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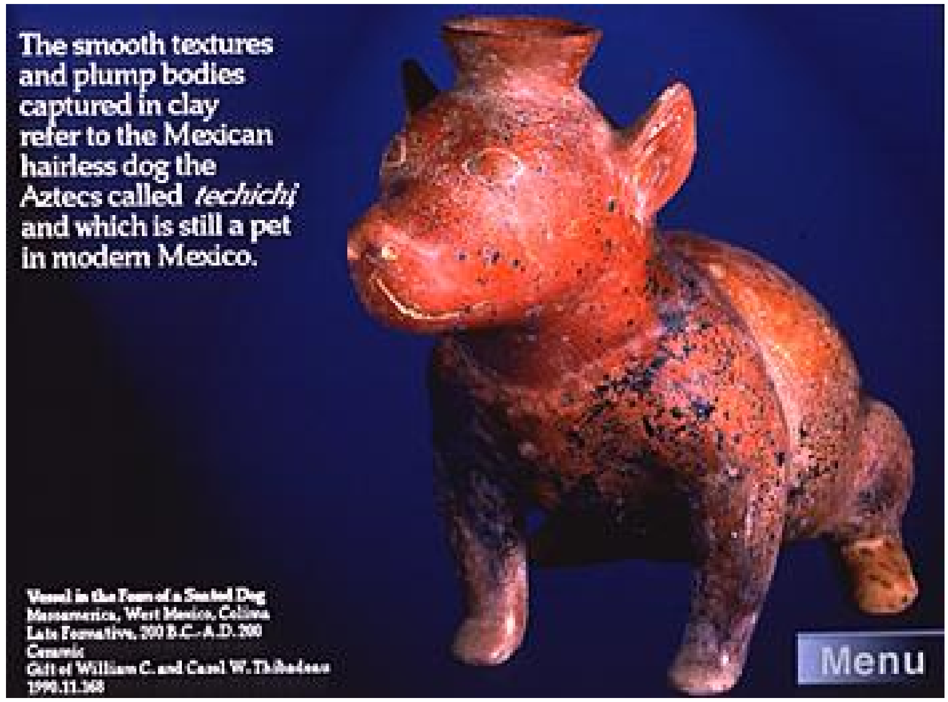

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Flying into the Future

Miniature flying machines could help with warfare, agriculture and more.

By Amy Stone

IS IT A BIRD? A PLANE? In the case of micro air vehicles -- tiny, self-piloted flying machines -- it's a little of both with some insect and robot characteristics thrown in.

photo by Stanley Leary

While not quite able to leap over a building in a single bound, microflyers (as they are called at the Georgia Institute of Technology) will have some fairly astounding characteristics. Georgia Tech engineers envision that these six-inch machines will be able to fly to a target and feed back or retrieve information in a variety of forms, including visual, chemical and biologic.

Adding to their complexity, microflyers will be able to accomplish their tasks by themselves: they won't rely on humans to provide remote control.

Robert Michelson's entomopter uses a micropropellant fuel to generate an up and down motion, such as beating wings or scurrying feet. [(200-dpi JPEG version - 148k)]

"Microflyers need to be nimble, fearless, safe and survivable in order to be successful," says Dr. Samuel Blankenship, a principal research scientist at the Georgia Tech Research Institute (GTRI) and coordinator of the Georgia Tech Focused Research Program for Microflyers. "The range of applications for a self-piloted, multi-mode tiny machine is truly great."

As with many engineering marvels, the initial applications for the microflyers will be for the military. However, Blankenship sees civilians, such as police and fire officials, scientists and farmers, as the ultimate users of this technology.

As useful as these flyers may be in the future, there are some immediate problems that have to be solved before microflyers are a reality. For example:

- **Size.** "You can't just shrink a 747 proportionally down to six inches and expect it to fly," notes Blankenship. Wind, rain, and even air itself, pose different problems to a six-inch flyer than they do to a large jet.

- **Autonomy.** The smaller a system is, the more skittish it acts. Therefore humans -- especially if they are looking through a camera -- will not be able to react in time to control a machine this tiny. Proposed means of making the microflyer autonomous include using a geographic information system (GIS) to provide a map of the terrain or a global positioning system (GPS), which employs a satellite to map the location of the flyer. However, GIS can't include power lines or cars and GPS is useful only outdoors.

- **Flight Controls.** Traditional planes use weighty motors and hydraulic machinery to maneuver control surfaces in the wings and tail. Altered wing design and channelled exhaust may help provide control without extra weight and allow the small aircraft to fly under control at very low speeds not possible with conventional wings and control surfaces.

- **Power Sources.** Since a drop of gasoline has more energy potential than current batteries of the same size, early models will probably use fossil fuels. GTRI researchers have proposed a micropulse jet engine which is not as efficient as a traditional jet turbine engine, but is much simpler.

- **Weight.** All of the components, including the payload, must weigh less than about four ounces.

To design a microflyer, Georgia Tech is drawing on expertise in aerodynamics, control systems, avionics, sensors, systems integration, electrical engineering and human factors. Tech has supplied initial funding to launch the project so that it will be ready to take off when the Defense Advanced Research Projects Agency (DARPA) announces its funding opportunities.

Also, Georgia Tech has reached out to bring the best minds together on this project: It has partnered with other agencies, such as the Air Force Institute of Technology and the Institute of Defense Analyses, and sponsored a national conference in February 1997, which served as a catalyst for the field.

The First Step: Airborn Microflyers

The initial goal of the microflyer program is to design a machine that can take off, land and follow simple instructions while aloft.

Robert Englar, a principal research engineer at GTRI, is working on a fixed-wing model for the microflyer. By combining an altered wing design that has a rounded trailing edge and channelling the engine exhaust out of the wings through tiny slots, Englar's model employs what is known as the Coanda effect to greatly augment the wing's lift and control without any external moving parts. This results in an aircraft's ability to lift, land and turn, all at very low speeds without complex control

What Could Microflyers Do?

- Kill harmful insects
- Crawl or fly down smokestacks to measure emissions
- Monitor concentrations of chemical spills
- Look over the next hill in combat situations
- Maneuver through buildings looking for survivors after a disaster

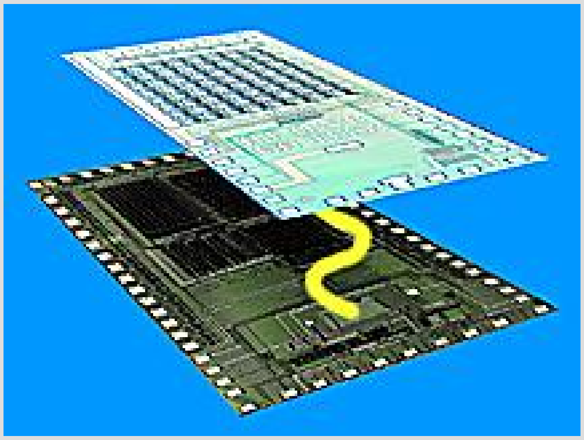
devices.

"Traditional planes rely on fast wind speeds to generate lift over their wings and allow them to stay aloft. Our blown model will allow the microflyer to take off and land at much slower speeds and turn while airborne," explains Englar. "This would allow these very small aircraft to fly within buildings, for example."

To change directions, Englar's model uses fluidics devices to control the stream of exhaust. In simplified terms, to turn to the left, the amount of exhaust is increased out of the right wing or reduced from the left. To lift or lower the craft, the quantity of exhaust is manipulated. More exhaust exiting equally through both wings makes the aircraft fly much slower.

- Fly spy missions, either outside or indoors
- Measure ammonia concentration in agriculture
- Track wild animal herds
- Toys

graphic by Martin Brooke



Stacking microchips and connecting them with light signals allow the chips to perform multiple functions in a small space. This technology may be used in micro air vehicles. (200-dpi JPEG version - 173k)

Robert Michelson, also a GTRI principal research engineer, was inspired by insects for his design. He envisions the microflyer as a multi-mode vehicle -- capable of flying, crawling, and perhaps, swimming.

To fulfill that vision, he has developed a reciprocating chemical muscle (RCM) which uses a monopropellant fuel to generate a reciprocating, or up and down, motion, such as beating wings or scurrying feet. As an added plus, the RCM can generate electricity, which could be used to power sensors for directional or mission purposes.

Resembling a metallic wasp with about a 10-inch wingspan, his prototype (dubbed the entomopter in reference to its insect-like characteristics) flaps its wings as the fuel is injected into the body, enabling it to fly forward. Gas generated as a byproduct of the RCM can be used to change the lift on one wing or the other to allow the otherwise autonomic symmetric wing beating to result in "rolling" of the device so it can turn right or left.

"The next step is to shrink the RCM device down to bug size," says Michelson. "Near-future goals for this model include trimmed, or directed, flight; multi-mode locomotion; and sensors which will enable it to perform simple homing activities."

At such a small scale, every piece of the microflyer has to perform double, or even triple, duty. For example, a radio antenna could also be used as a stabilizer for navigation while the legs could double as receptacles for fuel storage and for adjusting the entomopter's weight and balance during flight. Michelson believes even a "self-consuming" system is possible, in which the microflyer would consume itself to generate energy as it flies. Alternatively, the RCM concept is even amenable to conversion of biomass into usable fuel reactions, so future entomopters may be able to "eat on the run" to extend their mission endurance.

The Next Step: Airborn Potential

To be useful machines, microflyers will have to carry payloads ranging from cameras to chemical sensors. Therefore, other scientists on the Georgia Tech team are examining how to make miniature sensor systems.

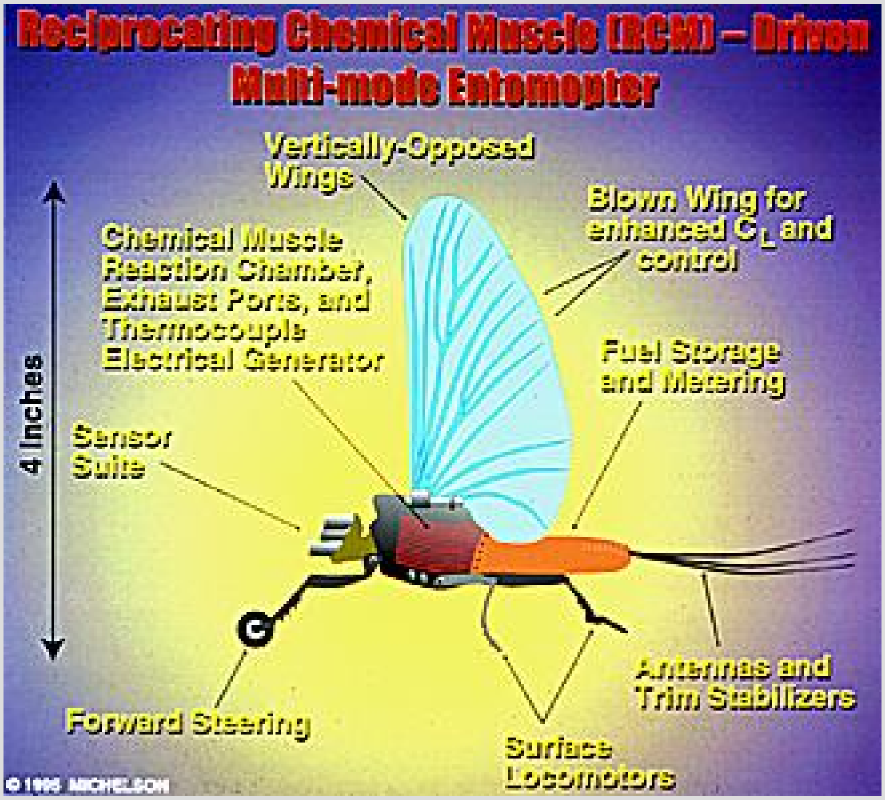
The prototype chemical and biologic sensors are basically small chips of glass with optical wave guides fabricated on their surfaces which can trap and manipulate light. On the most basic level, the sensor would have two channels: sensing and reference. When a laser beam is passed under the strips, the phase of the light contained in the guides is altered by the change in refractive index that occurs when the sensing channel interacts with the chemical or biological species it is designed to measure.

The information contained in the light is read after the laser beams passing under the sensing and reference channels are combined to generate a unique interference fringe pattern, which moves past a solid-state detector array in proportion to the phase change that has been caused by the sensing interaction.

"With this technology, you can design each sensing/ reference pair to respond to a particular type of analyte. In some cases, it is possible to design a sensing channel that will respond uniquely to the analyte you want to detect, and in other cases, where unique sensing chemistry is not available, you can

graphic by Robert Michelson

design multiple sensing/reference pairs on the same optical chip and use pattern-recognition techniques to sort out which analyte is being measured," explains Dr. Robert Schwerzel, a principal research scientist at GTRI. "We can put up to two dozen channels on a sensor chip to determine what the microflyer is flying through."



Reciprocating Chemical Muscle [RCM]-Driven Multimode Entomopter. [(200-dpi JPEG version - 305k)]

Already small (about 1 cm by 2 cm), the sensors will need to be further reduced for the microflyer. For example, the laser and detectors, which currently feed the information to circuit boards in laptop computers, are external to the sensors. Schwerzel and his colleagues, including Nile Hartman, who developed the original concept, and Dr. Dan Campbell, who has developed much of the sensing chemistry, are working on integrating all of these components, including the signal processing electronics, into one small unit.

"An important feature of these sensors is the ability to fabricate thin films of polymers, antibodies, or other chemical reagents on top of the waveguides. These thin films are the key to gathering chemical or biological information in a tiny space," says Schwerzel. "With these integrated-optic sensors, you can use chemical reactions, adsorption into polymers and other means to gather analytical information. Combined, these features make the integrated-optic sensors more specific and sensitive than other monitoring techniques."

A group of researchers in Georgia Tech's School of Electrical and Computer Engineering is working on other types of sensors -- those that would supply visual images and those necessary for communication.

The visual sensors could use active pixel arrays already used in the nose cones of missiles to allow for "real time" processing of images. The trick is, of course, to make the technology tiny enough.

"We're looking at the ultimate level of packaging the components for microflyers," says Dr. Joy Laskar, assistant professor of Electrical and Computer Engineering. "You can't buy these components off the shelf."

Additionally, Laskar and his colleagues are examining how to communicate with the microflyers once they are airborne, how to transfer information that the microflyer gathers and how to keep the information and communications secure -- an important consideration in wartime use.

Therefore, the microflyers won't use a standard cellular frequency band since that is easily jammed or crowded, but will use a higher frequency, which allows for a smaller antenna.

The Future

As the initial problems are solved, other specialists will begin work. Amy Mykityshyn, a researcher specializing in human factors, will work on the design of "human/machine interfaces." This area is important because even though the microflyers must operate autonomously after they have been given a task, humans must still play a large role in their missions, including:

- identifying tasks for the microflyers, such as specifying the mission objective and the information to be obtained;
- servicing the machines by providing logistics support in refueling and repair;
- receiving and interpreting the information obtained from the aircraft.

Helping to put together all the parts is Dr. Tom Collins, a senior research engineer in the Electronic Systems Laboratory.

"The integration of all the systems is important -- especially on such a small scale as the microflyer project," notes Collins.

"For example, if one person goes over the weight limit for a component, that weight has to come from someone else's project," continues Collins. "In industry, you'd

Projected Requirements for Microflyers

- Size: less than six inches at largest point.
- Weight: approximately four ounces.
- Speed: up to 50 mph.
- Range: up to 6.2 miles.
- Price: less than

parcel out weight limits and make people stick to them. However, that's harder to do in research since you're making it up as you go along."

- $1000 per unit.
- Sturdy: able to hold up in backpacks.
- Use: easy, with minimal training.

In spite of the many challenges that remain in order to get a microflyer in the air, Blankenship, the project's coordinator, is optimistic.

"We hope to have a machine flying in three years," says Blankenship. "It will cost over $10 million to produce the prototype. We know we're pushing the envelope with this project. However, you have to reach high and employ the push/pull strategy: technical requirements push you to develop new technology and then technology pulls research along."

Further information is available from Dr. Samuel Blankenship, Electronic Systems Laboratory, Georgia Tech Research Institute, Georgia Institute of Technology, Atlanta, GA 30332-0840. (Telephone: 404/894-7311) (E-mail: sam.blankenship@gtri.gatech.edu)

Rapid Prototyping

Key to Speedy Manufacturing

By Lea McLees

SPEED AND ACCURACY are the hallmarks of successful, profitable manufacturing in the 1990s. Products that miss target market dates or bear unanticipated design flaws can cost manufacturers dearly in lost sales and development investments, giving competitors an advantage.

And the window for meeting target market dates is shrinking, notes principal research scientist Tom Starr.

photo by Gary Meek

An ultraviolet laser cures a syrupy eposy liquid into a solid prototype inside a stereolithography machine. (200-dpi JPEG version - 276k)

"Today, products can miss their markets if they are even six months late," says Starr, a researcher in Georgia Tech's School of Materials Science and Engineering.

Leon McGinnis, professor of industrial and systems engineering, agrees.

"Companies today can't afford to make mistakes when they are bringing products to market," he says.

Rapid prototyping and manufacturing (RPM) technologies hold vast potential for ensuring quickly designed, precise products. These methods allow prototypes -- and perhaps one day, the products themselves -- to be built quickly from computer-aided design (CAD) files using photochemically sensitive resins or other materials. Rapid prototypes are ready within hours or days of design; conventional prototypes can require weeks or months to build or mold.

RPM offers monetary savings, as well. Pratt and Whitney's Rapid Prototyping and Casting Laboratory in Connecticut reported in 1995 having made 2,000 RP castings at a cost of $600,000 to $700,000 -- a savings of $6.4 million, when compared to the $7 million that would have been spent using conventional prototyping methods.

But the availability of RPM technology doesn't guarantee its productive use. Education and experience are necessary, and, as with any technology, RPM could be enhanced with further research and development.

A Project for Students and Industry

To that end, Georgia Tech has formed the Rapid Prototyping and Manufacturing Institute (RPMI) to educate students, address industry RPM needs and shed light on future research directions.

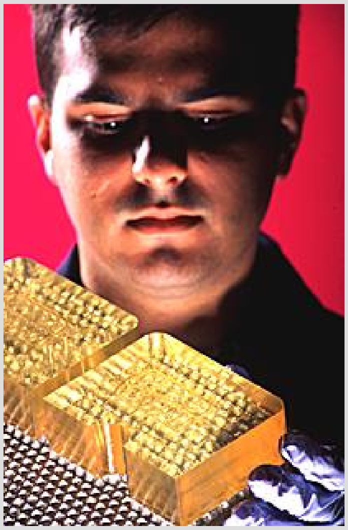
Working together to make RPM potentials reality are a dozen educators and researchers in mechanical engineering, materials science and engineering, chemical engineering, industrial design, management and aerospace industrial and systems engineering; representatives of eight companies interested in RPM; and 14 graduate students, says Tom Graver, RPMI director of operations.

"Industry has a clear need to learn how to apply these technologies and how to develop more challenging applications," Graver says. "By primarily focusing on education, we can address the needs of industry while creating outstanding opportunities for our students and faculty."

Member companies include Coca-Cola, Durden Enterprises, Eastman Kodak, Lucent Technologies, Motorola, Siemens, Procter & Gamble and 3D Systems.

"The idea of having a relationship with the RPMI allows us to take advantage of and participate in research and projects to press the edge of the envelope that we normally would not be able to do ourselves," says Allen Brand of Motorola Energy Products.

photo by Gary Meek



Georgia Tech mechanical engineering graduate Marcial Machado displays molds used to produce plastic, ceramic or metal parts. (200-dpi JPEG version - 224k)

RPMI began almost three years ago as part of a $1 million Technology Reinvestment Program grant from the Defense Advanced Research Projects Agency. Since then, member companies have each contributed $25,000 a year to support the educational mission of the RPMI, while researchers have brought in $500,000 in National Science Foundation monies, says McGinnis, one of the writers of the initial grant.

"Industry's immediate need is to be focused on understanding the technology and how to deploy it," McGinnis explains. "The interesting thing is that what comes out of our solving industry's technical problems is a research agenda. Educational activities that involve solving problems often lead to research."

RPMI researchers, member companies and students are working with three technologies, says Reginald Ponder, RPMI lab manager.

- **Stereolithography:** The first rapid prototyping technology introduced commercially, stereolithography (SL) appeared in 1987. It employs an ultraviolet laser that follows a computerized CAD file. As the laser shines through a syrupy liquid resin, it solidifies portions of the liquid into hard, thin, stacked layers, building a 3-D copy of the object modeled in the CAD file.
- **Fused Deposition Modeling:** Fused deposition modeling (FDM) relies on a thermoplastic filament protruding from a heated extrusion head approximately .0012 inches in diameter. A copy of the object in a CAD file is built as the filament melts, forming layers of thermoplastics below the extrusion head.
- **Jet-Modeling:** These machines are three-dimensional ink jet printers. They are used to quickly build inexpensive concept models.

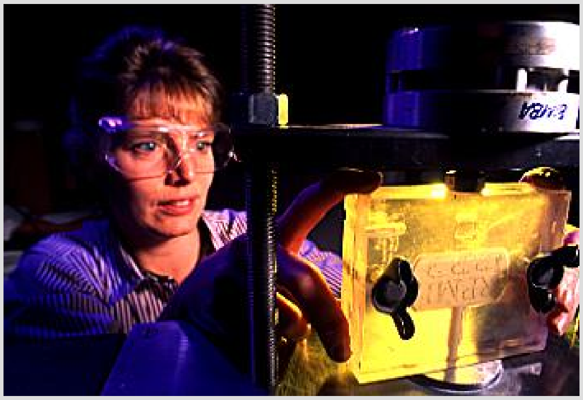
Read on to learn more about RPMI's achievements and goals for these technologies.

Rapid Prototyping for Ceramics

Combining rapid prototyping and powder injection molding technologies could enhance ceramics use in manufacturing by reducing the amount of time and money needed to use them.

One challenge remains: compensating for the shrinkage involved in powder processing.

photo by Gary Meek



Ph.D. student Beth Judson watches her rapidly made mold fill with aluminum oxide powder.

Ceramic parts created with powder molding shrink 10 to 20 percent during firing as the powder particles merge together at high temperatures to form the dense ceramic. This change from the as-molded size can affect the accuracy of the final product. Principal research scientist Tom Starr and Ph.D. student Beth Judson are developing a model that would predict the dimensions of the final, fired part within 0.5 percent of the intended size. That would allow designers to create molds that compensate for shrinkage.

"We're using finite element analysis," Judson says. "Right now we're working with aluminum oxide. It's the workhorse of the ceramic industry -- most technical ceramic parts are made of it."

If shape is a controlling factor, finite element analysis would be done with each shape. If material flow is a controlling factor, equations could be developed for different types of materials and process conditions.

Industries that might benefit from this research include textiles, where ceramic thread guides are used; and areas such as aerospace, automotive manufacturing or soft drink production that use nozzles, air foils, rotors or other such parts for high-temperature or potentially corrosive applications.

The work Judson and Starr are doing might be especially useful in short-term manufacturing, Starr notes.

"For example, if you wanted 100 parts out of stainless steel for a military aircraft that isn't made anymore, do you invest in a metal mold for $30,000, or do you do it this way?" Starr noted. "You can't amortize that cost over just a few parts. And the process we're working with would work for metal, as well as ceramic, parts."

Georgia Tech is pursuing a patent on the shrinkage prediction model.

Estimating Prototype Build Time

Once a CAD design is sent to a stereolithography machine for building, the user knows the part will be completed -- but not how long it will take.

"It is difficult to estimate build time because it is dependent on so many variables, such as part size, layer thickness, laser power, resin and other factors," says Joel McClurkin, a graduate student who completed his master's degree in mechanical engineering in June.

photo by Gary Meek

RPM has potential applications in preparing for medical procedures and re-creating damaged bone structure, says lab manager Reginald Ponder.

Notes his adviser, Dr. David Rosen: "The [rapid prototyping] machine must perform thousands or millions of small operations to make a part. Until now, no one has added up the times for all these operations."

Enter the build-time estimator. Developed by McClurkin working with Rosen, the program estimates how long a 3D Systems SLA (stereolithography apparatus) will need to build a part by analyzing the CAD file of the prototype in question.

"The build time estimator reads the vector and range files and makes an estimate based on the information in those files," McClurkin explained. "The vector and range files contain the 'low level' information that actually controls the operation of the SLA. The biggest task here was cracking the vector file to determine the location of the information I was looking for."

The program (available at http://rpmi.marc.gatech.edu/BTE.html) needs only three pieces of information: the name of the resin being used, the resin's penetration depth or critical exposure; the power at which the laser will be operating; and the name of the range and vector files of the drawing for which the user wants a build time estimate.

McClurkin made dozens of comparisons of estimates with the true build time for a variety of parts and gathered feedback from industry users, finding an average error of 2 to 3 percent.

The build time estimator is part of a software package McClurkin completed and demonstrated for his master's thesis. The package will help SL users select from numerous possible SL build styles, taking into account build time, surface finish, accuracy, post processing time and other factors.

Measuring What You've Made

No manufactured part is a perfect match to the CAD file from which it was generated. Defects occur randomly or because of problems associated with the manufacturing process, says Tom Kurfess, an associate professor of mechanical engineering.

His specialty is measuring objects with a coordinate measurement machine (CMM) to determine how to replicate them, or how closely they resemble original CAD files, Kurfess says.

"Once the object is in the CMM, a trigger probe touches the surface of the object in a variety of locations in three dimensions, giving XYZ coordinates off its surface," Kurfess explains. "The data points are connected with curves, surfaces and solids to represent or measure the object."

Among the issues Kurfess and his students are studying are the best ways to take data points, connect them and fit them to complex surfaces; ensuring a good data fit; and identifying the types of deformation that result during RPM, and their causes. If characteristic types of deformation are found to be associated with certain types of RPM, they might be eliminated in the future by modifying the CAD file involved.

"We have a lot of support from industry and government to address these issues," Kurfess said. "Our work extends beyond the rapid prototyping issues. Our target is extremely complicated geometry -- and we know exactly how to look at it."

Small, Speedy Product Runs

RPM is extremely useful for creating tooling used in short manufacturing runs, says Dr. David Rosen, assistant professor of mechanical engineering.

"We're looking for good ways to develop tools to produce a small quantity of plastic parts in end-use material, using manufacturing equipment like injection molds," says Rosen, who also serves as RPMI academic director.

Currently, injection molds can take several weeks or months to produce. Rosen's goal is to go from CAD model to molded parts in four days -- he thinks that will be possible within the next three years.

One aspect of this work involves fine-tuning the production of injection molds using

SL machines, and speeding up that process. An approach that Rosen and his students are looking at is building shells and filling them with epoxy or metal.

"Rather than building a solid mold on the SLA machine, which takes about 35 hours, we build the shell of the mold in about 15 hours and at one-tenth the cost," Rosen says.

Beyond Rapid Prototyping

Prototype development and use is part of a larger, holistic picture being explored by Rosen and Dr. Farrokh Mistree, professor of mechanical engineering. They are exploring the application of the best type of prototype -- physical or computer -- in different situations.

"Depending on the information we want to gain from the model, we don't necessarily need a product- representative prototype," Rosen says. "In some cases, we may not need physical prototypes -- virtual, computerized prototypes tend to be even more rapid."

They also are looking beyond product manufacturing to other needs that should be considered during design -- service and disassembly.

"At the end of a product's life there are a couple of different strategies," explains Mistree, who also works in Georgia Tech's Systems Realization Lab.

"One is to throw whatever you have into the waste basket. Another approach is to disassemble it and take out valuable components. Or, you could recycle the materials. How do you assess product assembly and disassembly characteristics? One way is to build a physical prototype and study it."

RPM will greatly contribute to development of principles for disassembly, a companion to the principles for assembly developed 15 years ago, he notes.

"Because we have rapid prototyping and virtual prototyping abilities, we should be able to come up with principles for disassembly much more quickly," he says.

Future RPM Research at Tech

What does the future hold for rapid prototyping and manufacturing technology? It could evolve into rapid manufacturing, predicts Steven Danyluk, director of Georgia Tech's Manufacturing Research Center (MARC). RPMI is one of the main focuses in MARC's work toward enhancing manufacturing education and research.

"If you needed to make a specific honeycomb product, you could make it out of a polymer, and further fabricate and use it in a production environment," he says.

Further materials research could make that prediction reality, says Bob Schwerzel, principal research scientist in the Georgia Tech Research Institute's Electro-Optics, Environment and Materials Laboratory.

"We'd like to develop new polymers and resins with new properties that would allow RPM to be used as a general manufacturing tool, and not just as prototyping tool," he notes. "I think controlling the material properties of the resin in the biggest challenge."

And eventually, RPM may contribute to the increased use of flexible systems in manufacturing that adapt quickly to changing market needs, Rosen notes.

"You really need your manufacturing equipment and tools to be modular and adaptable, and that's quite difficult to do -- so it remains to be seen how well rapid prototyping technologies can help us do mass customization and product variety," he says.

Further information on RPMI is available from Tom Graver, Rapid Prototyping and Manufacturing Institute, Georgia Institute of Technology, Atlanta, GA 30332-

Key Focus Areas for the Rapid Prototyping and Manufacturing Institute

- Making tooling rapidly: Harnessing emerging rapid tooling methods to develop processes that quickly, inexpensively produce five to 500 parts in end-use materials.
- Modeling and predicting form errors in rapid prototyping parts: Understanding errors in RPM processes so that parts more closely match design specifications.
- Rapid manufacturing of composites: Developing faster methods for building large, complex composite structures.
- Refining, validating and handling data: Making production of a prototype part from a solid CAD model easier.
- Developing functional prototypes: Making working prototypes that snap together, move as an assembly and look like a finished product.
- Finding alternate materials: Determining which are best and which meet specific needs.
- Investigating the role of prototyping in product design: Exploring how companies should use rapid prototyping resources in developing new products.

0406. (Telephone: 404/894-5676) (E-mail: tom.graver@marc.gatech.edu)

Check out RPMI's web site at: http://rpmi.marc.gatech.edu/.

- Optimizing rapid prototyping build parameters: Improving understanding of rapid prototyping processes so users know which variables to manipulate to achieve desired build speed, part accuracy, surface finish and prototype cost.

RPMI hosts a yearly symposium focusing on RPM applications. Over its first three years, the Gwaltney Manufacturing Symposium attained a reputation for being one of the premiere events of its kind in the world. This year's meeting is scheduled Sept. 30-Oct. 2. For more information, see RPMI's Web site at http://rpmi.marc.gatech.edu/.

Research Horizons
Georgia Institute of Technology

INTERACTIVE MEDIA TECHNOLOGY

Artifacts Become Life

Georgia Tech's Interactive Media Technology Center creates "hands-on" virtual museum visits

By Amanda Crowell

IN THE HUSHED GALLERIES of the Michael C. Carlos Museum of Emory University , visitors can do more than just gaze passively at ancient artifacts and works of art.

Through the "hands-on" capabilities of multimedia technology, they can reconstruct a fragmented clay pot, draw their own masterpieces and play a tune on a 1,800-year-old, bat-shaped flute.

It's all done on computer kiosks, thanks to an innovative program developed by the museum and Georgia Tech's Interactive Media Technology Center (IMTC).

photo by Stanley Leary

Among the kiosk's offerings is an interactive map that allows users to track a 1920s archaeological expedition. (200-dpi JPEG version - 210k)

"People go to places like SCITREK (Atlanta's Science & Technology Museum), and everything's hands- on," says Ed Price, IMTC's assistant director and director of the Carlos Museum project. "You come here and you can look, but you can't touch anything. In a way, we're letting people touch the objects now -- look at them, turn them around, find out more about them."

Elizabeth Hornor, who coordinates educational programs for the Carlos Museum, agrees.

"It's a museum educator's dream to be able to present information in this way," she says. "It makes objects in the museums seem more alive."

To make sure visitors connect what they see on the computer with the real objects themselves, the kiosks feature a holistic "virtual museum" approach that closely matches the design and layout of the real museum. Using touchscreen computers, visitors can access video and audio clips, pictures, computer animation, flythroughs and manipulable 3-D models.

The kiosks are located in small rooms off the galleries, and all six major collections are represented: African, Classical, Ancient American, Egyptian, Near Eastern and Drawings.

Although the Carlos Museum is not alone in exploiting this emerging technology, it has been on the leading edge, thanks to the vision of former director Maxwell L. Anderson and a 1992 grant from the prestigious Lila Wallace-Reader's Digest Museum Collections Accessibility Initiative. When the museum opened in a new building in 1993, it was the first art museum to have incorporated multimedia technology into its architectural design. It also was one of the first to set up a World Wide Web site.

"I think their vision was there early on and very appropriate for what could happen with technology," says Katherine Jones-Garmil, program director of the Museum Computer Network, a nonprofit group that supports the use of computer technology in museums.

Since the early 1990s, more and more museums have turned to multimedia projects like kiosks and Web sites to enhance their galleries. Currently, the Museum Computer Network has Web links to over 1,000 museums worldwide.

photo by Stanley Leary

Visitors can use the kiosks to "play" this 1,800-year-old, bat-shaped flute. (200-dpi JPEG version - 283k)

Although the group hasn't begun tracking kiosks, Jones-Garmil says most of the ones she's seen are tied to specific collections or events, while the Carlos Museum kiosks are uniquely comprehensive. Although they feature only a few objects from each collection, they offer rich detail about the pieces and behind-the-scenes information on how museum staff members -- like conservators and curators -- bring the art to the public.

"I thought that was an interesting way to look at it," says Jones-Garmil, who also is assistant director of information services and technology for the Peabody Museum of Archaeology and Ethnology at Harvard University. "It's not just focused on the collection, but on the working of the museum itself."

To achieve this result, the museum's curatorial and educational staffs developed the kiosks together, rather than handing the project off to a technology department to do in isolation, says Anderson, who now directs the Art Gallery of Ontario and serves as liaison for information technology for the Association of Art Museum Directors.

"We were always pushing the envelope and thinking about how network technology might ameliorate the visit for the average museum-goer," he says. "It was critical then and it is today to draw visitors into the multiple lives of works of art -- from the artist's studio to the conservation laboratory to the wall of a gallery."

From the Olympics to the Carlos

Georgia Tech's involvement in the Carlos Museum project began in late 1993 after the Interactive Media Technology Center's mock-up designs convinced museum officials that the best talent for their money was just across town.

The IMTC was formed in 1989 as the Multimedia Technology Laboratory to help bring the 1996 Summer Olympic Games to Atlanta. Since then, IMTC's faculty and students have worked on a variety of projects combining technology with the arts, education, sports, medicine and marketing.

Specific projects include an ongoing collaboration with the Atlanta Ballet to integrate art with advanced motion-capture, computer animation and projection technologies; development of surgical simulators to train doctors on new medical procedures; and design of the Georgia Resource Center, a multimedia presentation system designed to attract new industry to the state.

For the Carlos Museum project, IMTC's staff learned to coordinate a variety of multimedia technologies, including audio, video, 3-D animation, computer art and interactive authoring. More than a dozen people worked on the project, including IMTC students from Georgia State University and Atlanta College of Art.

photo by Stanley Leary

Ed Price, Brian Jones and Tiffany O'Quinn of the Interactive Media Technology Center examine a section of Carlos kiosk work in detail.

"While other projects generally require specific talents, the Carlos Museum project incorporated a wide range of multimedia technologies and allowed the majority of the lab to participate," says Brian Jones, an IMTC research engineer.

The finished product was installed in 1996 -- the first section in June and the final one in November. The long-term nature of the project meant researchers had to anticipate where computer technology was going.

"We realized that if the project didn't incorporate future technologies, the novelty of the kiosk might be lost," Jones says. "Therefore, such promised technologies as QuickTime VR were designed into the project's future."

Hornor praises IMTC's efforts, saying, "There has never been a single thing that we've wanted to do that, technologically, they couldn't figure out some way to do."

Others apparently agree. Earlier this year, officials at Atlanta's High Museum of Art hired Price and Tiffany O'Quinn, who served as IMTC's art director for the Carlos Museum project, to oversee a redesign of the interactive portion of their "See For Yourself" Visual Arts Learning Space. They also hired Anne Russell King, who served as the Carlos Museum's scriptwriter and consulting curator.

"When it came to finding an organization that we could work with and that understood museums, Georgia Tech immediately came to mind," says Kathleen Peckham of the High Museum's department of education. "They've been very good about knowing what they can do on their own and when they need to stop and check in with us."

The Visual Arts Learning Space introduces visitors to the four basic elements of art -- color, line, composition and light -- through interactive computer kiosks placed in the center of the room and representative art pieces on the walls. The kiosks offer a variety of multimedia features accessible through touchscreens.

"We really wanted to make this space very fun and interactive and hands-on and immediately engaging to people," Peckham says. "We knew that technology was one way to do that."

Exploring the Carlos Via Kiosk

Whereas the High Museum kiosks provide more introductory information, the Carlos Museum program is designed to give visitors far more detail -- including historical and cultural context and art historical interpretation -- than the small label cards posted with the art itself.

For example, visitors to the Carlos Museum's Classical section learn that one particular vase is the only surviving piece of ancient Greek art depicting the story of Melanippe, a lost play by Euripides. They can hear Melanippe's story and how it relates to the figures on the vase, and they can learn more about Greek mythology.

This section is narrated by Rush Rehm of Stanford University's drama department, and some of the scenes feature Rehm sitting atop Georgia's Mount Arabia, which resembles the Greek countryside -- a subtle attention to detail found throughout the kiosks.

Other features among the kiosks' several hours of information include:

- Detailed X-rays (called CT scans) of different parts of a 2,000-year-old Egyptian mummy, as well as scans of a living human body for comparison.

- An interactive map where visitors can track the 1920s archaeological expedition to the Near East led by former Emory University professor William Arthur Shelton. By touching different cities on the map, they can access Shelton's journals, sketches and photographs, which had been locked in archives for years.

- A picture of an ancient jaguar effigy vessel from Costa Rica that dissolves into video of a real jaguar. Visitors even hear the rattling sound of small clay balls hidden inside the vessel, which simulate a jaguar's snarl when the vessel is shaken.

- Video of Mexican musicologist Antonia Zepeda playing an ancient bat-shaped flute from Costa Rica, as well as an interactive function that allows visitors to "play" the flute themselves.

- A "magnifying glass" function in the Drawings section that lets visitors enlarge individual portions of a picture and a game that allows them to "draw" right on the computer screen. This section gives visitors access to delicate artwork only displayed every three years.

- General information on museum programs like tours, facilities rental and the cafe. The kiosk presentation opens with a guided tour by a "virtual guard," but will soon change to feature video of new director Anthony G. Hirschel, who joined the staff in February.

Visitors appear to love the kiosks so far, with many writing positive messages in comment books scattered throughout the museum. Molly Hill, a business communications instructor at Georgia State University and Emory University and a recent visitor to the Carlos Museum, cited presentations on ceremonial masks and the African water deity Mami Wata as favorites.

"I was surprised at the accuracy and the depth of the information," says Hill, who is working on a doctorate in English, focusing on primitivism and goddess imagery in 20th Century American literature. "I thought it would be more oriented toward children. While the format is ideal for children, the information is very thorough."

Hill also believes the kiosks should be linked to the Web, to "give children who don't have an opportunity to go to museums the same information as those who do."

photo by Stanley Leary

This [gold wreath] fashioned of sprigs of olive leaves and olives may resemble a victor's award in ancient Greek athletic games. [(200-dpi JPEG version - 348k)]

Currently, visitors to the Carlos Museum and IMTC Web sites can access video clips and [play the bat flute]. Future plans include creating a searchable, Web-linked database of the museum's 15,000 objects and producing a DVD-ROM (which offers far more storage capacity than a CD-ROM) of the kiosks.

Anderson calls Web sites a crucial element in how museums should use multimedia technology in the future. He also notes that the Carlos Museum site was included on a list of outstanding Web sites in the February 1997 issue of Museum News magazine.

"I think one of the bigger questions with multimedia technology is how to ensure that it is available prior to the visit and after the visit to a collection," says Anderson. "The Web site should work hand-in- glove with the kiosks."

As for the future of multimedia technology in art museums, Ned Rifkin, the Nancy and Holcombe J. Green Jr. director of the High Museum of Art, calls it "just another tool in the tool box for people involved with educating through visual culture.

"I think this is a critical moment for museums to understand and embrace this technology," he says. "It is, to many people, very intimidating. Many of us who are leaders in this field of art museums are not necessarily conversant or fluent in the technology that our own children are mastering. But most of us, I think, are getting with the program and really understanding the power of the mechanism and the technology to really advance our missions."

Further information is available from Ed Price, Interactive Media Technology Center, Georgia Institute of Technology, Atlanta, GA 30332-0130; or Elizabeth Hornor, Michael C. Carlos Museum, Emory University, Atlanta, GA 30322-1950. (Telephone: 404/894-3547, Price; 404/727-6118, Hornor) (E-mail: ed@skipper.oip.gatech.edu, ehornor@emory.edu)

Additional information about the Michael C. Carlos Museum of Emory University is available on the World Wide Web, at http://www.emory.edu/CARLOS/. Video and virtual reality images from the program can be found at http://www.emory.edu/CARLOS/aaa.html and at the IMTC Carlos Museum Web page, http://www.oip.gatech.edu/imtcproj/mccm.html.

Research Horizons

Georgia Institute of Technology

On-Line Fabric Inspection

New system could cut costs, reduce off-quality production

An automated on-line inspection system that uses advanced vision technology, neural networks, fuzzy logic and wavelets to quickly identify defects in fabric has been successfully tested at an Alabama textile manufacturing plant.

The system could cut inspection costs and reduce the amount of off-quality production.

photo by Stanley Leary

Industry representative Bart

Developed by researchers at the Georgia Institute of Technology, the equipment could ultimately be the basis for an integrated electronic feedback system that would monitor and control quality processes throughout the manufacturing cycle.

Appalachian Electronics, Inc., a West Virginia maker of textile equipment, has licensed the technology and expects to turn the prototype into a commercial system that can be retrofitted to existing looms and installed in new machines.

"Quality is extremely important to our industry," says Bart Krulic, sales representative for the Industrial Fabrics Group of Johnston Industries, which tested the system at its Phenix City, Ala., factory. "The potential of this system is tremendous because it would be a low-cost measure that could be added to looms to improve quality."

Krulic says the weaving sensor is a low-cost way to enhance quality in the textile industry. (200-dpi JPEG version - 150k)

Developed with support from the National Textile Center University Research Consortium, the system has operated on a loom at the company's Southern Phenix plant since July 1996. Krulic says the system has performed well, and he believes its use would give the company a strong competitive advantage by ensuring consistent, error-free inspection.

"This is a good opportunity to take our quality processes to the next stage," he adds. "You could reduce the labor and human error and improve the quality, making a company more competitive."

The new Georgia Tech system automatically identifies defects as the fabric comes off the loom, allowing immediate correction of process problems.

"This system allows you to prevent the production of defects by correcting problems more quickly on the machine," explains Dr. Lew Dorrity, a professor in the School of Textile and Fiber Engineering.

The system uses high-speed cameras to scan fabric. A computer analyzes the information using techniques that identify abnormal patterns.

The inspection system also can provide information that will help companies pinpoint factors that cause defects, as well as provide a record of weaving quality that manufacturers could use to optimize fabric use.

Adds Dr. George Vachtsevanos, a professor in the School of Electrical and Computer Engineering, "The software integrates learning and optimization tools that avoid false alarms and improve recognition accuracy."

Further information is available from Dr. Lew Dorrity, School of Textile and Fiber Engineering, Georgia Institute of Technology, Atlanta, GA 30332-0295; or Dr. George Vachtsevanos, School of Electrical and Computer Engineering, Georgia Institute of Technology, Atlanta, GA 30332-0250 (Telephone: 404/894-9076, Dorrity; 404/894-6252, Vachtsevanos) (E-mail: lew.dorrity@textiles.gatech.edu; george.vachtsevanos@ece.gatech.edu). Information also available from Bart Krulic, sales representative for the Industrial Fabrics Group of Johnston Industries (Telephone: 334/768-1075) (FAX: (334/768-1148).

Low-Cost Multichip Module Manufacturing

New class of polymer packaging materials in development

A new class of packaging materials derived from polymers of cyclic olefins is being developed by Georgia Tech researchers.

According to Drs. Paul Kohl and Sue Ann Bidstrup of the School of Chemical Engineering, the unique properties of these polymers are characterized by:

- Tg (glass transition temperature) greater than 350 degrees Celsius;
- dielectric constant less than 2.4 to 2.6;
- low moisture absorption of 0.1%; and
- good ductility.

Kohl leads the low-cost MCM research area of Tech's Packaging Research Center (PRC). Bidstrup and PRC graduate students conducted the research.

"These materials have been modified to have excellent adhesion to commonly used materials such as silica and aluminum," Kohl says. "They also fuse well with copper and metals such as gold and silver."

Further, he notes that these polymers adhere even in the absence of an adhesion promoter or adhesion layer such as titanium, tantalum or chromium. They also remain as adherent films even after being boiled for two hours.

"These materials are expected to demonstrate utility in both semiconductors and packaging by offering superior performance over traditional materials while reducing the device manufacturing cost," Kohl says.

This work is sponsored by B.F. Goodrich.

The PRC, the largest and most comprehensive packaging center in the United States, is funded by the National Science Foundation, the Georgia Research Alliance and 22 industry sponsors. The center's goal is to develop the next generation of semiconductor packaging technologies, thereby enabling development of more competitive electronic products and systems.

Further information is available from Dr. Paul Kohl or Dr. Sue Ann Bidstrup, School of Chemical Engineering, Georgia Institute of Technology, Atlanta, GA 30332-0100. (Telephone: 404/894-2893, Kohl; 404/894-2872, Bidstrup) (E-mail: paul.kohl@che.gatech.edu, sue.allen@che.gatech.edu)

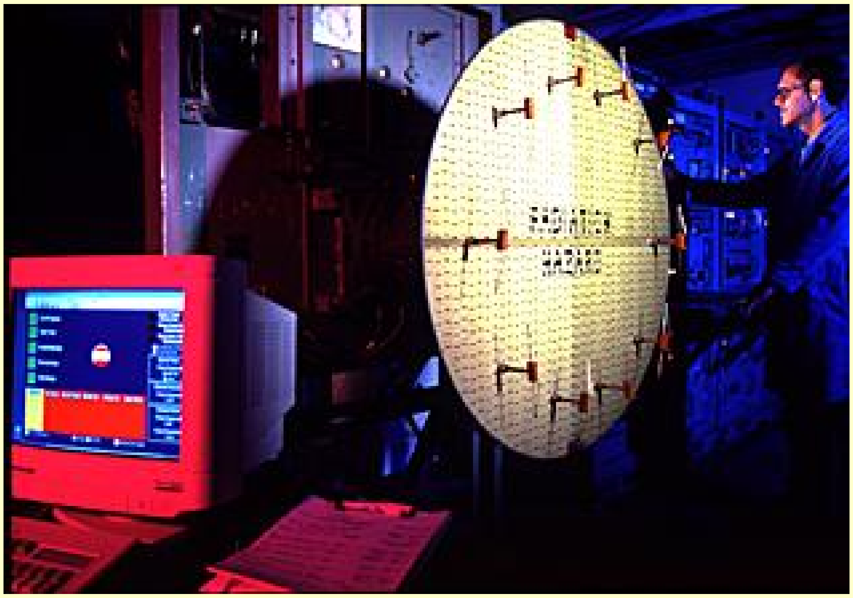
Technology Insertion: Extending the Life of Military Electronics Systems

Properly integrating new technology into older systems can keep them running longer

Because military electronics systems are remaining in service for longer and longer periods, they must evolve to meet new threats, yet remain reliable and affordable.

In many cases, these sometimes conflicting requirements can be satisfied with resourceful insertion of technology to alleviate obsolescence, increase reliability, lower costs and improve performance.

photo by Stanley Leary



A GTRI researcher uses an automated test bed to cycle test an F-15 antenna cable wrap. (200-dpi JPEG version - 227k)

The Georgia Tech Research Institute (GTRI) develops cost-effective, innovative and reliable engineering solutions for extending the life of military electronics systems. GTRI develops, implements and field upgrades systems.

Capabilities range from studies evaluating optimum technology insertion strategies to the development and manufacturing support of flight-qualified hardware and software.

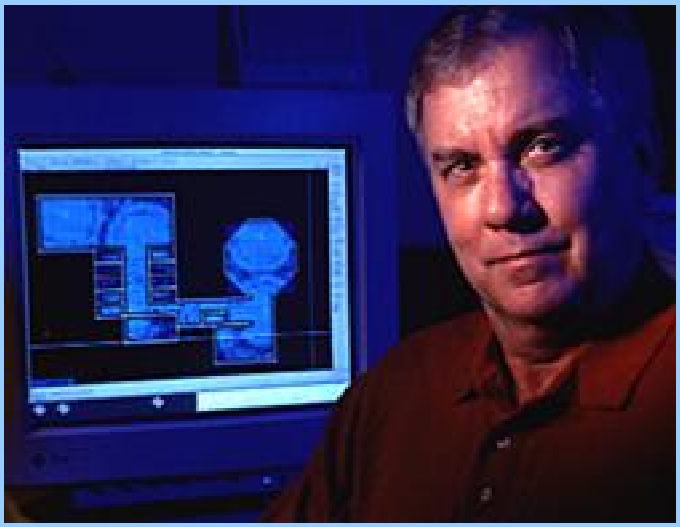
Further information and a brochure are available from Terry Tibbitts, Electronic Systems Laboratory, or Dr. Eric Sjoberg, Sensors and Electromagnetic Applications Laboratory, Georgia Tech Research Institute, Georgia Institute of Technology, Atlanta, GA 30332-0829. (Telephone: 404/894-7121, Tibbitts; 770/528-7779, Sjoberg) (E-mail: terry.tibbitts@gtri.gatech.edu, eric.sjoberg@gtri.gatech.edu

Information Technology Challenges

Broad-based GTRI research offers solutions to many problems

Information technology research programs at GTRI offer solutions to complex problems involving information processing, storage, representation and exchange.

photo by Stanley Leary



GTRI's information technology reserach achievements include the Cell Engineering Tool, which predicts how radio waves transmit and are reflected within buildings.

Research areas include database technology, broadband communications, Internet technologies, network security, mapping/ geographical information systems, network applications, modeling and simulation, and enterprise information systems.

Individual projects range from small-scale and prototype studies to full-scale system design, implementation applications in diverse domains such as business, government, education, law enforcement, logistics, transportation and defense.

Laboratory research also focuses on telecommunications and networking areas, including wireless access systems, broadband communications, compressed video networking techniques, satellite communications applications, and military communications technology. Providing new multimedia services over cable networks is also a major focus area.

Further information and a brochure are available from Randolph Case, Information Technology and Telecommunications Laboratory, Georgia Tech Research Institute, Georgia Institute of Technology, Atlanta, GA 30332-0832. (Telephone: 404/894-3456) (E-mail: randolph.case@gtri.gatech.edu)

H2Fuel Bus Joins Augusta Transit Operations

Vehicle offers near-zero emissions

In the next decades, the world's supply of fossil fuels will decrease while concerns about air pollution and global warming will continue to grow.

An alternative is hydrogen fuels, which are safe, clean-burning and renewable.

photo by Jane McCoggins, Southeastern Technology Center

In April, the H2Fuel Bus, developed by a coalition of academic, industry and government partners -- including GTRI -- was presented to Augusta-Richmond County Public Transit.

The bus, a prototype hydrogen-fueled, electric-powered vehicle with a metal hydride fuel storage system, will become part of regular transit operations for one year.

"The objective in this program is to prove that the metal hydride storage tanks can be safe and convenient, and that they can be user-friendly in commercial, utility vehicle operation," says Charles Stancil, a senior research engineer in GTRI's Aerospace Sciences and Transportation Laboratory.

With near-zero emissions, Stancil calls the bus "a key component to actions addressing air-quality issues."

GTRI researchers integrated the 33-foot bus's hybrid system, which consists of an internal combustion engine, electrical generator and metal hydride fuel storage system.

The U.S. Department of Energy (DOE) and Augusta-Richmond County Public Transit are primary sponsors.

The metal hydride system was developed at DOE's Savannah River Site and provided by Westinghouse Savannah River Co. (WSRC).

Other major partners include the Southeastern Technology Center, Hydrogen Components, Inc., the Education, Research and Development Association of Georgia Universities, and Blue Bird Body Co.

Supporters say hydrogen, the universe's most abundant element, is an ideal replacement for fossil fuels. It could be converted from water through renewable processes like biomass (burning plants for fuel), solar or wind power.

The bus's fuel storage system uses metal hydrides, which absorb and retain hydrogen in a solid form when cooled, then release it slowly when heated. Hydrogen in this solid form is much safer than when it is a compressed gas or liquid.

"The transit experience will provide critical data for the commercialization of hydrogen vehicles," says Dr. William A. Summers of WSRC. "Operating data will provide a measurement of the performance, reliability and maintainability of the various system components, primarily the hydrogen engine and the metal hydride storage system."

Other industrial participants include Energy Research and Generation, Inc.; Power Technology Southeast, Inc.; Air Products and Chemicals, Inc.; Air Liquide America Corp.; and Northrop Grumman Corp.

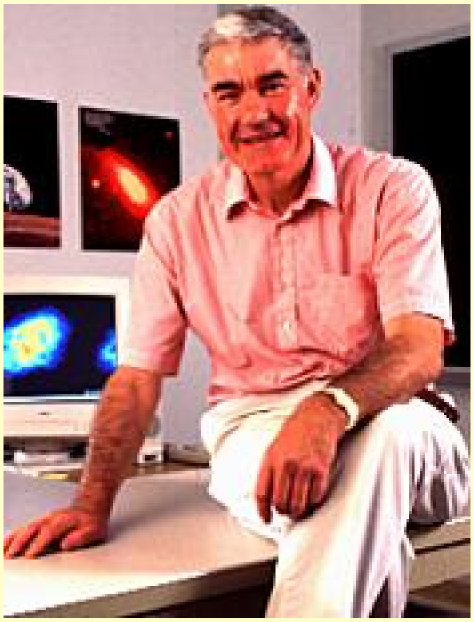
Further information is available from Charles Stancil, Aerospace Sciences and Transportation Laboratory, Georgia Tech Research Institute, Georgia Institute of Technology, Atlanta, GA 30332-0844; or Dr. Earl J. Claire, Southeastern Technology Center. (Telephone: 770/528-3224, Stancil; or 706/722-3490, Claire) (E-mail: charles.stancil@gtri.gatech.edu, EJCLAIRE@aol.com)

Flannery Elected to Royal Irish Academy

Dr. M. Raymond Flannery, Regents' Professor and the 1995 Distinguished Professor at Georgia Tech, recently was elected an honorary member of the Royal Irish Academy of Science.

Flannery is one of the leading theoretical physicists researching recombination processes involving electrons, ions, atoms and molecules and the theory of atomic and molecular processes. Recombination processes are basic to the earth and planetary atmospheres, astrophysics and laboratory plasmas.

photo by Stanley Leary



A leading theoretical physicist, Dr. Raymond Flannery has been elected an honorary member of the Royal Irish Academy.

The Academy was founded in 1785 for "promoting the study of science, polite literature and antiquities." Honorary memberships in the Academy are limited to 30 members within the science section, and at least half of the honorary memberships must be scientists living outside of Ireland.

Currently included are Sir Michael Atiyah (Oxford), Francis Crick (Cambridge), Alexander Dalgarno (Harvard), Lord Flowers (London), Izrail Gelfand (Moscow), Gerhard Herzberg (Ottawa), Dorothy Hodgkin (Oxford), Sir Fred Hoyle (Cambridge) and Sir Andrew Huxley (London).

"Even being listed on the same page with, and being part of, such a distinguished and eminent body of scientists is quite a mind-numbing and humbling experience," Flannery says.

"I am indeed indebted to the Royal Irish Academy for this rare and singular honor. I cannot think of any award in this world which gives me the most intense and personal satisfaction. To be so recognized by my native Ireland is somewhat overwhelming. But the real satisfaction ultimately lies in the achievement, and not just in the reception."

Dr. Flannery also is a Fellow of The American Physical Society and The Institute of Physics (London).

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

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