atlanta, we had just 20 violations of the federal air quality standard compared to 46 in 2000."

The FAQS team believes air quality in Georgia cities will return to a more normal state this year. With all of their field sites ready to go, they expect to collect a lot of useful data. "We don't know if it will get really bad this year, but it's important to be out there," Chang says. "Sometimes you don't know when a bad air day is going to occur."

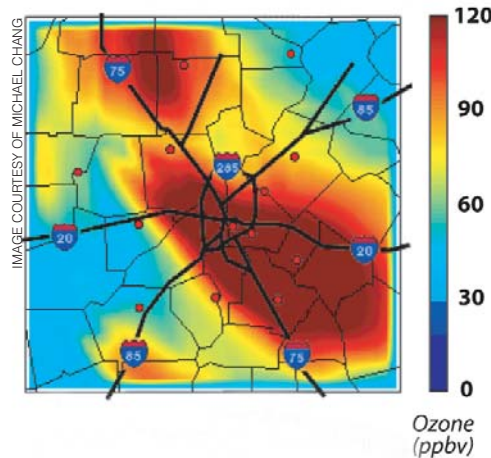
The challenge for FAQS researchers now will be the faster pace required to integrate field data with the complex computer models they will use to simulate air quality control strategies for Augusta, Columbus and Macon.

"There are different strategies for these different cities," Chang explains. "Augusta is very industrialized, but Columbus is service-oriented and half of Augusta's size. So the strategies and controls for a large metropolitan area like Atlanta may not be appropriate for these smaller cities. Modeling various strategies is much cheaper than doing a retrofit to address air quality and then waiting to see if it works."

Researchers plan to conclude the FAQS study by December 2003, probably about the time that the federal Environmental Protection Agency imposes a deadline for cities to comply with its stricter air quality standard. "We will get the best information we can by then to the people who need it before the regulatory agencies mandate them to come up with a solution. The cities want

Urban Airshed Model in Forecast Mode

METROPOLITAN ATLANTA PREDICTED PEAK 8-HOUR AVERAGE OZONE CONCENTRATIONS – AUGUST 17, 1999



This map shows the typical peak ozone concentration on a hot summer day in Atlanta.

local control in choosing their air quality management strategies."

FAQS is funded by an appropriation from the Georgia General Assembly and administered by the Georgia Department of Natural Resources' Environmental Protection Division (EPD). The total study cost is expected to be \$2.75 million.

Meanwhile, Chang's research team is entering its seventh year of participation in ozone forecasting for metro Atlanta. The project, funded for \$500,000 by the EPD for the past four years, provides both ozone forecasting tools and expertise to state officials.

"In the past several years, we've been able to improve both the accuracy and the length of our forecast," Chang says. "Now we want to know if we can stretch the forecast from 24 to 36 or 48 hours and remain within a level of accuracy that is necessary to maintain credibility. We've got an 80 to 85 percent accuracy rate now."

Six EPD forecasters and four Georgia Tech researchers, including Chang, make up a 10-member forecasting team that meets daily during smog season in an Internet chat room to forecast the



Lead researcher Michael Chang

"In the past several years, we've been able to improve both the accuracy and the length of our forecast... Now we want to know if we can stretch the forecast from 24 to 36 or 48 hours..."

OF INDUSTRY, TRADE AND TOURISM



“The goal is to get citizens and employers to reduce emissions-causing activities, such as driving, mowing and filling gas tanks during the day.”

next day's peak ozone level. By the time they gather in the early afternoon, the team members have reviewed the results from computer model simulations that require an entire night of automated number crunching. They also consider several different weather forecasts and assess what is happening with ozone levels that day — a big factor for the ozone forecast for tomorrow.

It takes about 15 minutes for the team to reach a consensus on the forecast. When they cannot, the chief of EPD's Air Protection Branch makes the decision on whether to recommend a smog alert. If the team recommends a smog alert, Georgia's Clean Air Campaign publicizes it via the news media and changeable message signs on the highways. The goal is to get citizens and employers to

reduce emissions-causing activities, such as driving, mowing and filling gas tanks during the day.

Researchers at Georgia State University are examining whether the public responds to smog alerts. They have found a small, but growing, benefit from these messages, Chang says.

"Atlanta is now taking the lead in the nation in terms of quantifying how people respond to smog alerts," he adds. **RH**

■ For more information, you may contact Michael Chang, School of Earth and Atmospheric Sciences, Georgia Tech, Atlanta, GA 30332-0595. (Telephone: 404-385-0573) (E-mail: michael.chang@eas.gatech.edu). Or visit **www.cure.gatech.edu** for more information.

PHOTOS BY STANLEY LEARY



Above: Columbus is one of the Georgia cities included in the Fall Line Air Quality Study.

Right: A mobile air quality monitoring unit is used to gather air quality measurements.

Inset: Researchers monitor air quality measurements inside the mobile unit.



PHOTO BY GARY MEEK

Novel Gas Sensors

Devices based on porous silicon offer potential for low-voltage, low-cost sensor arrays integrated with electronics.

A new type of sensor based on porous silicon and a unique metallization process could offer enhanced sensitivity, reduced power demands and lower cost compared to existing technologies for detecting gaseous compounds important in environmental, food and biomedical applications.

Because they are based on silicon wafers, manufactured using integrated circuit production techniques and operate at room temperature using relatively low voltages, the new sensors could be integrated into electronic equipment and used to build sensing arrays. Researchers at the Georgia Institute of Technology developed the devices, described earlier this year in the *Journal of Applied Physics*.

"The sensors show a rapid and reversible response to low concentrations of these gases at room temperature," says James L. Gole, a Georgia Tech professor of physics. "They operate on a voltage much less than that of a watch battery and would be small enough to be taken into the field with a troop contingent or any other group concerned about the presence of harmful

by JOHN TOON

James Gole displays a treated silicon wafer illuminated by ultraviolet (purple) light. The orange-red photoluminescence from the porous silicon is clearly visible.

Novel Gas Sensors

gases. The sensors are so simple that they could ultimately be mass-produced for pennies apiece."

Sensors based on porous silicon have been built before, but their practicality has been limited because of high resistance in the electrodes connected to the porous silicon and the power requirements of as much as 5 volts. Using a unique metallization process, however, Gole and his collaborators dramatically reduced the resistance of the electrodes built into the silicon, allowing their sensors to operate at between 1 and 10 millivolts — a dramatic improvement over earlier sensors.

The new devices can detect ammonia, hydrochloric acid and nitrogen oxides at concentrations of between 10 and 100 parts-per-million — if not lower — compared to 100 to 1,000 parts-per-million for the higher-voltage sensors. Because the chemical reaction they use to detect the gases can be rapidly reversed, the new devices are reusable. And after long-term use, they can be regenerated with a simple chemical treatment.

The introduction of gases onto sensitive porous silicon surfaces causes dramatic changes in their conductance. Simple and inexpensive electronic equipment can measure these changes. That could allow the sensors to be integrated onto a microelectronic chip and used as part of an "artificial nose" to detect a range of potentially toxic compounds.

The combination of low cost, low power consumption, room temperature operation and simple production for the Georgia Tech devices opens up new possibilities for sensing applications.

"We believe these sensors can be inexpensively built in arrays, which opens up interesting opportunities for mixture analysis in water quality, environmental sensing, food toxin detection and agricultural uses," says Peter Hesketh, a professor in Georgia Tech's School of Mechanical Engineering. "We also see the possibilities for biomedical

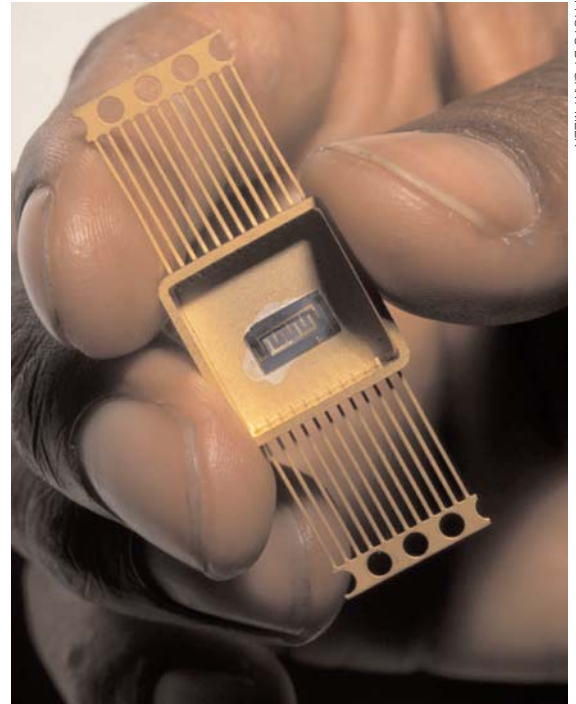
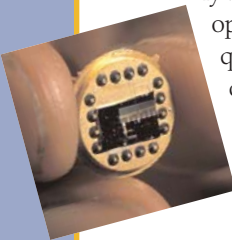


PHOTO BY GARY WIECK

analysis useful in blood analysis, pathogen testing and analyzing allergic reactions."

Production of the new sensors begins with a silicon wafer that is coated with a silicon nitride film deposited at about 250 degrees Celsius. Using integrated-circuit fabrication technology, a pattern is then applied on the film using a photoresist. Reactive ion etching then selectively removes the silicon nitride, leaving a pattern of exposed silicon.

Next, a hybrid electrochemical process that Gole describes as a "semi-hydrous" etch forms micropores in the silicon with diameters of 1 to 2 microns and aspect ratios of up to 400. Multiple applications of the etch treatment can create pores of consistent size. On top of these micron-scale pores, the Georgia Tech researchers then fabricate a layer of material with pores of a nanometer-scale size.



Ammonia



NO_x

NO_x

HCl

NO_x

N

A final electroless metallization process takes advantage of a unique property of porous silicon to produce low-resistance (~ 20 Ohms) contacts to which electrical leads can be attached. This overcomes one of the existing challenges in the fabrication of porous silicon devices: establishing low-resistance electrical contact to the porous silicon structure.

Porous silicon has attracted considerable interest because it produces a strong orange-red photoluminescence when subjected to ultraviolet light. Though the exact mechanism for this is the subject of debate among physicists, the Georgia Tech team believes the same electronic excitation mechanism that creates the orange-red glow also helps improve the efficiency of the electroless metallization process — thereby improving the conduction of the contacts.

The basis for the approach lies in the suggestion that the photoluminescence from porous silicon results from a surface-based process, and that this relatively long-lived photoluminescence can be used to enhance the rate of reduction of metallic ions from the electroless metallization solution in contact with the porous silicon surface.

The formation of surface-bound, electronically excited "centers" — whose interaction and reaction capability greatly exceeds that for the unexcited surface — provides an enhanced and controllable reduction capability for electroless solutions, the researchers argue.

The electroless processing technique produces contact resistances of as little as 20 Ohms. To facilitate electrical flow through the sensor, an aluminum film is deposited on the back of the wafer using screen-printing and thermal annealing techniques.



PHOTO BY GARY MEEK

Though initial testing suggests that the sensors have great promise, much work remains to be done on improving their selectivity, Hesketh notes. Techniques for calibrating them at lower concentration levels must also be developed.

In addition to Gole and Hesketh, the research team also included Lenward Seals, then a graduate student in the School of Physics, and Laam Angela Tse, a graduate student in the School of Mechanical Engineering. RH

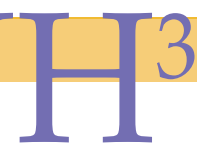
■ For more information, contact Jim Gole, School of Physics, Georgia Tech, Atlanta, GA 30332-0430. (Telephone: 404-894-4029) (E-mail: james.gole@physics.gatech.edu); or Peter Hesketh, School of Mechanical Engineering, Georgia Tech, Atlanta, GA 30332-0405. (Telephone: 404-385-1358) (E-mail: peter.hesketh@me.gatech.edu).

Above: James Gole and Peter Hesketh (left) prepare to operate a porous silicon sensor to collect data on its operation.

Left: A porous silicon sensor configuration is designed for the detection of glucose. Gold interdigitated electrodes generated from photoluminescence-induced metallization are shown.



Nitrogen Oxides



Hydrochloric Acid





Modernizing MEDITATION

Researchers create a virtual environment to teach and enhance meditation.

by JANE M. SANDERS

It took a 3D scientific visualization of the arterial tears and plaque buildup caused by high blood pressure for Diane Gromala to fully understand why she should reduce her stress level.

She turned to meditation for help and not only found that it reduced her stress, it also became the only treatment that systematically worked to deal with the chronic pain for which her doctors can provide no cure.

"I was resistant to the idea at first because it seemed to suggest that I was the problem," says Gromala, an associate professor in the Georgia Institute of Technology's School of Literature, Communication and Culture. "If I could just relax, then it would be all right. I wondered if meditation could do anything.... It does work, though, because it forces one to focus in precise detail on how one's body works. You can reconfigure your sense of how your body works and physically change it to some degree."

Now a 15-year veteran of meditation and convinced of its benefits, Gromala has collaborated with colleagues Larry Hodges and Chris Shaw in the Georgia Tech College of Computing on a project that may make meditation more appealing. The researchers

Diane Gromala, associate professor in the Georgia Institute of Technology's School of Literature, Communication and Culture, is collaborating with computer scientists on a virtual meditation chamber.

PHOTO BY GARY MEERK



PHOTO BY GARY MEEK

"Meditation chamber" users wear a head-mounted display and clip-on sensors for gathering biofeedback information, such as respiration and pulse. Computer science Professor Larry Hodges collaborated with colleagues Diane Gromala and Chris Shaw to develop the virtual-reality based technology.

and their students have created a virtual reality-based "meditation chamber," which they have field-tested and are now refining for potential commercialization.

In its current form, the program is a 15-minute virtual experience in relaxation techniques and meditation. Users wear a head-mounted display with audio and video that guides them through a series of sunset and moonrise scenes and muscle relaxation exercises. The system also monitors the users' respiration, pulse rate and sweat gland activity (a measure of calmness) to provide real-time biofeedback regarding the effectiveness of the virtual experience.

"This project started as a support system for doing meditation," explains Larry Hodges, a professor of computing and virtual reality expert, who is leading the research team. "... Some people find it very easy to see in their head whatever is the image they want to visualize. But some people have a very difficult time with this, so having visual images to look at and the audio helps a lot."

Also, the added benefit of biofeedback allows the program to modify the user's experience based

"When the sun is going down and the moon is going up, the actual timing of that depends on how your body is relaxing..."

on what their body is doing. "When the sun is going down and the moon is going up, the actual timing of that depends on how your body is relaxing," explains Hodges, also a veteran meditator. "If you're having a hard time, the program gives you a chance to start over. It actually says, 'Let's try again.' "

Researchers demonstrated the meditation chamber for almost 500 attendees at SIGGRAPH, the preeminent graphics conference held in Los Angeles in August 2001. With four booths, the researchers were booked for a week doing 20-minute individual demonstrations for people in the arts, animation and academics. Researchers are now analyzing biofeedback data from those demos and are also reviewing questionnaires completed by participants.

"From the anecdotal evidence people offered at SIGGRAPH, we found that people new to meditation thought it was great," Gromala says. "Even the computer scientists who were really cynical about it actually saw the benefits of the meditation chamber and thought it worked. They were really enthusiastic about it."

Researchers believe the meditation chamber's greatest value will be as a training tool and for delivering feedback to meditators of any experience level. They are now gathering information from clinical psychologists around the country who are offering the meditation chamber experience to their patients. The psychologists are customers of Hodges' Atlanta-based company, Virtually Better, which has an exclusive license to produce several virtual reality-based therapeutic technologies developed at Georgia Tech by Hodges and his colleague Barbara Rothbaum, a professor of psychiatry at Emory University and co-owner of the company.

Hodges believes patients who might not otherwise try meditation will embrace the virtual environment to learn and practice it. "If you read the medical literature, you see that the positive effects of regular meditation are undisputable," he says. "The problem is that people don't do it because it requires discipline. You have to make the time in your life to do these things.

"This is where the virtual environment comes in. It gives the structure to lead you through meditation, not only the audio cues, but also the visualizations," Hodges adds.

From a research standpoint, Shaw says: "The meditation chamber may be useful in situations where you want a standard exposure to a relaxation therapy that is timed relatively precisely. It may form a basis for comparative studies of relaxation."

Researchers hope to complete a second-generation version of the meditation chamber this summer based on feedback from the SIGGRAPH demos and psychologists' trials. It may expand to a 20- to 30-minute, more detailed and effective meditation experience.

"We'd like to refine it so your biofeedback is more obvious and continuous," Gromala says. "The tough problem in a multimedia realm with multiple inputs is which one you pay attention to. It's difficult in meditation because you want to block out any input. So to continually have graphs and charts being output is not a wise idea. So we're looking at when and how to give people feedback in real time. Maybe it will be a haptic device that you squeeze when you want the feedback."

Also, to give the program wider appeal, researchers plan to make the second version as neutral as possible in terms of audiovisual inferences to various meditation traditions. And they plan to give it a more inviting name, such as "the relaxation environment."

When the meditation chamber is ready for consumer use, Virtually Better will pursue three markets. One is its current target customer — clinical psychologists already using virtual environments and/or biofeedback for treatment. Another market is health spas, corporate wellness centers or even airport-based booths. The third, and perhaps largest, market is the home- and/or office-based consumer, who would run a shorter, PC-based version of the program that might include simple biofeedback.

Hodges estimates that the software might cost around \$5,000 if sold to smaller markets, such as therapists. But a PC-based version for a large market would be much less expensive. If Virtually

Better pursues this market, it would sublicense the technology to a distributor, Hodges adds.

Gromala believes the desktop version of the meditation chamber would even appeal to veteran meditators like her. "It would give me a sense of ambient time and cues," she explains. "When you meditate, even if you're experienced, it's still easy to be distracted. The meditation chamber will keep you focused." **RH**

■ For more information, contact Diane Gromala, School of Literature, Communication and Culture, Georgia Tech, Atlanta, GA 30332-0165 (Telephone: 404-385-1496) (E-mail: diane.gromala@lcc.gatech.edu); or Chris Shaw, College of Computing, Georgia Tech, Atlanta, GA 30332-0280. (Telephone: 404-894-6328) (E-mail: christopher.shaw@cc.gatech.edu). To read more about the meditation chamber experience, see <http://gtresearchnews.gatech.edu/reshor/rh-ss02/rlinkss02/med-experience.html>.



IMAGE COURTESY OF DIANE GROMALA

The meditation chamber's creators describe the program as a blend of Eastern and Western meditation traditions.

“Even the computer scientists who were really cynical about it saw the benefits of the meditation chamber...”

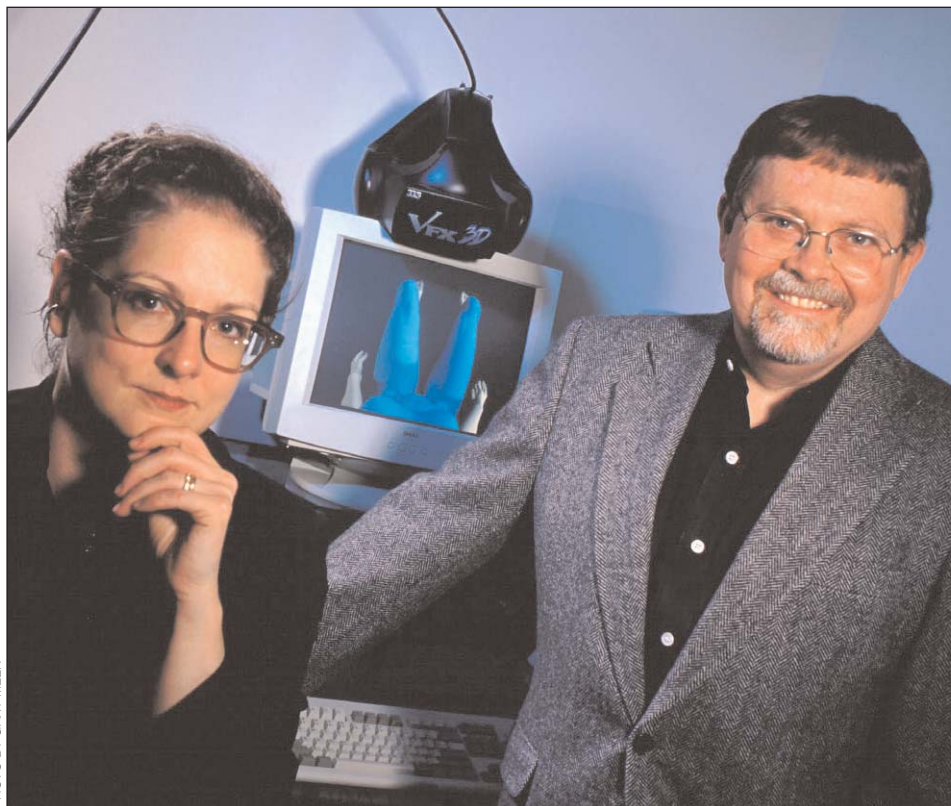


PHOTO BY GARY MEEK