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WINTER 1999

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ResearchHorizons

Deciphering the Genetic Code

Researcher's computer program analyzes DNA from around the world.

By Amy Stone

When Mark Borodovsky arrived in the United States from Russia in 1990, he did not envision the American dream upon which he was about to embark.

See related story: From Moscow to Atlanta

See sidebar story: A Genetics Primer

A scant eight years later, the Georgia Institute of Technology professor has developed the world's most-used computer program for deciphering bacterial DNA; is developing one for human DNA, and has seen his family flourish in his adopted country. Indeed, most people born in the United States live their entire lives without being profiled in Newsweek, which touted Borodovsky's field of bioinformatics as a "hot specialty" and credited him with creating it.

What Is Bioinformatics?

Bioinformatics employs mathematics, computer science and biology. It has developed from the need to more quickly and efficiently manage and make sense of the staggering amounts of genetic information contained in DNA strands.

A few short years ago, scientists developed the tools to decipher long strands of DNA into strings of their four underlying bases, the adenine (A), thymine (T), cytosine (C) and guanine (G), that make up the genetic code. But it was arduous work to take strings of bases and separate them into functional units, or genes, which govern traits. While still living in Russia, Borodovsky decided the computer would be a natural tool to manage vast amounts of genetic information.

"There are certain mathematical models which help biologists do their work," Borodovsky says. "In 1985, while I was still in Moscow, I came up with the idea of using Markov models to decipher genetic information."

The Russian mathematician, Andrey Markov, introduced his models early in the 20th century. Borodovsky believed Markov models could portray genes by the frequency of certain combinations of bases in known genes, contrary to non-genes. Therefore these probabilistic models could be applied to DNA sequences to predict where genes would lie on bacterial DNA.

Borodovsky did his initial work in Moscow from 1985-1989, laying the theoretical groundwork for his model. Then his research stalled as he looked for biologists to test his approach.

"The general economic situation and isolation of Russian scientists from the rest of the scientific world was not conducive to testing my ideas," Borodovsky recalls. "I needed research biologists who were sequencing DNA to compare my computer predictions with experimentally verified genes."

The following year, Borodovsky made a decision that would forever alter the course of his life. In 1990, he and his family traveled to Atlanta, and he visited the Georgia Institute of Technology.

"A scientific meeting at Georgia Tech made clear that my research work might have a level of support incomparable to what I had back in Russia," Borodovsky recalls. "Professor Roger Wartell, then newly appointed chair of the School of Applied Biology, encouraged me to think about the perspectives that were just unthinkable in Moscow. On the other hand, I saw that another dream might come true. The tradition of religious freedom, along with the opportunities for education for children, was something that the Soviet Union at that time was unfamiliar with."

So instead of returning to Moscow at the end of the Atlanta visit, the Borodovsky family decided to remain in the United States — even though they had with them only the belongings they brought in two suitcases from Moscow.

The decision to live in the United States proved fruitful. Within one year, Borodovsky met Dr. Fred Blattner from the University of Wisconsin. Blattner had sequenced a significant portion of the DNA of *Escherichia coli*. This DNA piece should have contained new genes, but their locations were not known. Borodovsky analyzed the sequence using the early version of his computer program, called GeneMark. The GeneMark predictions were later shown to be correct. In 1992, convinced of the accuracy of GeneMark, Blattner employed Borodovsky's method to analyze all of the raw DNA sequence data produced by his laboratory.

Another scientist, at Emory University in Atlanta, also was an early advocate of GeneMark.

"In the early 1990s, I was sequencing a gene in the worm *Caenorhabditis elegans*, and Mark Borodovsky contacted me to see if I was interested in testing his program. This was a great opportunity to work with someone in town, especially since the popular software program at the time was very difficult to use," recalls Dr. Guy Benian, an assistant professor of pathology and cell biology at Emory. "GeneMark gave very accurate predictions and was instrumental in annotating the gene."

The access to researchers, such as Blattner and Benian, who could test GeneMark "was exactly what was missing in Russia," Borodovsky says.

By 1992, Borodovsky, in collaboration with James McIninch, an undergraduate at Georgia Tech, had created a full version of GeneMark. When asked about the name GeneMark, Borodovsky says it works on a number of levels.

"GeneMark marks genes, which appeals to biologists; it is based on the Markov model, which mathematicians appreciate; and since my name is Mark, it is meaningful to me personally," says Borodovsky, smiling.

Subsequent use of GeneMark showed it was a powerful tool for finding bacterial genes. Researchers from around the world have sent their DNA fragments via e- mail to the GeneMark e-mail server, which predicts locations of genes. After mapping gene locations, the computer program compares the newly predicted protein sequence to known ones in a database. This determines protein function. The protein analysis is done in collaboration with the National Center for Biotechnology Information at the National Institutes of Health (NIH).

image courtesy of National Institutes of Health

Georgia Tech professor of biology Dr. Mark Borodovsky deciphered the complete bacterial genome sequence of *Haemophilus influenzae* -- the structure of which is depicted here -- using GeneMark, a powerful software program he developed. Now his research team has used the program to annotate, in biological terms, more than 10 bacterial genomes, helping to unravel the genetic code of these organisms.

A Genetics Primer

Mark Borodovsky's research strives to annotate DNA after it has been sequenced. For non-molecular biologists, that statement may be as clear as, well, the process of using a computer to translate DNA into genes and proteins.

To fully understand the import of Borodovsky's research, one must have basic knowledge of genetics. Following are a few concepts regarding some of the overriding principles of this science.

Human cells contain 23 pairs of chromosomes. Each chromosome contains a continuous double-helix strand of deoxyribonucleic acid (DNA). Four substances, called bases, compose DNA: adenine, guanine, cytosine and thymine. In genetics, their shorthand is A, G, C and T, respectively. The bases are bound in pairs, one of each pair on each strand of DNA, in a precise manner (A binds with T, and C binds with G).

Total human DNA is about 4.5 billion base pairs. These base pairs are divided into 50,000 to 100,000 genes that control all aspects of the human condition, from development to eye color to the origin of diseases.

Researchers now know that perhaps less than 5 percent of all of our DNA results in genes. The rest of our DNA consists of base pairs that do not contain genetic information and create gaps between and inside genes. These places of meaningless DNA are called introns and intergenic regions. The actual gene portions of DNA are called exons. Genes include more than genetic information; they also include codes to signal their beginning and end, much like a capital letter clues the reader into the beginning of a sentence and a period, the end.

Information stored in DNA is transferred to cell mechanisms producing protein molecules via the processes called transcription and translation. In transcription, the RNA copy of the gene containing DNA fragments is made, and the introns are removed, leaving only the bases constituting genes. In an oversimplification, what's left at this point is a string of letters that needs to be divided into meaningful words to yield information. Through research, scientists figured out that three adjacent bases are read together as a unit called a codon. Each codon corresponds to one of 20 specific amino acids, which are the building blocks of proteins. Finding genes, protein coding regions, was the major problem in annotating DNA sequences up to the size of a whole genome.

Borodovsky's computer programs take the DNA strand after molecular geneticists have deciphered the order of the bases and interpret it into exons and introns and make predictions about what proteins will result from this sequence. His earlier work created a program to interpret bacterial DNA. Unlike human DNA, bacterial DNA does not have introns inside of genes, making it simpler to predict where one gene begins and ends. The ability to use computers to interpret DNA has increased the speed and accuracy with which geneticists around the world are able crack the genomes of various organisms.

— Amy Stone

Publications about GeneMark in scientific journals caught the attention of researchers at the Institute for Genomic Research (TIGR). The TIGR scientists were pioneers in sequencing the complete genomes of numerous common bacteria. Understanding the genomes of key microorganisms may increase understanding of human genetics because lower organisms have some genes that correspond to human genes. Also scientists can design new drugs based on knowledge of disease-causing bacteria.

Borodovsky was asked to help decipher the first complete bacterial genome sequences. GeneMark was used on *Haemophilus influenzae*, *Mycoplasma genitalium*, *Methanoccocus jannaschii* and *Heliobacter pylori*, helping to unravel the genetic code of these organisms. Now more than 10 bacterial genomes have been decoded, or annotated in biological terms, with the use of GeneMark. Also, GeneMark has been used to annotate parts of genomes of other organisms, including fungi, plants, insects, rodents and primates.

"GeneMark is faster and more efficient than other algorithms and is more accurate than others in making predictions about where genes are," says Dr. Bruce Roe, a professor of chemistry and biochemistry at the University of Oklahoma. Roe, who holds the George Lynn Cross Distinguished Research Professorship, runs one of the eight human genome centers in the United States. His lab is sequencing a number of bacteria, in addition to human chromosomes. Roe uses GeneMark to annotate the bacteria work in his laboratory because it is more than 98 percent accurate, he says.

The Next Level: The GeneMark Family of Programs

Even while GeneMark was being used successfully to annotate the genes of bacteria, Borodovsky was refining his program. GeneMark has been successful in making predictions because it could "learn" based on previous knowledge, Borodovsky says.

His next version, called GeneMark Genesis, became necessary when TIGR scientists wanted to sequence the genome of the bacterium *Methanoccocus jannaschii*, for which there were no experimentally studied segments available to train the Markov models. The new program developed by Borodovsky and graduate student William Hayes "learned Markov models from anonymous sequences based on the grammar of the genetic code," Borodovsky explains.

photo by Stanley Leary

Dr. Mark Borodovsky heads Georgia Tech's new interdisciplinary master of science degree program in bioinformatics. The curriculum development is supported by the Sloan Foundation.

The latest step Borodovsky has undertaken uses GeneMark Genesis as its base to make even more sophisticated predictions — this time for the genomes of eukaryotic, or higher organisms. (The cells of eukaryotes, including humans, have nuclear membranes, paired chromosomes and complex cell division patterns. Prokaryotes, such as bacteria, are single-cell organisms with no nuclear membranes. They lack many of the more complex structures of eukaryotic cells, and divide simply through such mechanisms as budding.)

"Deciphering bacterial DNA is simpler than deciphering human DNA since its genes run continuously, without gaps. The genes of human DNA may be divided into pieces, called exons, with non-coding genetic material between the exons. These spacers in the genes, called introns, were hard to detect by a computer algorithm. Also, eukaryotic DNA is much longer, with an average gene size of 10,000 nucleotides," Borodovsky explains.

Therefore, the predictions of where eukaryotic genes lie on a strand of DNA must include predictions of the boundaries between the exons, which contain the genetic information, and introns, which are the non-coding regions. To create a computer program to achieve this, Borodovsky has employed another model, called Hidden Markov Models or HMM. His most recent NIH grant will fund incorporation of HMM into GeneMark, making the program responsive to the boundaries between genes and introns. GeneMark. HMM was developed in collaboration with Georgia Tech researcher Dr. Alexander Lukashin. The test of the program demonstrated its "state-of-the-art accuracy," says Borodovsky, meaning, when tested against current means of finding eukaryotic genes, GeneMark. HMM performed at least as well as the best current methods.

GeneMark.HMM will fill a need, as evidenced by early demand from scientists. Even before information about GeneMark.HMM has been published in a scientific journal — the traditional method of disseminating information for the community — almost 30 researchers have expressed interest to one of Borodovsky's graduate students, John Besemer, who gave a poster presentation on GeneMark.HMM at a recent conference on the eukaryotic organism *Chlamydomonas reinhardtii.*

A Start-Up Company and a New Bioinformatics Degree Program

Now with the whole family of GeneMark programs developed, Borodovsky, along with his former undergraduate and graduate student Dr. James McIninch, want to find a way to make these popular programs more accessible to the biological science community.

"The GeneMark programs are the type of research programs that should be incorporated into the user-friendly environment that is easy to understand and used by every biologist," Borodovsky says. "So we formed a start-up company to make them more user-friendly."

The company, called GenePro Inc., supported by the NIH grant, will commercialize GeneMark programs by making them more readily available and portable to different computer platforms. The company will also provide technical assistance and other services that cannot be done under the auspices of university research.

While his company strives to maximize uses of the GeneMark programs, Borodovsky is also heading Georgia Tech's new interdisciplinary master of science degree program in bioinformatics. But his decision to add teaching to his busy schedule was a challenge, he says.

"For six years, until 1996, I have had a strange feeling that I was not yet a full- fledged part of the Georgia Tech community since it emphasizes teaching," Borodovsky says. "When I became a professor, the addition of teaching greatly added to my busy schedule. But thanks to the strong moral support of Dr. Gary Schuster, I was able to make this move. In the past two years, I have taught four new courses. It was difficult, but a very satisfying experience. I am eager to see that students like my lectures. It is not easy, and I should say that I do not have success all the time."

Now, Borodovsky is devoting time to the new degree program, which is being supported by the Sloan Foundation. "I think that the major factor that will make this program a success is the enthusiastic support of Georgia Tech administration and faculty, including professors Anderson Smith, Roger Wartell, Robert Nerem, Leonid Bunimovich and Sham Navathe."

This new degree program is expected to start in the fall of 1999. Then, Borodovsky plans to move his lab to the new Parker C. Petit Institute of Bioengineering and Biosciences Building, where space is specifically designed for multidisciplinary research programs.

For more information, For more information, you may contact Dr. Mark Borodovsky, School of Biology, Georgia Tech, Atlanta, GA, 30332-0230. (Telephone: 404/894-8432) (E-mail: mark.borodovsky@biology.gatech.edu).

Research Horizons

Poised for Production

New process for applying thin film coatings being commercialized.

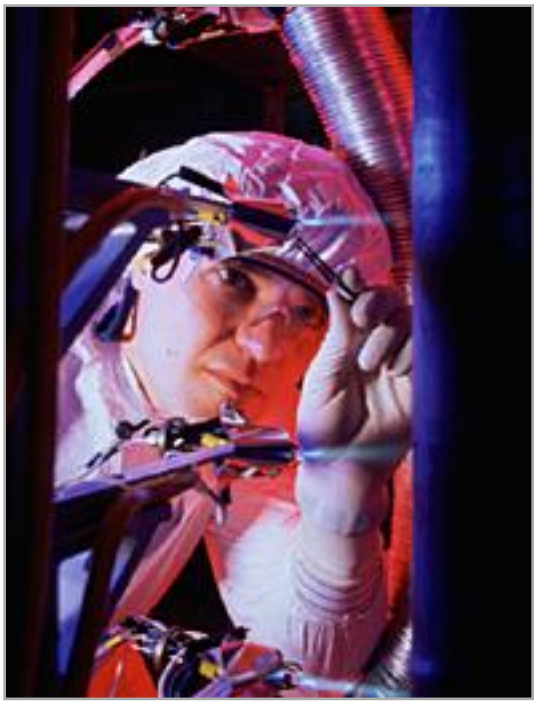
By T.J. Becker

In Andrew Hunt's world, being thin-skinned is no handicap. In fact, it gives his company a competitive edge.

While studying for his Ph.D. in materials science and engineering at Georgia Tech, Hunt developed a new process for applying thin film coatings. His technology allows thin films to be applied in the open air, which dramatically reduces costs and pushes the envelope on product applications.

Obtaining an exclusive worldwide license from the Georgia Tech Research Corporation to commercialize this process, Hunt launched MicroCoating Technologies (MCT) in 1993 and joined the Advanced Technology Development Center (ATDC), Georgia Tech's business incubator for high-tech start-ups. Graduating from ATDC in June 1997, MCT is on a fast track and ranks among the incubator's brightest stars.

photo by Stanley Leary



While studying for his Ph.D. in materials science and engineering at Georgia Tech, Dr. Andrew Hunt developed a new process for applying thin film coatings. His technology allows thin films to be applied in the open air, which dramatically reduces costs and pushes the envelope on product applications.

Great Expectations

Growth has accelerated in recent months as MCT evolves from the research and development stage and approaches mass production.

In 1998, MCT increased its staff from 12 to 40

Here, copper foil is coated with material for electronic usage.

employees. On the fiscal front, MCT's revenues have doubled every year since 1994, and Hunt anticipates this will continue during the next five years. Perhaps even more remarkable than its consistent black ink is that MCT's growth has been achieved without venture capital — rare for a high-tech start up.

The primary source of MCT revenues has been public sector funding from Small Business Innovation Research (SBIR) grants — until 1997 when about half of revenues came from the private sector. "The shift reflects the fact that we're getting closer to product," Hunt says.

Lighter, Faster, Cheaper

The idea behind thin film coatings is a simple one — cover the surface of an object to give it special properties, such as electrical conductivity, without making the entire object from the coating material.

"I like to think of coatings as alchemy," Hunt says. "You can take a plastic object and add a metal coating so that it looks like a chunk of gold." A steel object can be coated so it behaves like stainless steel, but costs less. Glass can be treated so it blocks light and reduces heat coming into a building.

Thin films result from vapor deposition — taking a material and heating it until gases are emitted. The physical properties of the material change, and the gas turns into a solid, forming the coating. Typically, such coatings are put down inside reaction furnaces or vacuum chambers, which is costly and limited to smaller objects. Yet with Hunt's patented technology, combustion chemical vapor deposition (CCVD), coatings are applied in the open atmosphere, using a flame as the energy source. This flexible technology opens up thin film coatings to a whole new arena of applications.

"Size is no object," Hunt says. With the CCVD process, protective coatings can be deposited on something as large as a ship or an aircraft.

The technology also allows a wider spectrum of materials to be used as coatings, which also lowers costs. "We can deposit very complex mixtures of materials because we use a single liquid solution rather than having to flow different vapors," Hunt says. To date, some 60 different materials can be used for coatings, providing a variety of applications: electronics, corrosion-resistant surfaces, fuel cells, glass and plastic coatings, catalytic systems and thermal barriers.

Preparing for Production

After leaving ATDC in June 1997, MCT set up shop in 7,000 square feet of space in an industrial park in Chamblee, Ga. The company quickly outgrew the space and added

another 6,500 square feet last spring.

The expansion is being used to create a prototype deposition station in preparation for mass production. MCT's current deposition station uses four flames, but in the new space, a station with up to 40 flames will be constructed. More flames enables larger areas to be coated more quickly, Hunt explains.

MCT is producing products on a small scale, but plans to enter mass production this year, beginning with products for the electronics and glass industries.

"We'll be covering millions of square feet," Hunt says. "We hope to have the largest scale production of thin film coating of any process."

Hunt credits much of MCT's rapid growth to ATDC. Being an ATDC member allowed MCT direct access to Georgia Tech, including equipment, faculty and library — "all of which are integral for high-tech development," Hunt says. "I probably wouldn't have started the company without ATDC. Even if I had, it wouldn't have been nearly as easy to grow."

For more information, you may call Andrew Hunt, MicroCoating Technologies, 3901 Green Industrial Way, Chamblee, GA, 30341. (Telephone: 770/457-8400)

Research Horizons

Happy, and Safe, Motoring!

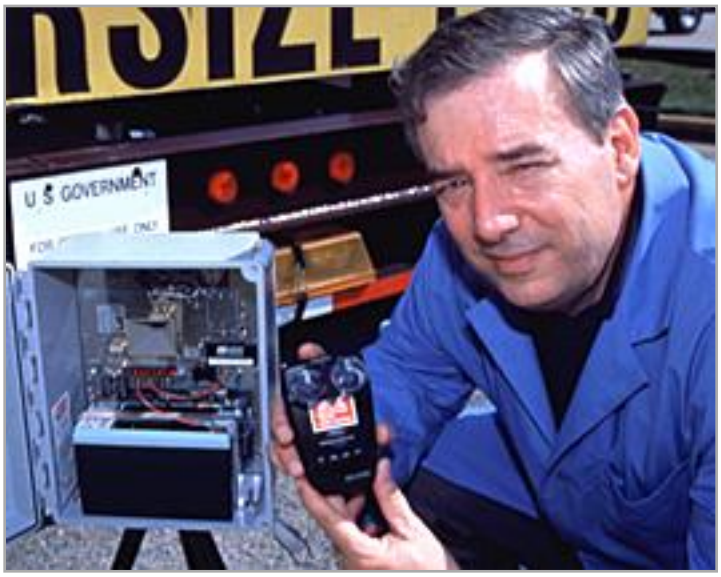
Safety Warning System will undergo field tests and refinement.

By Jane M. Sanders

The nation's highways could become safer and more efficient within the next few years as more motorists and public agencies begin using a commercially available traffic hazard warning system developed at the Georgia Institute of Technology in 1996.

The Safety Warning System (SWS), a microwave-based communications system, gives motorists a 25- to 30-second warning of hazardous traffic and highway conditions ahead. Messages are delivered via automated mobile or fixed-site transmitters and received by either advanced, in-vehicle receivers or older model radar detectors in individual vehicles.

photo by Joann Vitelli



GTRI researcher Gene Greneker is refining and field testing a device he developed called the Safety Warning System (SWS). On the market since 1996, SWS is a microwave-based communications system that gives motorists a 25- to 30-second warning of hazardous traffic and highway conditions ahead.

Available on the market since 1996, SWS is now being refined and field tested by the Georgia Tech researchers who first developed it at the request of a consortium of radar detector manufacturers. New capabilities under study may allow traffic managers to transmit specific details on traffic problems just ahead. The three-year project, which started in October 1998, is being funded by a $2.1 million grant from the U.

S. Department of Transportation (DOT).

"SWS is an inexpensive, functional and available in-vehicle safety system that fits the concept of an intelligent transportation system," says SWS inventor and senior research engineer Gene Greneker of the Georgia Tech Research Institute. "But we want to make it do even smarter things."

SWS is now part of more than four million advanced radar detectors in use in the United States today, and its signal can be picked up by about 15 million older model detectors, as well. Its manufacturers are BEL-Tronics, Santeca, Uniden and Whistler. SWS has received preliminary approval and is awaiting final approval from the Federal Communications Commission, and a patent is pending. The current model sells for about $200, but manufacturers are developing an SWS-only detector that will sell for about $100.

SWS alerts drivers to real-time hazards, dangerous weather and other traffic conditions with an audible alarm, one of 64 pre-programmed text messages shown to drivers on a light-emitting diode display (LED) and/or synthesized voice message. Five categories of messages are incorporated in the SWS messaging system. They are: warnings for highway construction or maintenance zones; weather-related hazard messages; highway hazard advisories; travel and convenience information; and fast/slow-moving vehicle warnings.

The DOT grant for refining and testing SWS was part of an allocation Congress approved last summer. It also provides DOT funds for grants to state and local governments to purchase SWS and study its efficacy. Greneker will use his grant to conduct extensive field tests of SWS fixed-site and mobile-unit transmitters. He also plans to investigate the feasibility of adding variable text messaging to SWS fixed- site transmitters. That would allow public safety and highway officials to program the transmitters with specific messages.

photo by Joann Vitelli

The Safety Warning System is now part of more than four million advanced radar detectors in use in the United States today, and its signal can be picked up by about 15 million older model detectors, as well.

Greneker is collaborating with Dr. John Leonard, a Tech assistant professor of civil engineering, in conducting a one-year SWS fixed-site transmitter test in metro Atlanta. It will involve as many as 500 participants and be the largest scale test to date.

"We will also be testing the SWS transmitters mounted on police cars," Greneker says. "We want to see how durable and reliable the signal strength is under a variety of conditions."

The other part of the DOT-funded study will add modem, and thus variable text messaging, capability to fixed-site SWS transmitters, Greneker says. A two-way modem link between the transmitter and an Advanced Traffic Management Center could deliver a traffic manager's alternate route messages to motorists in urban areas. In rural areas, fixed site transmitters could be equipped with microprocessors and smart software. The system would collect radar-derived speed data to determine the speed of the traffic flow, then analyze it and decide if a traffic advisory message should be sent to motorists alerting them to problems ahead.

SWS L.C., the organization licensing the technology, has placed SWS transmitters in 26 states with school buses, trains, police departments and departments of transportation since 1997. These transmitters have a 1.5-mile range and cost about $900 each. By the end of 1999, the consortium expects to have "a significant infrastructure in place," a spokesman says. SWS L.C. estimates that the sale of SWS products will grow by more than two million each year as transmitter installations become more widespread.

For more information, you may contact Gene Greneker, Sensors and Electromagnetic Applications Laboratory, Georgia Tech Research Institute, Atlanta, GA, 30332-0856. (Telephone: 770/528-7744) (E-mail: gene.greneker@gtri.gatech.edu). You may also visit the SWS L.C. Web site at www.swslc.com.

ResearchHorizons

Rehabilitating Bridges

Carbon fiber-reinforced polymer shows promise for repairing structures.

By Jane M. Sanders

Breaking tradition isn't such a bad thing when the new practice is equivalent to the difference in pasting on wallpaper vs. repairing a wall. Such is the difference between a new material and method for repairing bridges and time-consuming, labor-intensive traditional methods.

The new material is a high-performance, carbon fiber-reinforced polymer, which was applied last fall to an overpass bridge in metro Atlanta in just a matter of hours. It is one of the first such applications of its kind in the nation. The reinforcement is expected to strengthen and extend the life of the bridge.

The rehabilitation of the bridge is part of a Georgia Institute of Technology research project funded by the Georgia Department of Transportation (GDOT) in cooperation with the Federal Highway Administration (FHWA).

photo by Joann Vitelli

Georgia Tech civil engineering professor Dr. Abdul-Hamid Zureick, center, works with fiber-reinforced polymeric material suppliers preparing material to apply to and strengthen a bridge near Atlanta.

The Lee Road bridge over Interstate 20 in Douglas County, Ga., suffers from cracks in its concrete deck. A research team led by Dr. Abdul-Hamid Zureick, a professor in the School of Civil and Environmental Engineering, hopes that strips of fiber-reinforced

polymeric (FRP) material will extend the bridge's life at least five to 10 years. They are monitoring the bridge closely to gather durability data.

"We are taking an integrated field/laboratory approach," Zureick says. "We lack sufficient guidelines for engineers, contractors and the GDOT regarding the use of these new materials. We need information about safe construction procedures, GDOT design guidelines and bidding documents. They are the keys for the success of this technology."

Indeed, a future goal of Zureick's research is to generate national guidelines, which could be used in FRP structure repair projects worldwide, he says. Such documentation could be in place within two to three years.

The need for repair guidelines stems from the widespread problem of substandard bridges — those that are structurally deficient and/or functionally obsolete. The FHWA 1996 Better Roads Bridge Inventory indicates that about 31 percent of the nation's bridges are substandard.

Several factors contribute to the problem. They include: aging bridges; shorter durability because of airborne pollutants and de-icing salts; increasing daily traffic; and insufficient repair funds.

"Traditional repair and replacement of bridge components, including bridge decks, pile caps and pre-stressed concrete beams, is very expensive," Zureick says. "But with high-performance, fiber-reinforced polymeric composites technology, repairs can be made very fast, and that cuts costs in the long term."

In fact, the Lee Road bridge repair took workers less than a day to complete what could have taken several weeks to do traditionally, Zureick says.

With time and money at stake for highway departments nationwide, Zureick's research team is simultaneously conducting laboratory and field tests on FRP materials. So far, laboratory tests have determined that FRP materials can make bridges 30 to 40 percent stronger than the original design. They are gathering long- term data and plan to estimate the benefits over a bridge's lifespan once all data are analyzed.

Additional FRP material laboratory tests conducted in an environmental chamber are addressing every potential aspect of bridge component behavior during the structure's lifespan, expected to be 75 years under current design criteria.

Researchers are exposing components to extreme conditions, including humidity, temperature, salt and ultraviolet light. They will incorporate the durability data they collect into predictive models that will estimate FRP bridge component lifespan, Zureick

says.

For the full text news release, see www.gtri.gatech.edu/res-news/BRIDGE.html.

For more information, you may contact Dr. Abdul-Hamid Zureick, School of Civil and Environmental Engineering, Georgia Institute of Technology, Atlanta, GA, 30332-0355. (Telephone: 404/894-2294) (E-mail: azureick@ce.gatech.edu)

Research Horizons

Faculty Profile: Dr. Helena Mitchell

Back to the Future

With roots planted long ago, distance learning gains ground in the 20th century.

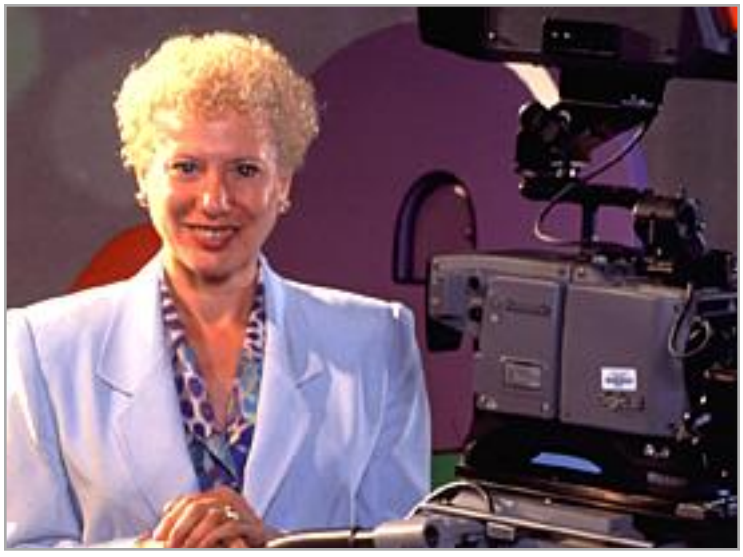
By T.J. Becker

In the 1800s, western expansion sparked a need for schools in remote areas, and in response, correspondence courses were developed to groom new teachers. Fast forward a couple of centuries: Distance learning has become a major initiative in education with demand driven by demographic shifts, rather than geographic ones.

"You no longer have the same base of students who go straight from high school to undergraduate school," says Dr. Helena Mitchell, Georgia Research Alliance (GRA) Eminent Scholar for Distance Learning. The student profile is changing — those returning to school are older, and more are juggling jobs as they pursue degrees. These factors present time and commuting constraints that make it difficult to get to a classroom.

"Academic institutions have to change or they won't be able to survive," Mitchell stresses. "Administrators and faculty who

photo by Stanley Leary



The mission is clear for Dr. Helena Mitchell, Georgia Research Alliance Eminent Scholar for Distance Learning. Her goal is to improve educational telecommunications throughout Georgia because telecommunications has been the catalyst for raising the

recognize the role of distance learning will be able to position their campus in leadership roles for the next century."

profile of distance learning.

Mitchell is understandably passionate about the issue. She was named eminent scholar on the subject matter in April 1997, a joint academic appointment at the Georgia Institute of Technology's School of Public Policy and Clark Atlanta University. To her, the mission is clear — improve educational telecommunications throughout the state because telecommunications has been the catalyst for raising the profile of distance learning.

"Whereas teaching was once primarily 'chalk and talk,' there has been an explosion of delivery modes," says Mitchell, citing satellite, cable, the Internet, the Web, video and audiocassette, radio, telephone, CD-ROM. "Traditional learning is no longer traditional."

Multiple Careers

Mitchell brings to her post an unusual blend of academic, business and government experience. Most recently, she served as an associate chief of strategic communications at the Federal Communications Commission (FCC) in Washington, D.C. During her tenure there, Mitchell became the first female chief of the Emergency Broadcast System (EBS) and was responsible for its modernization.

Mitchell began her professional life as a high school and junior high teacher. "Although I enjoyed teaching, I kept feeling there was something bigger out there. . . a way to reach more students," says Mitchell, who earned degrees in education from the State University of New York at Brockport and Syracuse University, and a doctorate in telecommunications policy, also from Syracuse.

In 1971, she moved into the broadcast industry, albeit her transition was somewhat of a fluke. Mitchell stopped by WNYC offices in New York to drop off a package. "They thought I was looking for a job and handed me an application," she explains. Because it was summer and she had no classes, Mitchell filled out the application. She was offered a position as educational coordinator at the public radio/television station, charged with developing new program pilots.

Before joining the FCC, Mitchell directed the Office of Television and Radio at Rutgers University, where she developed a distance learning program and launched a national satellite system.

Her appointment as Eminent Scholar for Distance Learning allows Mitchell to draw upon this diversified background in technology, information and education, as well as her love for navigating new waters. "It seemed like a natural fit for me," she says. "I understand where companies are coming from, as well as where government and academia is coming

from. . . . I see how the three spectrums complement each other."

This ability to see multiple perspectives is important as distance learning has become an interdisciplinary effort. "You can no longer go to government and ask for money for one program. They are looking for projects that are collaborative," Mitchell says.

Reaching Out

Mitchell has organized recent conferences to help teachers and librarians tap into federal funds for educational technology. "Educators may know funds are out there, but the process is so complicated that it's easy to become intimidated," she says. A face-to-face encounter with agency representatives can greatly simplify the paper chase.

Mitchell began teaching last fall and is developing a public policy course for distance learning. Understanding public policy is crucial to addressing technology's impact on education, she explains.

Another of Mitchell's goals is to create a mobile lab to travel throughout the state, demonstrating how technology can be used for educational purposes. Distance learning can be nebulous because it has grown to encompass such a broad array of technologies.

"It's hard to put distance learning in a box," Mitchell says. "It's not just Web- based or broadcast. Distance learning is putting the subject matter in the most appropriate medium or combination of media to reach students at a distance."

Educational goals come before the technology, Mitchell stresses: "You should never look just at the technology. Look first at what you want to teach and then decide what is the best technology to achieve your educational goals."

For more information, you may contact Dr. Helena Mitchell, Room 536, Georgia Center for Advanced Telecommunications Technology, Georgia Institute of Technology, 250 14th St. NW, Atlanta, GA 30318. (Telephone: 404/894-0058) (E-mail: helena.mitchell@pubpolicy.gatech.edu)

Research Horizons

Research Notes

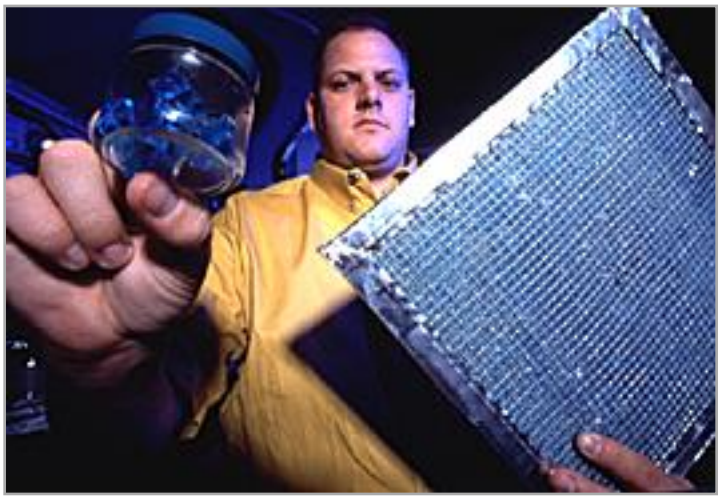
Out With Polluted Particles and Gases

Hydrogel air cleaners do double duty.

A newly invented, inexpensive hydrogel does double-duty removing pollutants from indoor air — and might one day be available commercially.

Known as the hydrogel air cleaner, the gel removes both particles and volatile organic compounds from air that is filtered through it, explains principal research scientist Charlene Bayer of the Georgia Tech Research Institute (GTRI). She and Dr. Jan Gooch, a polymers and coatings consultant, invented and patented the substance.

photo by Stanley Leary



The hydrogel air cleaner developed at the Georgia Tech Research Institute removes both particles and volatile organic compounds from air that is filtered through it.

"Other air cleaning media remove either particles or gases, but not both," says Bayer, of GTRI's Electro-Optics, Environment and Materials Laboratory. "In addition, the hydrogel air cleaner doesn't support microbial growth. Microbes growing on other kinds of filtering materials can emit volatile organic compounds, aggravating indoor air quality problems."

Hydrogels are essentially chains ofw simple molecules, many of them water. The gels demonstrate solid and liquid qualities, making them useful in many applications — from repairing internal body parts to absorbing moisture in diapers.

Preliminary studies show that the prototype hydrogel air cleaner removes 50 percent of respirable-size airborne particles, and 80 to 90 percent of gaseous air pollutants. Some other air cleaning media do remove a greater percentage of particles or similar amounts of

gases from the air compared to the hydrogel air cleaner. But these media absorb either particles or gaseous materials — not both. And some also may provide fertile ground for microbe growth.

The preliminary studies were conducted by fashioning the hydrogel into a filtering mesh, and also by applying it directly to existing furnace air filters.

The hydrogel air cleaner works via absorption and adsorption, but the exact mechanism is a mystery even to Bayer, who plans to continue exploring the workings of the gel.

With funding from the Faculty Research Commercialization Program through Georgia Tech's Advanced Technology Development Center, the researchers have worked to move the hydrogel air cleaner closer to a commercial product. Bayer and her colleagues would eventually like to develop the hydrogel into a form that could substitute for the standard air filter in building, vehicle and military applications. They also want to improve the lifetime of the hydrogel air cleaner, incorporating enough of the substance into a filtering device to make it competitive with the three-to-six months minimum lifetime of standard air filters.

— Lea McLees

> **For more information,** you may contact Charlene Bayer, Electro-Optics, Environment and Materials Laboratory, Georgia Tech Research Institute, Atlanta, GA, 30332-0820. (Telephone: 404/894-3825) (E-mail: charlene.bayer@gtri.gatech.edu)

Quality Air in the Classroom

Study is investigating active humidity control in schools.

Your kids spend most of their day at school — so how good is the indoor air quality in their classrooms?

The answer could depend on whether certain climate control technologies are used in their schools, says principal research scientist Charlene Bayer of the Georgia Tech Research Institute (GTRI). Bayer is leading a study that examines the effects of continuous active humidity control and ventilation on schools' indoor air quality.

"Our hypothesis is that if schools have active humidity control, the air quality will be better — thus, the learning environment will be improved, and

student learning will be enhanced," says Bayer, who conducts research in GTRI's Electro-Optics, Environment and Materials Laboratory.

Photodisc photo

Georgia Tech Research Institute researchers are studying the effects of continuous active humidity control and ventilation on schools' indoor air quality.

The results of the study could be an important part of school modernization and construction efforts around the country, Bayer says. Many indoor air quality issues affect children more dramatically than adults.

"Children are generally more susceptible to respiratory ailments," she says. "Asthma, which is increasing among children, is linked to indoor air quality problems — particularly molds, moisture and dust mite feces. Dust mites are prolific in areas of high humidity."

The study is one of only a few statistically controlled, quantitative studies of school air quality ever conducted. It is sponsored by the U.S. Department of Energy via humidity control systems manufacturer SEMCO Manufacturing Inc.

Researchers have divided the 10 participating Georgia schools — four in metro Atlanta and six in high-humidity coastal regions — into five pairs. Each pair of schools is similar in design, building age, mechanical systems and location. But only one school in each pair uses active humidity control technology. Any significant impact of active humidity control on air quality will be readily apparent, Bayer says.

Researchers are tracking carbon dioxide, temperature, humidity, airborne and surface microbes, and microbial emissions of volatile organic compounds. They are taking measurements at each school in fall, winter and spring, and have set up continuous monitoring devices on site. Unlike previous studies, this work avoids schools with known air quality problems.

"We specifically did not take schools with problems for this study so we could get good, baseline data," Bayer says.

The active humidity control systems used by participating schools are manufactured by several different vendors, to prevent vendor bias from affecting the study's results.

Georgia Tech's School of Earth and Atmospheric Sciences will perform particle analysis. Dr. Sidney Crow of Georgia State University's Department of Biology will analyze

microbial findings.

Students at participating schools also will benefit intellectually from the study. Researchers are teaching them about research, sampling and scientific method related to the project. Youngsters are monitoring air quality measuring devices at their schools, and they chart their data with help from the researchers via an Internet site.

The study will be completed at the end of spring 1999, with results available at the end of summer 1999. The researchers are interested in expanding their work to other states.

— Lea McLees

> **For more information,** you may contact Charlene Bayer, Electro-Optics, Environment and Materials Laboratory, Georgia Tech Research Institute, Atlanta, GA, 30332-0820. (Telephone: 404/894-3825) (E-mail: charlene.bayer@gtri.gatech.edu)

Tissue Substitutes

National Science Foundation establishes first tissue engineering center at Georgia Tech.

The next generation of medical implants is one step closer to reality, with the awarding last fall of a $12.5 million grant from the National Science Foundation to the Georgia Institute of Technology. The grant established the first Engineering Research Center for the Engineering of Living Tissues at Georgia Tech, with Emory University as a core partner institution.

Tissue engineering research may soon produce advances in the regulation of blood glucose for diabetics, the regeneration of bone to correct genetic defects, and the creation of bioartificial blood vessels for high risk heart patients, Georgia Tech researchers say.

photo by Billy Howard

Dror Seliktar, a Georgia Tech graduate student,

The National Science Foundation (NSF) is funding the one-of-a-kind Engineering Research Center (ERC) with $12.5 million over the first five years, with a potential duration of 10 years. The center is conducting research on the

design and development of tissue substitutes that replace, enhance or maintain natural tissue. Dr. Robert M. Nerem, director of Georgia Tech's Petit Institute for Bioengineering and Bioscience, is also director of the ERC.

prepares tissue-engineered vascular grafts. The research focuses on ways to grow artificial veins for use in bypass surgery, eliminating the need to use veins taken from patients' legs. The artificial veins will be stronger and less likely to clog than veins taken from a patient.

"Tissue engineering represents the next generation of medical implants, and this award allows us, working with our industrial partners, to take the lead in harnessing the products of the biological age and to revolutionize this important industry," Nerem says.

The ERC is focusing on specific research projects in three core areas: cell technology, cell construct technology (prototype organ or tissues structures) and their integration into living systems. Current research projects in tissue engineering include: the development of substitute blood vessels; the creation of a bioartificial pancreas; and engineering bone repair.

After years of maintaining a grassroots collaborative relationship, Georgia Tech and Emory University signed formal agreements to establish a biomedical research program in the mid-1980s. In the fall of 1997, in a pioneering academic collaboration, the two institutions established a joint department of biomedical engineering, creating Georgia's — and possibly the nation's — first joint department between a public and private university. Both the new research center and the Georgia Tech/Emory Department of Biomedical Engineering will be housed in the $30 million Bioengineering and Bioscience Building, which is under construction on Tech's campus and scheduled for completion in 1999.

— Victor Rogers

For more information, you may contact Dr. Robert Nerem, Petit Institute for Bioengineering and Bioscience, Georgia Tech, Atlanta, GA, 30332-0363. (Telephone: 404/894-2768) (E-mail: robert.nerem@ibb.gatech.edu)

Biotechnology Partnership

Emory/Tech partnership strengthens with biotech incubator.

The Georgia Institute of Technology and Emory University have formed a partnership to create a new center that could hatch some big business for the state of Georgia. It's an incubator for nurturing biotechnology companies.

Emory purchased the 42-acre Georgia Mental Health Institute complex on Briarcliff Road in Atlanta for $2.9 million and plans to convert much of the campus into an incubator for start-up biotechnology firms. The biotech industry includes companies that develop diagnostic procedures, medical devices and drugs.

The incubator concept draws on the success of Georgia Tech's Advanced Technology Development Center. The concept has the support of the Georgia Research Alliance and is a continuation of the partnership Tech has with Emory's research efforts.

"We think that this is an important expansion of the Emory/Georgia Tech collaboration," says Georgia Tech President Wayne Clough. "This is something that will substantially enhance the growing biotech movement in Atlanta. It will provide another piece to the foundation that will allow Atlanta to become one of the nation's premier biotechnology centers. The critical components for biotechnology success are research and space. This park, with the business incubator component, helps to satisfy both needs."

The concept of the biotechnology development center also takes full advantage of Georgia's biomedical resources, beginning with Emory and Georgia Tech, two of the fastest growing research institutions in the nation. Both have laboratories and scientists already producing technologies that are moving from the laboratory into production and patient care.

Journal of Technology

New scientific journal to post third edition on line.

The third issue of an on-line technical journal featuring the work of the Georgia Tech Research Institute (GTRI) will be posted on the World Wide Web in early February. The *Journal of Technology*, found at www.gtri.gatech.edu/jot/ targets scientists, engineers and research sponsors.

Articles in the third edition of the *Journal of Technology* include the following:

- "Pneumatic lift and control surface technology applied to high speed civil transport configurations," Robert J. Englar, Curt S. Niebur, Scot Gregory, Aerospace & Transportation Laboratory;
- "PC Based Tools for electronic combat systems," R. David Zobel, Jean Sands, Electronic Systems Laboratory;
- "Assessment of Scandium Additions to Aluminum Alloy Design," Henry G. Paris, T. H. Sanders, Y. Riddle, Electrooptics, Environment and Materials Laboratory, School of Materials Science and Engineering.

The *Journal of Technology* showcases the broad gamut of GTRI research, ranging from information technology to defense electronics and simulation to materials and manufacturing. The publication features both abstracts and full text of articles along with photographs, charts and illustrations. Authors' biographical information and e-mail addresses are provided along with links to the home pages of their respective laboratories.

The on-line publication, edited by GTRI researcher Henry Paris, is being updated quarterly.

For more information, contact Henry Paris, Electro-Optics, Environment and Materials Laboratory, Georgia Tech Research Institute, Atlanta, GA 30332-0826. (Telephone: 404/894-3688) (E-mail: henry.paris@gtri.gatech.edu)

Water, Water Everywhere

Water Technology and Management Research Center established at Tech.

Researchers at the Georgia Institute of Technology and the French conglomerate Vivendi have begun a partnership to develop and demonstrate innovative technologies to improve the environmental and economic issues related to urban water and wastewater management.

The partnership created the Water Technology and Management Research Center in Atlanta last fall. The center serves as the North American node for Vivendi (formerly Compagnie Generale des Eaux) and is the second largest facility in the company's global research center network. Vivendi spends more than $40 million a year on water research.

photo by Stanley Leary

Georgia Tech environmental engineering student Brian Skeens, left, and Dr. Appiah Amirtharajah, a professor in the School of Civil and Environmental Engineering, inspect water mixing equipment at the city of Atlanta's Water Pilot Plant. Amirtharajah and other Tech researchers are collaborating with scientists from Vivendi in a new endeavor called the Water Technology and Management Research

The center draws upon the expertise of 11 faculty members and more than 100 graduate students in the Environmental Engineering Program of Tech's School of Civil and Environmental Engineering.

"One of the major factors that led to Vivendi's choice of Atlanta for

establishment of the research center was Center.
the nationally recognized expertise of
the faculty in the Environmental Engineering Group," says group leader and Tech professor Dr. Appiah (Amit) Amirtharajah. "They also were impressed with our state-of-the-art analytical capabilities, especially in drinking water treatment and wastewater management, developed with assistance from the Georgia Research Alliance.

"Also, Georgia Tech has a history of working with established companies to build research centers," Amirtharajah says.

He and his faculty are collaborating with Vivendi researchers in France, the United Kingdom, Denmark, Australia, Thailand, Malaysia and China. Vivendi has 210,000 employees worldwide and annual expenditures of $38 billion. Vivendi is the parent company of Air and Water Technologies and its engineering division, Metcalf and Eddy Inc.

Specific areas of research activity at the Tech center are:

- drinking water treatment and distribution;
- wastewater collection and treatment;
- wastewater reclamation and reuse;
- bio-solids management and disposal;
- and urban water management economics.

One example of collaboration between Tech and Vivendi researchers is a project headed by French researchers on static mixers for enhancement of drinking water ozonation. Tech researchers have been developing a computational fluid dynamics model of a static mixer and studying its use for mixing disinfectants to kill the parasite Cryptosporidium. The parasite has caused major waterborne disease outbreaks in Carrollton, Ga., Milwaukee, Wis., London, England, and Sydney, Australia.

The research center is linking these ongoing research activities and assisting in global technology transfer of these innovations for supplying safe drinking water. For now, the center is housed in the School of Civil and Environmental Engineering. Within a few years, Vivendi expects to have 50 researchers at the Tech center and coordinate research of $8 million to $9 million a year.

— Jane M. Sanders

For more information, you may contact Dr. Appiah (Amit) Amirtharajah, School of Civil and Environmental Engineering, Georgia Institute of Technology, Atlanta, GA, 30332-0512. (Telephone: 404/894-0628) (E-mail: appiah.amirtharajah@ce.

gatech.edu)

Math Multiplicity

A single algorithm unlocks several problems.

Creating a stir in ciphering circles, a Georgia Institute of Technology math professor and his collaborators have solved the even directed cycle problem — an algorithmic enigma that has kept graph theorists and computer scientists scratching their heads for some 25 years.

In simple terms, a cycle is similar to a tour of one-way streets, returning to the starting point without passing through any intersection or street more than once. Thus, an even cycle means travelling down an even number of streets without repetition — a problem of great interest to computer scientists for modeling purposes. Deceptively complex, the problem may have been easy enough to state, but remained difficult to resolve.

photo by Stanley Leary

Dr. Robin Thomas, right, a Georgia Institute of Technology math professor, has solved the even directed cycle problem — an algorithmic enigma that has kept graph theorists and computer scientists scratching their heads for some 25 years. Student Christopher Carl Heckman, left, has helped implement the algorithm.

Two years ago, Georgia Tech's Dr. Robin Thomas, along with Dr. Neil Robertson, a math professor at Ohio State University, and Dr. P.D. Seymour, a math professor at Princeton University, spent the summer at Princeton scrutinizing the decades-old problem. Their powwow produced a proof, which they then simplified over the next year. During the refinement process, the trio was able to design an efficient algorithm (one that tackles a complex system of streets and produces the answer in real time) for determining whether an even-directed cycle exists.

What's more, this algorithm can be applied to several other situations. "There are about six problems, that sound different at first, but over the years have proven to be equivalent. So, if you solve one of them, you can solve all of them," Thomas explains.

For example:

- **Economics —** The new algorithm sheds light on economic relationships. Consider a model of a banana trade with four economic quantities: the supply of bananas, the demand for bananas, the price of a banana and people's taste for bananas.

  "Now simple economic principles tell us that as the price of bananas increases, so does the supply (farmers will produce more bananas), and the demand decreases (people will buy fewer bananas)," Thomas says. "And, for a fixed price, as people's taste for bananas increases, so does their demand for bananas. From these observations it is possible to mathematically prove that as people's taste for bananas increases, so do the price and demand.

  "Thus we deduce something about qualitative relationships of the quantities without knowing their actual values," Thomas says. "To decide in general (when you have hundreds or thousands of such quantities) what relationships exist is equivalent to the even cycle problem, and hence can be solved by our algorithm."

- **Statistical mechanics —** Atoms often bond with each other, and physicists are interested in calculating the so-called "entropy," which measures the capacity of a system to undergo change. One method, developed in the 1960s, works for planar lattices, but it was not known how far this method could go. "With our algorithm, we provide a way to determine precisely for which structures this method works, and when it works we have a tool for calculating the entropy," Thomas explains.

- **Permanents —** This is related to the concept of determinant of a matrix, which is a common engineering tool. The permanent is very similar, but much harder to compute. The new proof makes it possible to decide when a permanent of a matrix can be calculated by reducing it to a determinant of a related matrix, answering a question posed by mathematician George Polya in 1913. Even though the permanent can't be calculated efficiently in every case, it widens the scope.

  An extended abstract of "Permanents, Pfaffian Orientations and Even Directed Circuits," was presented at the Symposium on the Theory of Computing in 1997, and the complete paper was recently accepted for publication in the Annals of Mathematics.

  Two of Thomas' students, Christopher Carl Heckman and Petr Hlineny, have implemented the algorithm and made it available interactively on the World Wide Web. Interested researchers can point their browsers to http://math36.math.gatech.edu:8080/evenc.html.

— T.J. Becker

For more information, you may contact Dr. Robin Thomas, School of Mathematics, Georgia Institute of Technology, Atlanta, GA, 30332-0160.

(Telephone: 404/894-2733) (E-mail: robin.thomas@math.gatech.edu)

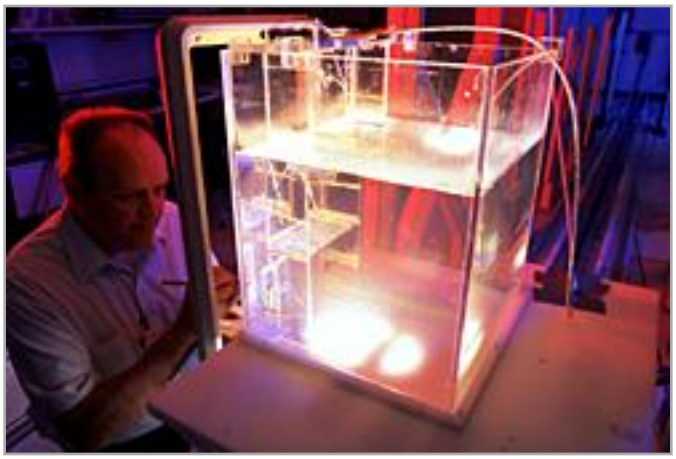
Protecting the Beat of Life

Test center studies interaction between pacemakers and electronic article surveillance systems.

As electronic components become smaller and smarter, they allow development of increasingly sophisticated pacemakers, implantable defibrillators and other medical devices that have improved life for more than a million people worldwide. At the same time, growing concern about theft from retail stores has led to widespread use of electronic article surveillance (EAS) systems that generate fields of electromagnetic energy while in operation.

Those electromagnetic fields can potentially interfere with operation of sensitive medical devices, causing concern for some store customers using pacemakers or implantable defibrillators.

photo by Stanley Leary



GTRI senior research engineer Jimmy A. Woody tests a pacemaker at the EAS/Medical Device E3 Test Center. Concern exists that such devices can malfunction when they encounter fields of electromagnetic energy generated by electronic article surveillance (EAS) systems in retail stores.

Researchers at the Georgia Tech Research Institute (GTRI) are working with manufacturers of both types of equipment to understand, and therefore help prevent, potentially harmful interactions. The work takes place at the EAS/Medical Device E3 Test Center, a unique facility supported by manufacturers of the electronic article surveillance systems.

"As both groups of manufacturers learn more about one another, there will be fewer and fewer potential interactions," says GTRI senior research engineer Jimmy A. Woody, manager of the test center. "What's unique here is that the manufacturers of the energy source and the manufacturers of the medical devices are cooperating to set up and use a test center that benefits both groups."

Support to set up the test center came from the International Electronic Article Surveillance Manufacturers Association, which estimates that 400,000 EAS systems are used worldwide. Typically placed near store exits and entrances, the EAS systems use electromagnetic energy to detect special tags placed on items stores wish to protect.

In the test center, Woody and research engineer Ralph M. Herkert subject pacemakers, defibrillators and other devices to the energy fields created by a representative sample of eight EAS systems and two EAS system tag deactivators provided by their manufacturers. Using standardized test procedures, they measure how the medical devices respond through their full range of operation.

The resulting data is used by the manufacturers' design and quality assurance departments to improve their products, if necessary. Thus, this data helps the manufacturers ensure that interference, which could harm wearers of medical devices, does not occur.

Testing takes place with the devices submerged in a tank of saline solution that simulates the electromagnetic behavior of the human torso. Using a computer-controlled positioner, the tank containing the medical device is moved through each merchandise control system in a manner that simulates the way customers might walk through such systems in retail stores. The test protocol also simulates customers standing in a checkout line near equipment used to deactivate the control tags.

Because of a non-disclosure agreement, Woody and Herkert provide the data they generate only to the manufacturers who submit the devices. The researchers do not have medical training, so they do not render judgments about the health implications of the data they measure.

But Woody says the medical devices are carefully designed to handle interference. So when the researchers do measure a response to any electromagnetic field, it tends to be subtle — such as temporary changes in pulse rates and missed beats. And the devices recover quickly.

— John Toon

> **For the full text news release**, see www.gtri.gatech.edu/res-news/E3TEST.html.
> **For more information**, you may contact Jimmy Woody, Sensors & Electromagnetic Applications Lab, Georgia Tech Research Institute, Georgia Institute of Technology, Atlanta, GA 30332-0822. (Telephone: 404/894-8326) (E-mail: jimmy.woody@gtri.gatech.edu); or Ralph Herkert, Sensors & Electromagnetic Applications Lab, Georgia Tech Research Institute, Georgia Institute of Technology, Atlanta, GA 30332-0822. (Telephone: 404/894-8602) (E-mail: ralph.herkert@gtri.gatech.edu).

Faculty/Staff Honors and Awards

Joseph Bruder, a principal research engineer at the Georgia Tech Research Institute, was

elected a fellow of the Institute of Electrical and Electronics Engineers (IEEE). Only about 1 percent of IEEE's 300,000 members have earned the fellow designation.

J.G. "Jim" Dai, an applied probabilist with joint appointments in the School of Mathematics and the School of Industrial and Systems Engineering, received the Erlang Prize for his outstanding contributions to the field of applied probability. Sponsored by the Section on Applied Probability of the Institute for Operations Research and the Management Sciences, the Erlang Prize is the most prestigious award for young applied probabilists.

Patricia Dove, an associate professor in the School of Earth and Atmospheric Sciences, and graduate student H. Henry Teng won the Mineralogical Society of America's Best Paper Award. Their paper titled "Surface Site-Specific Interactions of Aspartate with Calcite: Implications for Biomineralization" appeared in the 1997 American Mineralogist (Vol. 82, p. 878-887).

Rosario A. Gerhardt, an associate professor in the School of Materials Science and Engineering, was inducted as a fellow of the American Ceramic Society (ACeRS). Only 26 members were elected fellows in 1998. Gerhardt also is the new program chair of the electronics division of ACeRS.

M. Jackson Marr, a professor and experimental psychologist in the School of Psychology, was elected president of the Division of Experimental Analysis of Behavior of the American Psychological Association. Marr's recent research activities address the development and assessment of precision learning techniques and other instructional systems for teaching engineering physics. He also studies the applications of dynamical systems theory to operant conditioning, applications of behavior analysis at Zoo Atlanta and theoretical issues in behavioral analysis.

Robert Michelson, a principal research engineer at the Georgia Tech Research Institute, won the 1998 Pioneer Award presented by the Association for Unmanned Vehicle Systems International. The award is the highest recognition in the unmanned systems industry for technical contributions that advance the state-of-the-art, while moving the community toward the new millennium. The 1997 winner was former U.S. Secretary of Defense William J. Perry.

Ward O. Winer, Regents' professor and chair of the School of Mechanical Engineering, received the 1998 University of Michigan Alumni Society Merit Award from the Department of Mechanical Engineering and Applied Mechanics.

Jan Youtie, a senior research associate at the Economic Development Institute, and Phil Shapira, an associate professor in the School of Public Policy, won a Lang Rosen "Gold

Award" for their article, "Tracking Customer Progress: A Follow-up Study of Customers of the Georgia Manufacturing Extension Alliance." They received a similar award in 1997 for "Coordinating Manufacturing Extension Services: Impacts and Insights from the U.S. Manufacturing Extension Partnership." The awards, given annually by the Technology Transfer Society, recognize excellence in content and writing.

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Send questions and comments regarding these pages to Webmaster@gtri.gatech.edu

Last updated: October 7, 1998

Research Horizons

Making the New Currency Safer to Transport

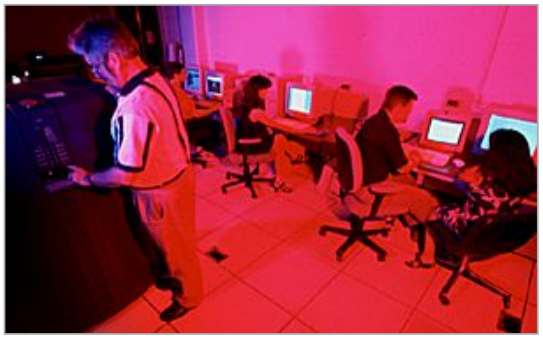
Georgia Tech's Information Security Center studying technical and policy issues.

By Jane M. Sanders and **C. Blake Powers**

From customer records to advanced product research, information has become the cornerstone of operations for business, government, industry and the military. Every day, threats to the safety of this "new currency" blare from news headlines:

curious hackers, computer-based terrorists, industrial espionage and even "information warfare" between nations. Protecting this new commodity is of critical importance.

photo by Stanley Leary



GTRI researcher Jim Cannady, right, and his colleagues are using a Cray supercomputer to develop information security technologies.

Last year, the Georgia Institute of Technology moved to address both technical and policy issues

See sidebar story: Two Infamous Cases of Computer Hacking

of information security with the establishment of the Georgia Tech Information Security Center (GTISC). Researchers are now identifying the problems and developing solutions to those problems. GTISC is expected to make great strides under the leadership of its new director, Dr. Blaine Burnham, who assumed his position in December 1998. He formerly worked at the National Security Agency.

"Until now, most efforts at information security have been ad hoc in that a problem is discovered and a Band-Aid applied," said Dr. J. Michael Cummins, the director of Georgia Center for Advanced Telecommunications Technology (GCATT), who also served as GTISC's interim director. "There is no underlying conceptual framework to think through all these issues — particularly on a policy level. We formed the Information Security Center to be the leader in developing that theoretical infrastructure, while providing specific solutions to both technical and policy issues."

Among the fundamental issues under study by GTISC are the sources of information security breaches and the importance of information security to economic growth. Specific technical issues being investigated include: network security evaluation; external attack detection; computer performance versus security tradeoffs; broadband network security; the security and viability of the Internet II; and security applications to make telecommuting more widely adopted. GTISC is addressing these issues with a cross-disciplinary group of researchers from: the Georgia Tech College of Computing, the organizational seat of GTISC; Georgia Tech Research Institute; GCATT; and the Sam Nunn School of International Affairs.

"We have strengths in both basic and applied research, and researchers are already collaborating with each other," says Peter Freeman, dean of the College of Computing. "Georgia Tech also has a lot of experience working with top industry, governmental and academic leaders. So we bring a strong and integrated approach to the information security issue."

Fundamental Issues of Information Security

Just what is information security? Dr. Philip Enslow, a professor in the College of Computing, explains it this way: "It means that tomorrow morning when I get to work and turn on my computer, all my systems and processes will work correctly, my information will be available and not be corrupted, and no one will have had access to my data."

Such issues as defining the standard for information security represent the theoretical side of the problem, Enslow says. "There are a lot of pieces required to make a secure operating system," he explains. "There's encryption for data links, firewalls and other issues like digital signatures.... But I want to help develop the overall framework for such security issues and not get mesmerized by individual components such as firewalls.

"Security systems operate in an environment created by government regulation, criminal law and the mores of society," Enslow says. "These are political issues that are important to business, society and government."

Educating the stakeholders about security issues is Enslow's focus. He wants to emphasize the importance of information security to economic growth.

"There's been a lot of focus on the Y2K problem, but after it is dealt with, I think more businesses will start to realize that their economic survival depends on the security of their information," Enslow says. "But it may not get enough attention until there's some nasty litigation like a stockholder lawsuit. Really, information security is as much the responsibility of the board of directors as is having sprinkler systems and guards for their warehouses."

Enslow also wants to dispel a common misperception. Most information security breaches are not external ones. They are internal ones caused by sabotage, accidents or incompetence, he says. Businesses need to learn how they can verify the reliability of their employees and their information processing operations to maintain security.

Evaluating Security of Networks

Meanwhile, businesses are addressing security issues such as electronic commerce conducted via the Internet. They are increasingly dependent on the security of their computer networks. Yet they lack an effective method for assessing the security of external networks that could dramatically degrade their own computer network security, says Jim Cannady, a research scientist at the Georgia Tech Research Institute (GTRI).

"The current lack of a standard method of assessing the security of networks is one of the factors that has prevented the large-scale use of electronic commerce," Cannady says.

So GTRI researchers are developing a standard methodology — called the Network Security Evaluation Criteria (NetSEC) — for evaluating the security of external network systems. It will also help system administrators identify improvements needed to elevate their networks to desired levels of security.

Learning the Characteristics of Attacks

While internal attacks on information security may be more widespread, the threat of external attacks by hackers is still very real and quite complex.

"The individual creativity of attackers, the wide range of computer hardware and operating systems, and the ever-changing nature of the overall threat to targeted systems have contributed to the difficulty in identifying network system intrusions," Cannady says.

The need to detect both known and new types of external attacks on a system is the focus of another GTRI research project. Cannady is addressing this need with the power and flexibility of artificial neural networks. These networks consist of collections of processing elements that are highly interconnected. Each collection transforms a set of inputs to a set of desired outputs.

In a neural network demonstration project called SENTINEL, Cannady is developing an intrusion detection system that identifies not only previous types of attacks, but new ones — something current rule-based systems cannot do. The system gains experience with each effort so that it "learns" the characteristics of attacks. That should allow the system to eventually predict attacks and monitor activities, collecting information for responses to attacks and the prosecution of those behind them.

Cannady has compiled promising results from tests of two prototype neural networks. One, the multi-level perceptron (MLP) network, was able to correctly identify each of the embedded attacks in the test data. This test demonstrated the ability of a neural network to identify specific events that may be part of an intrusion. But most attacks involve a series of events, Cannady says. So he also tested a hybrid MLP/self-organizing map prototype. Results showed the network's ability to identify seemingly subtle, time-evolving attack patterns interspersed randomly in ordinary Internet traffic.

Two Infamous Cases of Computer Hacking

The New York Times

In September 1998, hackers sabotaged The New York Times Web site in the first known successful hack of a major media organization. The hackers were able to break in to the Times Web site and replace its front pages with pornography and hidden messages. When the Times attempted to update its site, the hackers responded with counterattacks. Finally, the Times gave up and took its site down for about eight hours.

The Times was using what is called a common gateway interface, or CGI, to create its Web pages. Experts believe the hackers probably launched their attack through holes they found in the siteÕs CGI scripting. This language is used for various interactive features on Web pages.

Citibank

In a series of break-ins in 1994, the bank's payment system was compromised for about $10 million. The bank says it eventually recovered most of that sum. Subsequently, Citibank tightened its computer security system.

But before those measures were taken, the Russia-based hackers were able to electronically transfer large sums of money into their international bank accounts.

The hackers apparently used valid user IDs and passwords of other banks to accomplish the fund transfers. How they got those passwords, given Citibank's security, remains a mystery. Some officials believed the hackers had inside help, but Citibank says no employees were involved.

— Jane M. Sanders

Information Security vs. Application Performance

Yet another issue is the tradeoff between information security and application performance. Security computations consume a great deal of application processing resources, and this detracts from the performance of shared, collaborative, real-time and electronic commerce software programs. Thus host computers often cannot handle Internet user demand for applications — such as ones designed for electronic commerce — that require high levels of security.

Enter the concept of adaptive security being developed by researchers in the Georgia Tech College of Computing. Adaptive security provides a protocol for systems to adapt to changes in user/application security requirements and host system computation resource capability.

"Our mission is to address performance vs. security tradeoffs by adapting to the constantly changing availability of computation and communication resources," says Dr. Phyllis Schneck. She is a recent Ph.D. graduate conducting this research with Dr. Karsten Schwan, a professor in the College of Computing, and Dr. Santosh Chokhani, president and CEO of CygnaCom Solutions, an information security company in McLean, Va.

"We want to provide an on-line, near-optimal allocation of these resources over time," Schneck says. "The end goal is to minimize overall risk by borrowing available security processing resources on one communication stream to 'lend' to other application streams that may currently be lacking."

She and her colleagues have developed a suite of dynamic authentication heuristics (basically, exploratory problem-solving techniques) to help achieve high levels of security with scarce computation resources. The suite optimizes the use of host computer resources while still preserving appropriate levels of security and providing feedback to users when any changes are made. Users can initiate changes in security level as well, while applications are running. A Georgia Tech Research Corporation patent is pending on the heuristics suite.

Uniqueness of GTISC

Expectations are high for the success of GTISC in solving major information security problems because of its unique comprehensive approach. Several institutions in the United States collect statistics, investigate vulnerabilities and conduct research, Schneck says. But Georgia Tech is unique because it offers a "fusion" of technical and policy expertise.

"One of the special qualities about Georgia Tech is the way in which the research here is often a cross-disciplinary, collaborative effort done with industrial partners," Schneck says. "In that same spirit, GTISC symbolizes the synergistic combination of academia and industry to conduct new research, commercialize new technologies and educate our community. It is this combination that eventually enables greater global economic growth."

For more information, you may contact Dr. Blaine Burnham, College of Computing, Georgia Institute of Technology, Atlanta, GA 30332-0280. (Telephone: 404/894-3152) (E-mail: gtisc-info@cc.gatech.edu); or Jim Cannady, Information Technology & Telecommunications Laboratory, Georgia Tech Research Institute, Atlanta, GA 30332-0832. (Telephone: 404/894-9730) (E-mail: james.cannady@gtri.gatech.edu)

ResearchHorizons

Dependability Upgrade

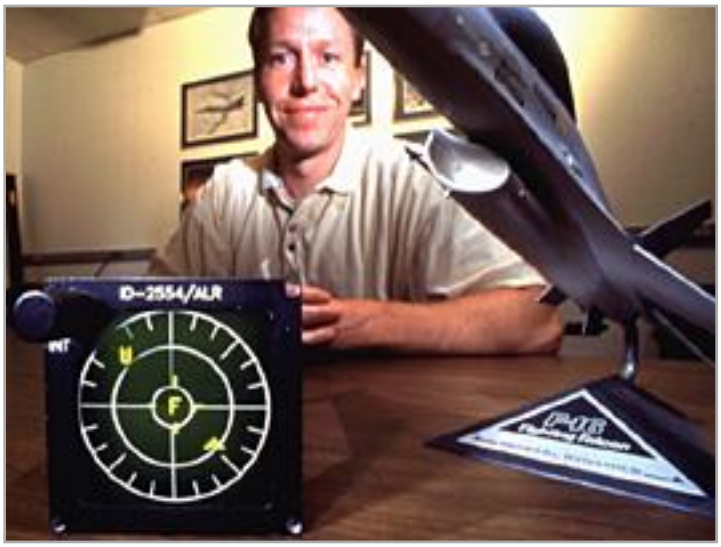
Display unit of military aircraft Radar Warning Receiver revamped by GTRI researchers.

By Rick Robinson

In an ongoing effort to improve military aircraft performance, engineers at the Georgia Tech Research Institute have redesigned a vital component of a widely used radar warning system — making it easier to maintain and dramatically more dependable.

The Georgia Tech Research Institute (GTRI) team recently finished revamping the display unit found on the ALR-69 Radar Warning Receiver (RWR), a system used on 2,000 U.S. and 1,000 foreign aircraft. The refurbished display unit has all-new electronics that improve its predicted reliability by more than 500 percent, researchers say.

photo by Stanley Leary



A GTRI research team, including engineer Byron Coker, developed this flat panel display for the ALR-69 Radar Warning Receiver. It features low power electroluminescent technology. It is night vision compatible and sunlight readable. The changes will dramatically improve reliability of the display unit.

"In layman's terms, the ALR-69 is the military version of a Fuzzbuster (consumer radar-warning device)," says Michael J. Willis, a senior research engineer with GTRI's Electronic Systems Laboratory. "It's the same basic principle, though much more complex in design. It lets pilots know when an enemy has a radar pointed at them, so they can take evasive action."

Because any such device is useless if it cannot relay a visible or audible warning signal, the dependability of the ALR-69's display hardware is critical. In place of the old model's oblong 3-inch by 9-inch cathode ray tube (CRT), Willis and his colleagues installed a flat-panel electro-luminescent screen — chosen because of its relatively low power requirements — and three printed circuit cards. The new model's container is identical in size and shape to the old model, allowing plug-in unit-swapping in the field. The only visible difference between the two designs is the new model's amber monochrome screen, a departure from the green used by the old model.

The new display unit offers higher brightness, night vision compatibility, sunlight readability and is fully compatible with the rest of the system, Willis says. It has a predicted reliability of some 14,000 hours — versus an actual reliability of about 2,500 hours on the old CRT-based model.

A major element in such improved reliability and maintainability is the better capabilities, features and reliability of today's electronics compared with the decades-old electronics used in the CRT-based display unit, Willis explains. The new model has no adjustable components, better fault diagnostics and built-in test capability.

"Twenty or 30 years ago the electronics of that day didn't have the features and capabilities that we have today because of newer integrated circuits," he says. "The reliability improvements are more a function of improved electrical performance and integrated circuit performance than any special mechanical changes."

GTRI's current work for the U.S. Air Force on the display unit is the most recent chapter of an extensive involvement with the ALR-69 RWR system going back more than 15 years. GTRI has worked extensively on both hardware and software aspects of the complex system, which includes radio-frequency, microwave, analog, digital and other kinds of circuits — all of which require the support of embedded software, ground equipment and laboratory tools.

Among the GTRI accomplishments was the Class IV Reliability and Maintainability Upgrade, which was completed in the early 1990s. The Class IV Upgrade consists of a series of circuit card assemblies that provided the ALR-69 with a large computational power increase by expanding the microprocessor count from one to three. That upgrade is now flying throughout the world on some 2,000 U.S. and 1,000 foreign aircraft. The U.S. military uses the ALR-69 on the B-52 bomber; A-10 and F-16 fighters; MH-53J and H-60 helicopters, and C-130 and C-141 cargo planes.

"There's a wide variety of platforms, and that's one of the challenges of the system — being able to support all of the different aircraft that the system is on," Willis says.

The redesigned display unit is now undergoing extensive electrical, environmental and field testing. If all goes well, the new model should begin service around the world within two years.

For more information, you may contact Michael Willis, Electronic Systems Laboratory, Georgia Tech Research Institute, Atlanta, GA, 30332-0829. (Telephone: 404/894-7146) (E-mail: michael.willis@gtri.gatech.edu)

Research Horizons

From Moscow to Atlanta

Russian emigre recalls moving his family and career.

By Amy Stone

Even though Mark Borodovsky drove a car when he lived in Moscow, he did not drive in the United States until he needed to travel 260 miles from Atlanta to Hilton Head, S.C., by himself to attend a conference. The experience, he recalls, was "somewhat terrifying." And so it goes on the long road to assimilate into American life.

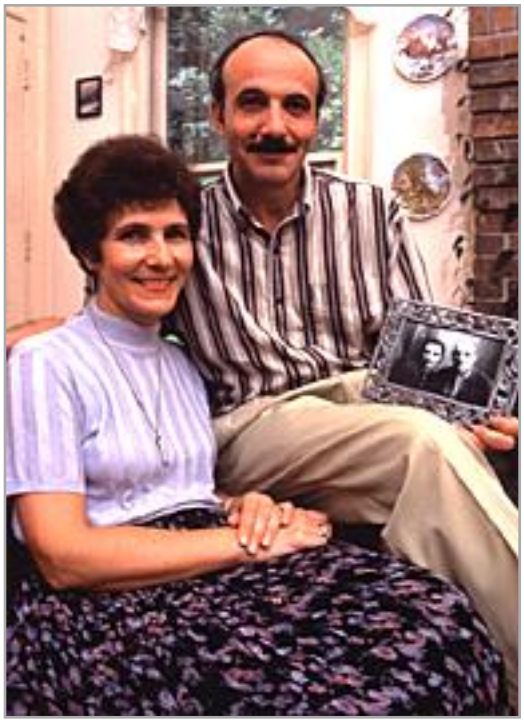
But, after eight years of living in the United States, the Borodovsky family is doing a good job of "keeping up with the Joneses." For example:

Borodovsky has a successful research career in a hot new field and is called upon by scientists around the world to aid them in decoding segments of DNA.

See main story: Deciphering the Genetic Code

He holds a faculty position at Georgia Tech and is heading its new master of science degree in bioinformatics. His wife, Nadia, is a research scientist at Georgia Tech, where she works in DNA and peptide synthesis and high-performance liquid chromatography at the Institute of Bioengineering and Bioscience. His daughter, Anna, received her undergraduate education at Emory University and is now at Harvard, working on a Ph.D. in molecular biology with the help of a prestigious National Science Foundation

photo by Stanley Leary



Dr. Mark Borodovsky holds a faculty position at Georgia Tech and is heading its new master of science degree in bioinformatics. His wife, Nadia, is a

scholarship. His son, Alex, graduated from Paideia High School in Atlanta last May and entered Georgia Tech last fall.

research scientist at Georgia Tech, where she works in DNA and peptide synthesis and high- performance liquid chromatography.

What a life, right? On the surface, it appears the American dream is alive and well for the Borodovsky family. But to think there are no down times, times when they miss their home or when they can't escape their past, is wrong.

"The blue-gray oak trees that loom now into the window of my office are the same type of tree that were looking into the window of our apartment — also on the second floor — back in my native city when I was a child," Borodovsky says, giving a hint to how many memories he left behind when he came to a new country at 40 years of age. He also lost grandparents to the Holocaust, and left behind family and friends.

"In Russia, I used to pick mushrooms — this is a wonderful thing, walking in the woods looking for mushrooms. I also miss the Black Sea. The water is as green as the Gulf of Mexico, and there are fabulous beaches at the Caucasus Mountains," Borodovsky says.

But even leaving everything they owned in Russia and starting a new life with no money for a house, a car or clothes — "starting from zero point," according to Borodovsky — the family has no regrets.

How the Borodovsky family ended up in Atlanta began with a simple scientific meeting. Back in 1990, the family embarked on its first trip to the Western world, a trip to the United States. The visit was supposed to be short, so the family brought only a couple of suitcases. After the meeting, Mark was offered the opportunity to stay on and work at Georgia Tech.

"This is a lifetime opportunity," he recalls thinking.

And so the family stayed on, renting an apartment in Atlanta. One thing Borodovsky credits with his family's assimilation into American culture was the moral support they received from the Atlanta Jewish community.

Earlier this year, Borodovsky returned to Moscow for a work-related trip. The family's apartment is still there, exactly as they left it.

"When we left, we never thought we would not be back," he said. "But thanks to our U.S. friends, we received support to start new and productive lives in the United States."

And now, the Borodovsky family is comfortable in the United States. Indeed, it is their home.

"I will always remember the day when I returned to Atlanta from my first trip abroad in 1991," Borodovsky recalls. "At the airport, the immigration officer checked my travel document and said, 'Welcome home, sir.' Nobody in the Soviet Union ever told me those words."

Send questions and comments regarding these pages to Webmaster@gtri.gatech.edu

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