MINNESOTA
TECHNOLOG
November 1995 University of Minnesota Volume 76 Number 1

environmental engineering

Dear Readers,

Seventy-five years ago this fall the *Minnesota Techno-log*, as it was then known, began as a monthly publication by the students of the College of Engineering and Architecture and the School of Chemistry. The magazine included updates on the latest technological and engineering innovations as well as a smattering of gossip on current and past students. The pages of our magazine have seen a lot of changes since the inaugural issue, but our basic mission has always remained constant—to provide students a forum to discuss science- and technology-related issues at the University of Minnesota.

As we begin the 1995-96 academic year, look for new changes in the continually evolving *Minnesota Technolog*. As a result of our last readership poll, we're strengthening our focus on the University of Minnesota's scientific and technical community. Beginning with this issue, we're also including a review of past stories and articles from our archives. We're adding a section summarizing the news from other engineering college magazines. In future issues we'll be inserting an entertainment corner in addition to a survey of the latest news in the Institute of Technology. Additionally, the *Minnesota Technolog* is merging onto the Information Superhighway this year; in the next several weeks we'll begin publishing on the World Wide Web for all of you electronic travelers. Stay tuned for further details . . .

Despite the changes, the *Minnesota Technolog* will retain much of last year's character. We're continuing with Chris Lee's design and layout of the magazine, and Joe Scrimshaw's cartoons will be staple reading material. Feature articles will continue to highlight research and educational news here in the Institute of Technology. And as usual, our traditional sci-fi issue in Spring quarter will be continued.

We have ambitious plans here at the *Minnesota Technolog* for the upcoming year, but we need your help. We're looking for savvy writers and editors, talented graphic artists, and HTML-literate computer gurus. If you possess these skills, please come on down and join the staff!

—Gregory Lauer
Editor-in-Chief, *Minnesota Technolog*

MINNESOTA TECHNOLOG

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Minnesota Technolog welcomes freelance submissions, both articles and illustrations. If you've got a great idea for a story and would like to work with our editorial staff in developing it, call 624-9816 or stop by our office at 5 Lind Hall.

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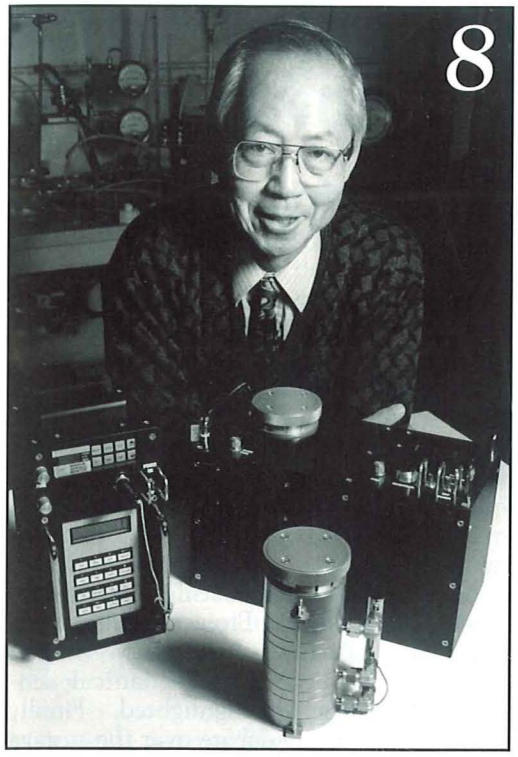

About The Cover

Dr. Michael Semmens examines hollow-fiber membrane tubes used in pure oxygen aeration systems. The cover story begins on page 11.

Cover photograph and contents page photos by Joshua Zuckerman

EDITORIAL

by Gregory Lauer

Environmental Engineering: An Ethical Responsibility

By awarding the Nobel Prize to three researchers studying the impact of industrial chemicals on the Earth's protective ozone shield, the Royal Swedish Academy of Sciences recently brought issues of environmental stewardship into the international spotlight in addition to recognizing outstanding scientific achievement. The efforts of Crutzen, Molina, and Rowland led to the adoption of a global phase-out of chlorofluorocarbons in 1992. The attention showered on these researchers is a sure sign the environment is moving up on the list of global priorities.

Unfortunately, however, much damage has already been done. The morning newspapers and the evening news broadcasts repeatedly highlight stories of environmental decay and neglect. From old-growth logging practices in the Pacific Northwest to the toxic-laced Love Canal in New Jersey, from the Exxon Valdez oil spill in Alaska to declining reservoir levels in the Oklahoma Panhandle, we are bombarded with reports of environmental mismanagement on a daily basis. Globally the problems are just as bad. To cite just a few cases, China's Yangtze experienced its worst flooding in years recently, huge swaths of Brazil's rainforests are being clear-cut, and the Aral Sea in the former Soviet Union is draining at an alarming rate.

Elected representatives in the House and the Senate are addressing these issues by formulating environmental management policies. Seemingly every Beltway insider and political activist has a prepared press statement on eco-related issues. Motivated by the Republican's Contract on America, Congress is madly preparing to slash the budget of the Environmental Protection Agency and deregulate the industries of many historic polluters. At the same time, celebrities, conservationists, and concerned citizens are performing cameos for groups such as the Sierra Club and Greenpeace opposing the new measures.

Lost in this cacophony of debate, however, are the voices of the engineer and the scientist. A meticulously prepared environmental impact statement, extensively documented with footnotes and references, is no match compared to the headline-grabbing abilities of Barbra Streisand or Al Gore's cute little book, *Earth in the Balance: Ecology and the Human Spirit*. The debate over environmental policy and regulation nowadays is on a Slim-Fast diet of thirty-second sound bites, vitriolic ad campaigns, and distorted information. Unbiased and objective scientific reason is noticeably absent in discussion.

Compounding matters, Americans perceive scientists and engineers to be a morally ambivalent bunch at best. The popular stereotype of an engineer boasting a pocket protector and sporting a slide rule isn't too compatible with the image of a concerned social thinker. Pop culture reinforces the notion that scientists are socially inept and ethically irresponsible. From Steven Spielberg's *Jurassic Park* to *Mary Shelley's Frankenstein*, audiences are continually reminded of the dangers of science and technology. As engineers and scientists we're put on the defensive as being hell-bent on ruining the world, not intent on preserving it.

It is important to combat these perceived images and stereotypes. Although there is no denying the mistakes made in the past, engineering today must make strides to correct the errors of previous generations. By and large, it is. This issue of the *Minnesota Technolog* focuses on environmental engineering here at the University of Minnesota. The efforts of Dr. Daryl Dwyer and Dr. Michael Semmens, researchers studying methods of treating wastewater, are profiled. Projects underway at the Particle Laboratory in the Department of Mechanical Engineering are highlighted. Finally the burning debate over the storage of high-level nuclear waste is explored.

In *Broca's Brain*, Carl Sagan explores the ethical responsibilities of scientists and researchers. Several of his essays attempt to resolve the following question: is knowledge, in and of itself, amoral? In other words, can the inventor be separated from her invention or can a researcher be separated from his research? Ultimately as engineers and scientists we have a responsibility to be caretakers of technology. We are obligated to step forward and insure that our work is environmentally correct in addition to satisfying traditional criteria such as cost, efficiency, safety, and reliability.

As a small child, I remember Mom reading Dr. Seuss's call for environmental awareness, *The Lorax*. Amid the colorful illustrations and the simple text, the message was clear —we are the stewards of this planet, not the owners. As engineers and scientists, we are both qualified and obligated to keep civilization on the path of environmental correctness and steer clear of an apocalyptic Doomsday. T

News from Other Schools

When Brandon Lee, the star of *The Crow*, was shot and killed accidentally in March of 1993 on the set of the movie, the director of the film, Alex Proyas, decided to complete the film without Lee. Even after screenwriters had modified the script, Lee's presence was still required. The filmmakers hired Dream Quest Images, a motion-picture, television, and commercial special-effects company. Electronic imaging technicians were charged with the task of blending existing footage of Lee into new scenes. They achieved this by digitally tracing Lee and blacking out the background. They then used the computer to alter Lee's face, forming a composite of that image and the one of Lee's body. The result blended so well into the scenes that audiences couldn't tell the difference between live footage of Lee and scenes that included his digitized image.

—*Wisconsin Engineer*, September 1995

The Denver International Airport contains several improvements over existing airports. Passengers have two options for checking in luggage: a curbside system or an indoor ticketing process. Both are designed to minimize congestion at the airport, which handles a high volume of traffic each day. The number of parking spaces is 15,000, nearly twice that of Stapleton, which only has 8,500. The atrium located in the main terminal contains 216,000 square feet of space and offers a picturesque view of the Rocky Mountains. Security has also been upgraded to include checkpoints on the atrium level and again before entry to the concourses. The gates at the airport are wider than those at Stapleton in order to accommodate wide-body aircraft used for international travel. The multi-lingual customs agents will be able to process 600 passengers per hour, and signs written in several languages direct international passengers to baggage claim areas and connecting flights.

The construction of the terminal required one year of foundation and tunnel work, two years of construction, and six months of tenant finishing. When the automated baggage system is free of bugs, it will handle 42,000 pieces of luggage per hour through the use of 21 Destination Coded Vehicles, which each carry one piece of baggage and move through a 21-mile underground track at 19 miles per hour. Opening day was set for May 15, 1995.

—*Colorado Engineer*, Spring 1994

UW-Platteville has constructed a Distance Education Room, complete with cameras, monitors, and audio equipment, whose purpose is to simultaneously instruct students from Platteville and UW-Stout. The instructor conducts a class of up to 42 students. Microphones are located near each student and the instructor has a wireless microphone. Students from Stout and Platteville use the microphones to ask questions, but because they are always on, they must be careful not to talk or shuffle papers. The course is taught like all others, the only difference being that students at Stout can only see what is shown through the camera. For this reason, instructors have become accustomed to slowly writing notes on notebook-sized paper.

Other UW schools, including Eau Claire and Madison, have set up similar programs, and other branches of the university are in the process of completing distance education rooms. In the future, the room may be used for video conferences, company interviews, and technical electives.

—*Geode*
(University of Wisconsin-Platteville), April 1995

Most students don't bother to look at their electric bills, but it can pay to examine them closely. The meter uses an electromagnet to measure energy use, which is conveyed by the rotation of the disc on the inside of the meter. The disc then rotates the dials to indicate the amount of energy used. An increase in current flow results in a faster rotation of the disc and a higher electric bill. What should be measured is the amount of current originating in your house or apartment, but the electromagnet can be influenced by outside sources. An air conditioner with two breakers, one seemingly hidden, can contribute to unintended energy use when only one is turned off.

In Kansas, customers have a choice of two meters: standard or demand. A flat rate is charged to those with standard meters; the rates vary with demand meters. The better economical choice depends on energy consumption. Apartment residents are usually charged the demand rate, so the standard rate should be requested if energy use is high enough to warrant the change.

—*Kansas State Engineer*, Spring 1995

Blasts from *Technolog's* Past

MINNESOTA TECHNO-LOG

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Published monthly during the school year by the students of The College of Engineering and Architecture and the School of Chemistry University of Minnesota

Cover of the December 1920 issue (Vol. 1, No. 2)

Athletic Engineers?

It is not the purpose of this article to tell what Minnesota did in football this year, but rather to tell what the engineers did in Minnesota football. By far the most powerful man on the Gopher line this year was Festus (Pat) Tierney. Pat was the only man picked by Coach Eckersall to represent Minnesota on the mythical All-Conference team. This season marked the completion of the third year of varsity football for Fred Enke, a Senior Civil. His great work at center in the Wisconsin game will long be remembered. John Gillian, substituting at right guard, showed himself as a comer this fall and will bear watching next season. Too much credit cannot be given these men for carrying engineering courses and going out for Varsity athletics.

—December 1920

Communication Crisis

It is an Engineer's business to spend other people's money. At best that is a delicate matter. At worst, it is almost impossible to satisfy many of the dyed-in-the-wool mugwumps that they are getting their money's worth. It is an Engineer's business to know what other men need in their business equipment, what corporations need for the conducting of their business, and what towns and cities must have for sanitary and aesthetic reasons. It is one thing to know what is correct, essential, and useful, but it is another to be able to go into a directors' meeting, a session of the town council, or a caucus and sell that thing to the people who are placing the order. Cities as well as small towns all over this part of the world have plenty of monuments to the failure of Engineers to show buyers what was safe and sensible in construction and planning of all kinds.

To judge by the quality of the speeches and discussions staged in recent meetings of the Engineering students, the present generation of Minnesota Engineers is no improvement in this respect. Man after man rises to give voice to opinions which his audience is anxious to hear, but fails to interest them because he drones on and on, repeating himself endlessly, tacking rambling statements together with interminable "and's" and getting nowhere. Daniel Webster said that 'the only way to learn to be an orator is to make a speech every time anybody is damn fool enough to ask you.' Graduate Engineers cannot afford to wait for this trial and error method of learning public speaking. Out of nearly a thousand Engineering students, the number who have elected public speaking this year is twelve. The facts, coupled with the size of the audiences at Engineers' meetings, speak for themselves.

—May 1921

Meddling with Metrics

The postwar period is an excellent time to consider adopting the metric system. This method of measurement is preferable to the English system for several reasons: it is simple, it saves time, it is useful in foreign trade, and it provides the necessary standardization of units.

The metric system is based on units of ten; proportional increases and decreases in the dollar-meter-liter-gram system can be achieved simply by moving the decimal point to the right or left, reducing the time needed for conversions between units. If the United States and

Great Britain, the only two nations in the world currently not using the metric system, would adopt it, no time and effort would have to be expended converting between standards. The confusion created in foreign trade by the existence of multiple systems of measurement could be eliminated by the use of a single standard, the natural choice of which would be the metric system since it is used by virtually every nation.

During wartime, for instance, converting blueprints and specifications from the metric form to the English system caused delays in production. Comparing the systems of Great Britain and the U.S. results in even more difficulties as many fundamental units share the same name but indicate different quantities.

—November 1945

Traditional Four-Year Track Not So Traditional

The Society for the Promotion of Engineering Education (SPEE) recommended broadening the engineering curricula to include courses in the natural and social sciences and the humanities. The goal of this modification is to provide engineers with the human relations background necessary for a more active and effective role in public affairs. SPEE recommended that twenty percent of the undergraduate engineering curriculum be devoted to the humanities and science.

Many universities believe that an expanded liberal education requirement can't be accommodated without either reducing the number of required engineering courses or increasing the length of the engineering program to five years. A committee in the Institute of Technology began studying the feasibility of such a five-year program nearly two years ago. On January 22, 1945, the faculty adopted the five-year curriculum and voted that it be required of all freshman students beginning in September of 1946.

—March 1946

Before the Days of the Information Superhighway

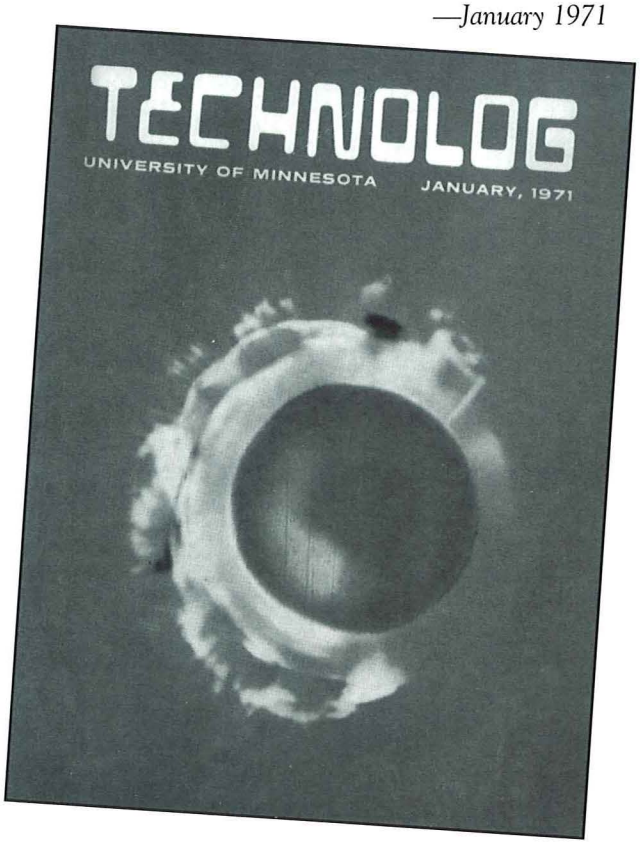
The Hybrid Computer Center serving university students and faculty features a connection of two EAI 680 analog computers and one Control Data Corporation 1700 computer. The interface unit is a two-way system for digital-analog and analog-digital relay using Fortran. University students and faculty members conduct research and data analysis at the center, and state agencies and local industries also use equipment there. One project for private industry allows architects to feed a blueprint into the computer, which stores the data. The graphics terminal, a CDC 274 Digigraphics console, serves as the means for communication. "The complete magnitude of the center's potential is overwhelming."

—December 1970

No Light at the End of the Tunnel

In a wave of futuristic thinking, Dr. Don Yardley of the Department of Civil Engineering proposes underground highways for the Twin Cities area. Criticizing current metropolitan planners as having their heads in a hole in the ground, Yardley envisions a system of transit arteries buried beneath the surface. In the area surrounding Minneapolis and St. Paul lies a deposit of St. Peter Sandstone approximately 150 feet thick. Structurally self-supporting tunnels may easily be excavated from this geological formation, and Yardley confidently asserts, "There aren't any problems that we don't have the technology for." Technical feasibility aside, cost considerations and long-range transit needs will ultimately determine the fate of this pipe dream. Dr. Charles Nelson, the Metropolitan Transit Commission's administrative assistant, is optimistic about the possibility of tunnel travel. Underground highways, he claims, will cut construction costs, eliminate weather worries, and reduce visual blight.

—January 1971



Cover of the January 1971 issue (Vol. 51, No. 4)

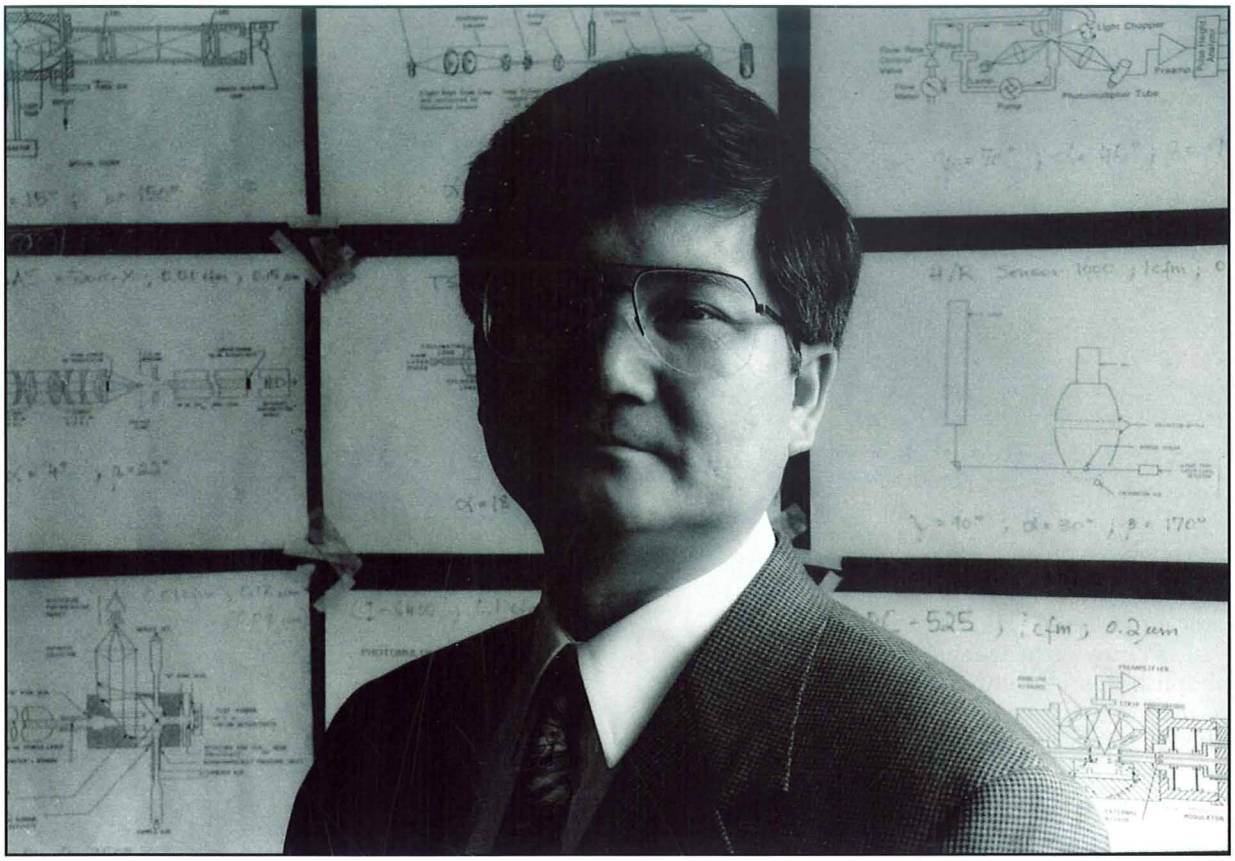
EXPLORING WORLDS WE CAN'T SEE: PARTICLE RESEARCH TECHNOLOGY

Professor Benjamin Liu displays some of the products of the Particle Research Laboratory.

by Steve Gigl

Photographs by Joshua Zuckerman

To most people, environmental engineering means developing non-polluting machines and industrial processes in everything from paper plants to automobile factories. The field, however, also encompasses the creation of special environments useful in industry. The University of Minnesota Particle Technology Laboratory is well-known and has provided industry with solutions to many particle-related problems. "We have research sponsored by both government agencies and industrial consortiums," says Professor and Director David Y. H. Pui. The nine faculty members and nearly 40 graduate students use the laboratory space, clean rooms, wind tunnel, and vacuum facilities to research areas as diverse as hard disk damage and particle beam mass spectrometers.



David Y. H. Pui stands in front of schematics of the instrument package taken aboard the Space Shuttle Columbia.

Each minute, we release around 500,000 particles into the air. Regents' Professor Benjamin Liu, the head of the microcontamination division of the Particle Technology lab, explains: "A person like you or I may release fibers from our clothes, or dust that had been resting on our skin." We see people through a cloud of their own dust, but the particles are too small to see even in such great numbers, so they are not a concern in our daily lives.

In the closed environment of the space shuttles, however, an abundance of such particles could cause problems. On Earth, the individual particles of our dust clouds slowly fall to the ground due to the force of gravity. In orbit aboard the space shuttle, however, the particles float in the air. If enough of the free-floating dust were to get into sensitive equipment carried and used by the astronauts, damage from these particles could threaten the missions. As a result, NASA became concerned that the space shuttles were becoming contaminated.

To help NASA decide if a contamination problem existed, the Particle Technology Lab designed an instrument package to be taken aboard the Space Shuttle Columbia on two separate occasions. Dr. Liu and his associates developed two battery-powered instruments, one to count particles in the air, and one to collect particles for later analysis. The counter uses a laser to detect particles in the air and activates every 15 minutes during a 10-day mission in order to collect 10,000 data points. The sampler consists of 4 stages; each stage corresponds to a specific particle size, and each size corresponds to an area of the body a particle is likely to reach. Anything larger than 100 microns doesn't get past the nasal region and is usually breathed out. Particles in the 10- to 100-micron range will not pass further than the throat area. Some irritation could occur, but it would be quickly cleared. Those particles in the 2.5- to 10-micron range tend to pass into the trachea and bronchi, but no further. Only particles smaller than 2.5 microns make it into the lungs and alveoli, the most sensitive part of the system. Airborne asbestos is dangerous partly because it is in this size range, which allows it to get into the lungs.

Two of the samplers were taken for each mission, so that 24-hour samples could be analyzed on the ground for the first day of each mission and a day halfway through. It was found that there was a far larger concentration of particles in the air than had been assumed when the shuttles were built, so NASA decided to install air filters in the shuttles to keep the atmosphere as clean as possible for the astronauts and the equipment.

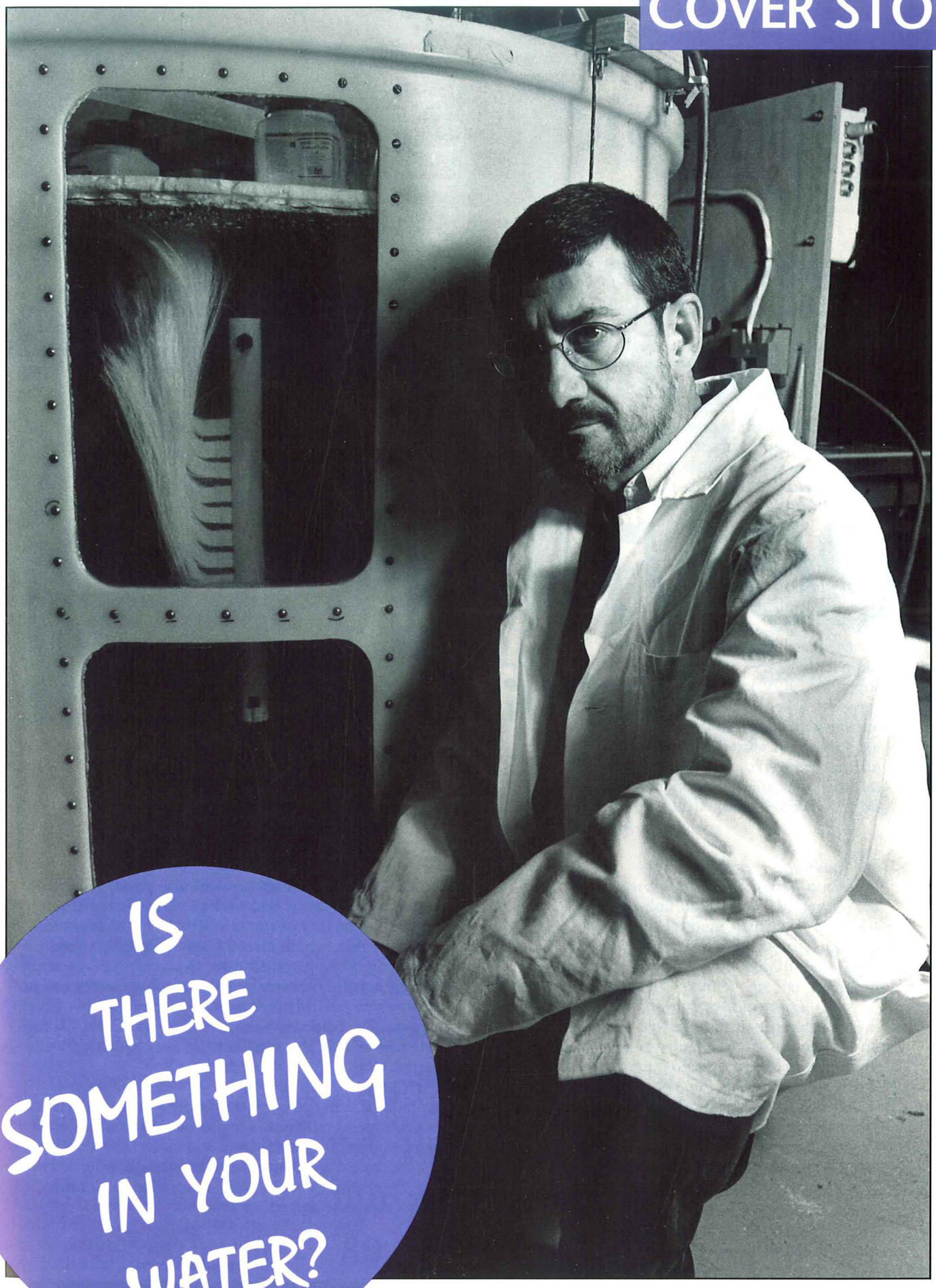
Many industries also need controlled conditions for manufacturing. During the production of semiconductors, it is vital that as few contaminants as possible are allowed into the product. For this reason, these materials are manufactured by machines under "clean room" conditions to avoid flaws and contamination, which would lead to loss of yield. Gases used in the manufacturing of semiconductors must be just as clean as the machines. To accomplish this, a "point-of-use" filter is used in the gas line. This type of filter draws gas in through a membrane from all directions and passes the filtered gas through the line. "When the company that makes this filter first developed it, back in the 1980s, they didn't know how good the filter was . . . so they came to us to do some testing," explains Dr. Liu. To test the filter, a system was developed in which particles of a certain size and material are created and passed through it. A particle counter capable of detecting concentrations of 1 part per billion is used to determine the number of particles the filter allowed to pass through. "So now we're trying to improve the system, to go down to maybe 0.1 parts per billion," says Dr. Liu.

Semiconductors can also be contaminated by particles while being manufactured into actual devices. Silicon dioxide, silicon nitride, aluminum oxide, and tungsten are all potential contaminants in the manufacturing stage for silicon semiconductor devices. One way to detect these contaminants on a silicon wafer is through the use of a wafer surface scanner. Silicon wafers are very reflective, but when a particle rests on the surface of the wafer, it will scatter laser light, indicating its presence to the particles. This equipment, though, must be calibrated to properly detect the 500 to 3000 particles that may inhabit the surface of a 6-inch wafer. Normally, the wafer surface scanner is calibrated with wafers carrying polystyrene latex spheres. Since the real-world contaminating particles are neither spherical nor polystyrene latex, the development of realistic calibration methods for these scanners is desirable. Dr. Liu and his colleagues are working to understand how particles of uniform size but nonuniform shape affect the scattering of the laser light and the detection of particles. To do this, they deposit particles present in the manufacturing of the devices onto silicon wafers and put the wafers through a surface scan. The calibration of the equipment for more realistic particles allows for better detection of contaminants on the wafers. "We are probably the only place in the world that has enough experience to make good calibration wafers," says Dr. Liu, "so they are very interested in us continuing this research."

"They didn't know how good the filter was, so they came to us to do some testing."
—BENJAMIN LIU

The Particle Technology Laboratory in the Department of Mechanical Engineering is dedicated to the study of minute particles and problems they can cause. By making itself a resource for industry, the Particle Technology Lab has helped its students gain experience and knowledge in their fields. T

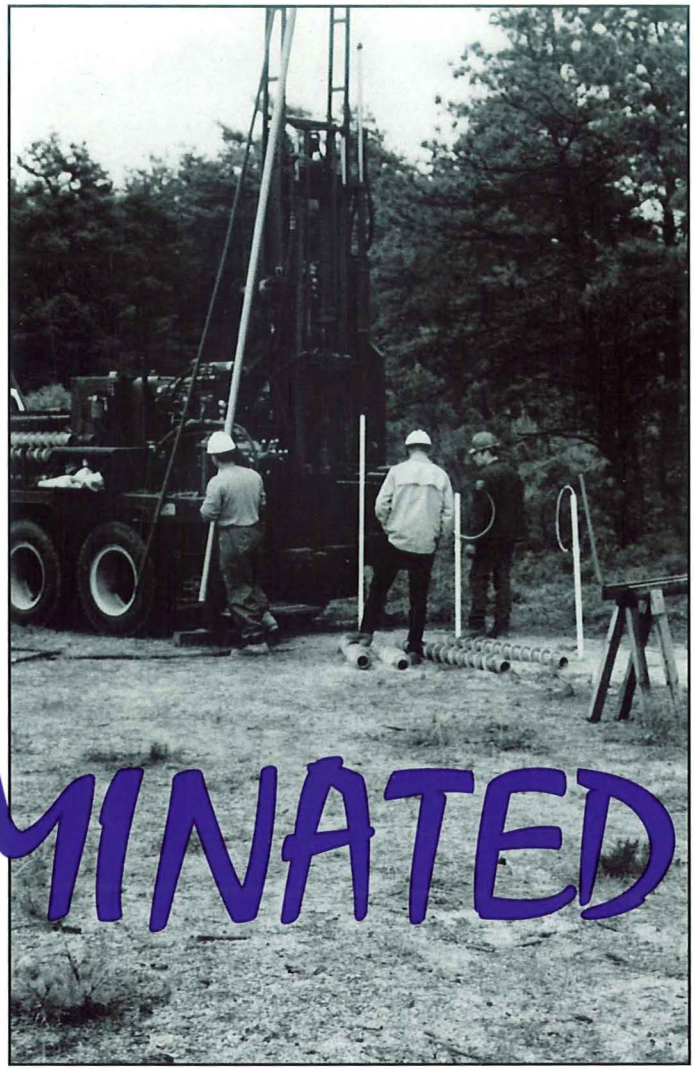
• STEVE GIGL is a member of the 1995-96 IT Board of Publications. He's majoring in undecided studies.



IS THERE SOMETHING IN YOUR WATER?

Dr. Michael Semmens is profiled next to a tank designed to test methods of hollow-fiber membrane aeration. Story begins on the following page. **Photo by Joshua Zuckerman.**

The Physical & Biological Treatment of CONTAMINATED Water

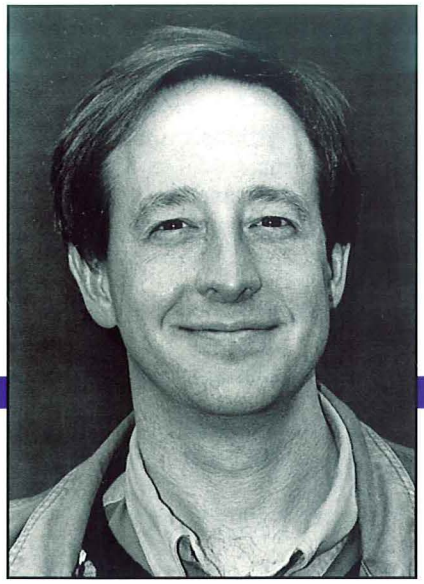


by Laura Walbrink

Because it is essential for survival, the purity of groundwater is a chemical and biological issue that directly affects the quality of human lives. The enactment of the Clean Air Act, which forced large companies to reduce pollutant emissions, inspired more research into treating and extracting groundwater pollution. Two professors in the University of Minnesota's Department of Civil Engineering, Dr. Michael Semmens and Dr. Daryl Dwyer, are each researching the treatment of contaminated water in different ways.

Dr. Semmens is using physical methods to make an existing hollow-fiber membrane pure oxygen aeration system viable for large volumes of contaminated water. Dr. Dwyer, who is taking a more biological approach, is testing synthetic bacteria to determine if they can neutralize pollutants, a process known as bioremediation.

Photo on this page: Workers prepare to drill holes at the U.S. Geological Survey Cape Cod Groundwater Contamination Site. ***Photograph courtesy of Dr. Daryl Dwyer.***



Dr. Daryl Dwyer, professor of civil engineering, researches bioremediation. (Photograph by Joshua Zuckerman)

The process of aeration (adding oxygen to water) has long been used to treat contaminated wastewater because bacteria, which need oxygen for respiration, effectively break down the pollutants. Unfortunately, the traditional method of aeration, which is similar to that used to aerate an aquarium, is expensive and energy-inefficient. Therefore, it represents a high proportion of operation costs at waste treatment facilities.

Additionally, negative environmental consequences result from the bubbles formed by the diffusion of oxygen into water. Pollutants in the water are released into the bubbles, which reach the surface of the water and break, thus transferring the pollutants into the air. Odors are a common result of this process. Although aeration effectively removes contaminants from wastewater, it can also transfer them to the air, which creates another environmental problem. If wastewater contains volatile organic compounds (VOCs), such as solvents and gasoline, then aeration causes the VOCs to be released into the bubbles and then into the air rather than be treated by the bacteria. The organic content of the water is reduced, but the pollutants are transferred into the air. In addition to Clean Air Act regulations restricting VOC emissions, the presence of VOCs in air is undesirable for health reasons. VOCs also impact air quality and contribute to the depletion of the ozone layer.

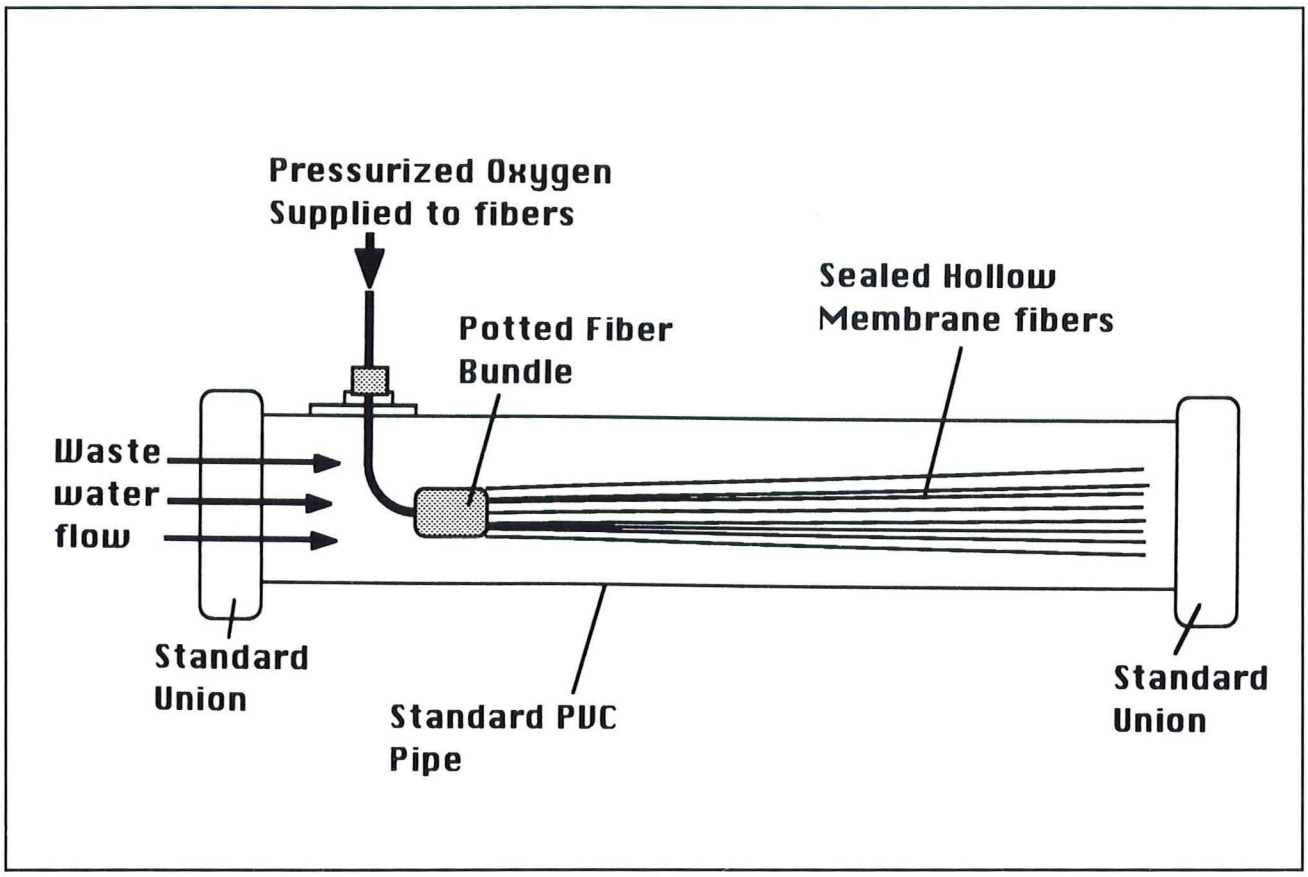
The goal is to find a more environmentally-friendly and cost-effective way of putting oxygen into water. One such alternative is adding pure oxygen to water. Using pure oxygen rather than air requires approximately one-fifth of the volume of air because oxygen is only twenty percent of air by volume. The amount of VOCs released into the air is directly proportional to the volume of oxygen pushed through the water. Thus, substituting pure oxygen for air in the aeration process can theoretically reduce VOC emissions and odor problems by approximately eighty percent.

Substituting pure oxygen for air in the aeration process can theoretically reduce volatile organic compound emissions and odor problems by approximately 80 percent.

Despite these benefits, adding pure oxygen to water is not always a viable or necessary alternative to using air for aeration purposes. First, producing pure oxygen is expensive, whereas air is free. At small companies, the problem of VOC emissions may be relatively minor, so the traditional aeration method may make more financial sense. Because of the high cost of pure oxygen, even the most effective pure oxygen aeration system will be more expensive than one using air.

In some instances, however, the environmental benefits outweigh the additional cost. In Japan, for example, where space is at a premium, treatment systems are housed in the basements of buildings. These "package plants" are so common that they are sold in stores. A compact system that can handle a high rate of water flow is essential. The system must also reduce or eliminate odor problems because of its proximity to the residents of the building. Europe is encountering similar problems related to population densities and resolving them using the pure oxygen aeration method.

Dr. Semmens's research focuses on increasing the rate of water flow and improving the performance of the pure oxygen system using a hollow-



An illustration of a membrane aeration module showing the fiber bundle inside a standard pipe section. Water is oxygenated as it flows over the outside of the oxygen-filled stationary fibers. The modules are easily retrofitted into existing systems for oxygen supplementation. The aerator is not susceptible to solids fouling since the membranes are fluidized inside the housing. (Graphic courtesy of Water Environment Federation)

fiber membrane aerator. The system suppresses the formation of bubbles by pushing pure oxygen through hollow fibers. The aerator contains a number of these gas-permeable fibers, each of which is sealed at the end and contains pure oxygen under pressure.

The oxygen does not escape the walls of the fiber; rather, it remains at the surface of the membrane. When water contacts the surface of the fiber, oxygen is dissolved directly into the water without forming bubbles. The membrane of the fiber allows high oxygen permeation, and the transfer occurs rapidly enough to make the presence of the membrane virtually unnoticeable.

The fibers, which are made from microporous polypropylene membrane, measure between 200 and 400 micrometers in diameter. A small aerator can hold a proportionally large surface area of membrane because the diameter of the fibers is so minuscule. The equation for oxygen transfer is:

$$dC/dt=K_La(C^*-C)$$

K_La represents the overall oxygen transfer coefficient; C^* is the saturation concentration, and C is the actual concentration of dissolved oxygen in the water. Optimal oxygen transfer occurs when K_La and C^* are large.

The rate at which water flows past the fibers and the direction of the fibers determines the value of K_L. More effective contact is attained if water strikes the surface of the fibers at an angle perpendicular to the direction of the fibers than if water flows parallel to the fibers. Specially coated membranes can increase the value of C^*. When pure oxygen is used, the membranes can handle pressures of up to 60 psi.

The hollow-fiber membrane aeration system works well with small volumes of water, but it is not as successful with large volumes of water such as those encountered at wastewater treatment facilities. Although pure oxygen is inserted at 4 atm, twenty times its normal pressure, using large volumes of water results in a pressure drop across the fiber modules, which requires a great deal of energy to resolve.

Dr. Semmens, who has researched since the late 1980s the adaptation of the pure oxygen aeration system to treat large environmental systems, added that the method is not currently suitable for environmental applications. Solids, sediment, bacteria, and other contaminants in the water can block up the small tubes.

As these problems are solved, hollow-fiber membrane aeration using pure oxygen will become more viable. With the increase in population and environmental restrictions and regulations, more companies, cities, and countries are searching for energy- and space-efficient alternatives to traditional methods of decontaminating water. For them, the research that Dr. Semmens is conducting and the resulting technology may prove to be very beneficial.

Dr. Dwyer, whose research is centered around biological rather than physical methods, is studying the bioremediation of aquifers. In bioremediation, microorganisms remove or degrade contaminants in water. In the past, bioremediation relied on natural bacteria to treat hazardous waste, but inoculation has recently emerged as a supplement to this standard method of removing contaminants. Inoculation uses synthetic bacteria, grown in labs for the purpose of treating waste, to degrade chemicals in water.

Dr. Dwyer has researched this topic since 1989. He began his study at the German Institute for Biotechnology and works in cooperation with the U.S. Geological Survey (USGS). Field work is conducted at the USGS Cape Cod Groundwater Contamination Studies site, chosen for its proximity to a military base. The groundwater there, which is contaminated by pollutants from the military site, is buried beneath layers of sand.

The bacteria are grown in large quantities at the Bioprocess Technology Institute, which is located in the Twin Cities, and then centrifuged from 200 L to 1L. After being concentrated, the bacteria are transported to the Cape Cod site. Inserting the bacteria into the ground involves a process very similar to that of digging a well. A drilling rig digs holes about 50 feet deep, and the bacteria are then inserted into the aquifer.

The population density and the consumption of natural resources are increasing, but environmental engineering promises a cleaner, healthier future.

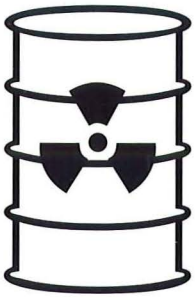
Within a short period of time, the inserted bacteria are recaptured for testing. Success is indicated by the survival of the transported microorganisms. Their survival rate is determined by counting the number of live bacteria and dividing that figure by the original number of bacteria. If they live, they have broken down the contaminants; if they die, they are not robust enough to degrade the pollutants. Back in the lab, the microorganisms are tested for their degradative ability. Simulated aquifers are used to collect this data.

Three synthetic strains of bacteria are commonly used to combat their pollutant counterparts at the Cape Cod site. *Pseudomonas cepacia G4* counters trichloroethylene, a degreasing agent used for a multitude of purposes, including dry cleaning. *Pseudomonas putida* breaks down phenol, and *Pseudomonas sp strain B13* degrades 3-chlorobenzoate and 4-methylbenzoate.

Using bioremediation to treat contaminated sites like Cape Cod is an attractive method for several reasons. Bioremediation, like other methods, helps to clean the environment, and using bacteria is cheap and environmentally safe. One alternative is to bulldoze the site, pump the water out, and then treat it, but this damages the environment and is time-consuming and expensive. Bioremediation through inoculation of synthetic bacteria has thus far proved to be largely effective.

Drs. Dwyer and Semmens are approaching a similar problem using different methods—physical and biological, respectively—but their research into the treatment of groundwater has important and useful applications. As the United States and other countries grow more concerned about environmental waste and contamination, efficient processes for the removal and treatment of pollutants in water and air become increasingly necessary. The population density and the consumption of natural resources are increasing, but environmental engineering promises a cleaner, healthier future. T

• LAURA WALBRINK is a computer science major who plans to attend law school.



The Never-Ending Story: High-Level Radioactive Waste Disposal Efforts in the United States

by Gregory Lauer

Like the Hydra, the nine-headed serpent from Greek mythology that grew two heads after one was cut off, the debate over high-level radioactive waste in the United States is a seemingly invincible bureaucratic and scientific monster. After years of study and research, the construction and operation of a high-level radioactive waste repository is still decades away. Several researchers here at the University of Minnesota and a local consulting engineering firm are contributing answers, however, to a process perpetually producing questions.

The need to store high-level radioactive waste is a byproduct of America's nuclear energy program. In the 1950s, commercial nuclear reactors began producing electricity by harnessing the power of the atom. Proponents hailed nuclear power as a cheap, clean, and plentiful energy source capable of fulfilling the needs of a population accustomed to light bulbs, refrigerators, and television sets. Nuclear energy was a symbol of scientific and engineering excellence, and the concerns of critics were by and large ignored.

Unfortunately, there was little attention given to storing the highly radioactive waste products of nuclear power. In a typical nuclear reactor, fuel rods filled with thousands of uranium pellets are inserted into the reactor core. Nuclear fission occurs when the nucleus of an atom of an unstable isotope of uranium is bombarded by neutrons and splits into two parts. At this point mass is converted into energy and neutrons are liberated to continue the chain reaction. After the bulk of the available fissionable material is utilized, the fuel rods are depleted and must be replaced. The spent fuel casings, however, are still highly radioactive.

Finding an environmentally safe and politically palatable repository for "used" nuclear fuel constitutes the bulk of the debate concerning the disposal of high-level radioactive waste. By far the largest considerations are scientific and technical in nature; issues of safety, storage and retrieval, and cost must all be resolved. The corresponding political issues of storing nuclear waste, however, must also be addressed.

The burden of finding a repository for high-level radioactive waste falls primarily on the Department of Energy (DOE). In 1982, the Nuclear Waste Policy Act required DOE to characterize three potential repository sites and formally select one. In subsequent amendments to the National Waste Policy Act in 1987, DOE was directed to examine only one site at Yucca Mountain in Nevada. In terms of funding, the owners and generators of nuclear waste — primarily the utilities operating nuclear power plants — are required to pay the costs associated with waste disposal efforts; since the program's inception, DOE has spent more than eight billion dollars.

In the Energy Policy Act in 1992 Congress charged the Environmental Protection Agency (EPA) to review earlier guidelines concerning the disposal of high-level radioactive waste and develop "findings and recommendations on reasonable standards for protection of public health and safety." That mandate led to the creation of a health-risk based standard for Yucca Mountain. The EPA's criteria include individual, population (local, regional, and global), and groundwater protection among other things. The repository must provide adequate safeguards for a period of 10,000 years, and it must minimize human exposure to carcinogenic and toxic agents.

The third major governmental agency to play a role in the disposal of high-level waste is the Nuclear Regulatory Commission (NRC), which is in charge of licensing the high-level radioactive waste repository after a site is selected by DOE. NRC conducts on-site inspections, evaluates safety procedures and contingency plans, and reviews quality assurance programs.

The Department of Energy, the Environmental Protection Agency, and the Nuclear Regulatory Commission are only the principal government organizations involved in the nuclear waste repository scavenger hunt. A plethora of committees, task forces, and representatives from other federal, state, and local agencies are also involved. Additionally the interests of corporations and utilities associated with

nuclear power have a voice in the process. Not surprisingly, progress in establishing and operating a national repository for high-level waste is bogged down by bureaucratic inertia and the sticky nature of governmental red tape and regulations.

A preliminary site is currently being studied at Yucca Mountain in Nevada, approximately 100 miles northwest of Las Vegas. Yucca Mountain is similar to many outcroppings in this desert region with peaks just under 5,000 feet above sea level. The site is very dry and averages less than six inches of rainfall per year.

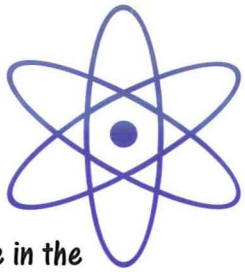
The Yucca Mountain Site Characterization Project will determine if the geologic and hydrologic setting of the site will effectively isolate spent nuclear fuel and high-level waste from the environment. Several issues must be addressed such as whether the geology of Yucca Mountain is capable of isolating high-level radioactive waste, whether volcanic activity or earthquakes pose a threat to the repository, and whether there is a threat of contaminating underground water tables. In addition to the technical issues under consideration, socioeconomic studies will also be conducted to assess the direct and indirect impacts on employment, communities, Native American populations, tourism, population distribution, social conditions, and government structures.

In sci-fi literature, the threat of radioactive contamination is a frequently visited topic. Writers in the genre often conjure up scenarios where characters are exposed to massive doses of high-level radiation and suffer hideous mutations. Not surprisingly, the public has a deep-seated fear of all things radioactive. In order to satisfy these concerns, many studies are addressing possible modes of radioactive contamination.

Scientists and researchers are especially interested in the transport of radionucleides by groundwater flow. Dr. Charles Fairhurst of the Department of Civil Engineering is actively involved in the debate over high-level waste storage in the United States, and he chairs a committee of the National Research Council focusing on radioactive waste disposal; additionally Dr. Fairhurst advises both the French and Canadians on issues related to the disposal of radioactive waste. The transport of radioactive particles is a significant concern, he says, because of the threat of groundwater contamination. Current research has shown thus far that radionucleides travel more slowly than water due to chemical retardation and matrix diffusion which is encouraging news. Federal standards limit the movement of these particles to less than three miles over the course of ten thousand years.

Since 1983, a series of seventy-two deep and shallow holes were drilled at Yucca Mountain in order to understand the mechanisms associated with water flow. Several mineral barriers that inhibit the downward flow of water have been identified. Surface water is often kept from entering very deeply into the ground by layers of calcium carbonate. The layers are compact and often present a nearly impassable barrier to water. Rock formations formed millions of years ago from violent volcanic eruptions are also present near the surface and block the downward flow of water. By and large, rock comprising Yucca Mountain is very impermeable to water; typical rates of flow are on the order of inches per hundreds of years.

However, water may flow downward fairly quickly due to faults or fractures in the rock. Faults present conduits for water and accelerate the underground flow. There is concern that fractures may develop allowing water to come in contact with high-level waste in the repository. If the containers corroded, seeping water could become contaminated with radionucleides. Ultimately these particles could leach into underground reservoirs and travel southward with groundwater flow before finally resurfacing.



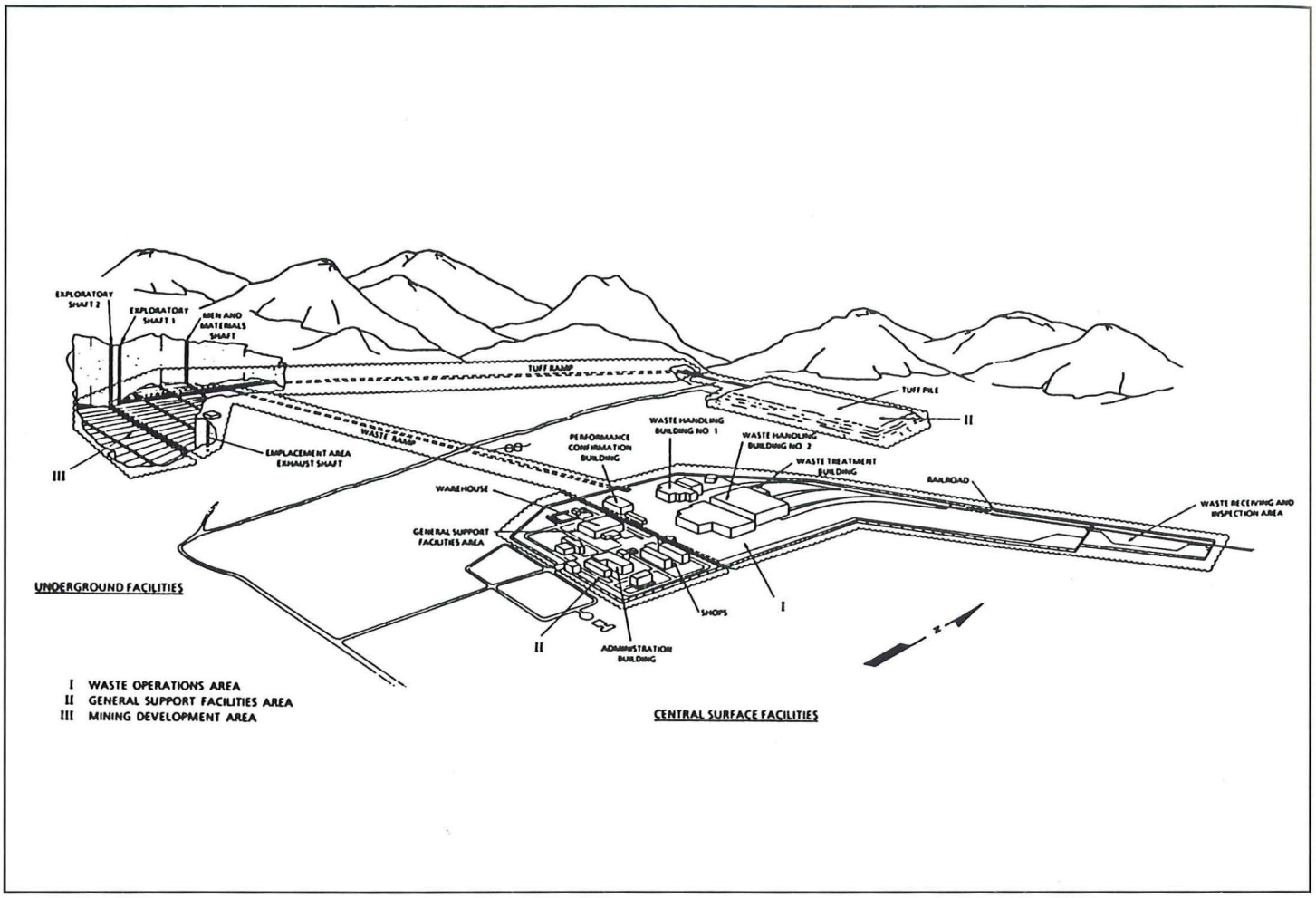
For more information on the high-level waste debate in the United States, check out the following WWW sites:

- **http://www.ymp.gov/faq/default.htm**
- **http://ees5www.lanl.gov/EES13/EES13.html**
- **http://www.wizard.com/~vantage/unlv/no_dump.html**

Understanding the mechanisms of rock fracture and fluid flow is important, especially in view of the unique engineering constraints related to the disposal of high-level radioactive waste. Itasca Consulting Group, a local engineering consulting firm here in the Twin Cities specializing in geo-engineering and rock mechanics, has prepared studies for the US. Nuclear Regulatory Commission analyzing various aspects of the Yucca Mountain repository. Itasca Consulting Group is unique among many engineering consulting companies because of its close ties to the University of Minnesota and its heavy emphasis on computational modeling.

In a typical study several years ago, Terje Brandshaug of Itasca Consulting Group investigated rock mass modification around a nuclear repository. By excavating material from existing rock formations, additional stresses are induced and joint deformations may occur. Thermal effects of disposal must also be considered because high-level nuclear waste generates enormous amounts of heat while decaying. Determining the behavior of the modified rock mass is important to scientists and researchers at Yucca Mountain as it may present special engineering or safety concerns that must be addressed.

In order to more fully understand the mechanisms and processes asso-



Perspective view of the proposed high-level nuclear waste repository at Yucca Mountain. (Courtesy of the Site Characterization Plan Conceptual Design Report)

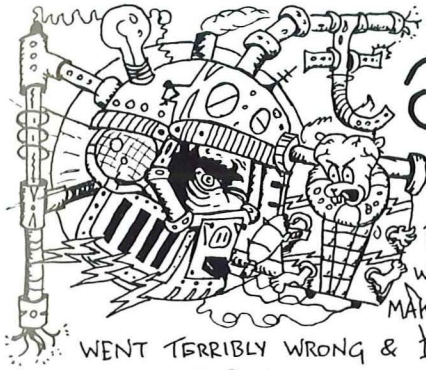
ciated with excavation and thermal effects, computer codes based on boundary element and distinct element methods were employed. Using *FLAC* (Fast Lagrangian Analysis of Continua) it is possible to model a nuclear waste repository numerically and study the stress contours, temperature contours, and displacements of rock masses. In the rock mass modification study, zones above and below the repository were identified as likely candidates to have modified rock properties. In particular, these changes may alter the rock mass hydraulic characteristics and increase its permeability to fluid flow.

The work of researchers and consultants like Dr. Charles Fairhurst and Terje Brandshaug is providing answers to some of the questions in the high-level radioactive waste debate. The controversy surrounding Yucca Mountain, however, is likely to continue indefinitely. Politicians and the public are expecting perfection from science when it comes to radioactive waste disposal. Even with all of the exhaustive studies and voluminous reports, however, scientists and researchers can't guarantee the safety of the repository over the course of ten millennia.

Sadly enough, the United States' stockpiles of nuclear waste are sitting in temporary storage facilities at nuclear reactors around the country. Most experts agree this is an unsafe and insecure method of high-level waste disposal. Earlier this month, for example, NSP filled its second cask at the Prairie Island complex with highly radioactive, spent nuclear fuel. These stop-gap solutions will continue to be necessary until a permanent repository is established.

The future of the high-level waste repository at Yucca Mountain is certainly in question. Many different agencies, corporations, and public interest groups are actively competing to influence the final decision of politicians and policy-makers in Washington. Don't expect to see action soon, however, as the earliest start-up date of an American high-level radioactive waste repository is 2013. T

• GREGORY LAUER is a lost math major in civil engineering and computer science.

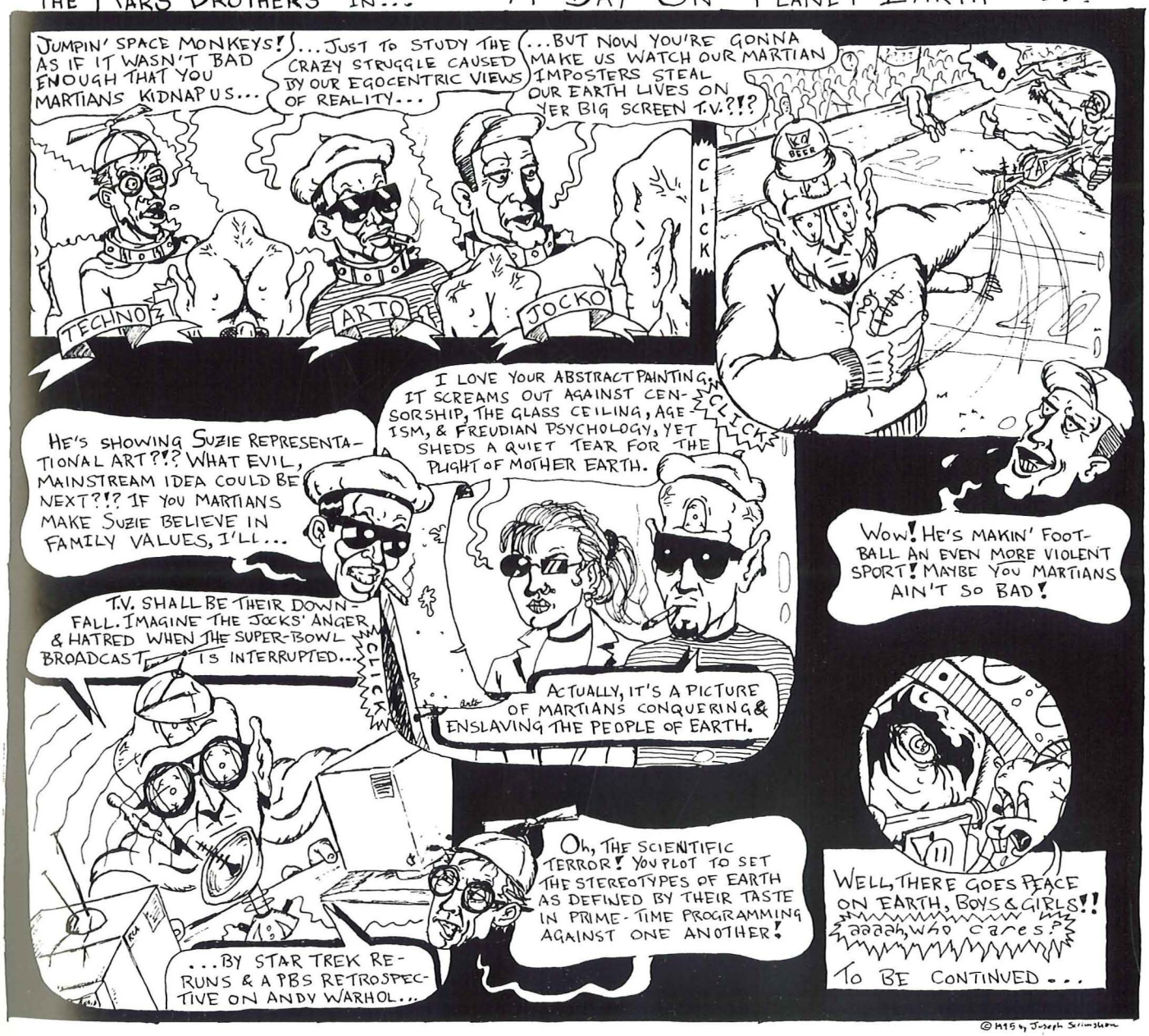


ales of technology...

by Joseph SCRIMSHAW

HELLO THERE, BOYS & GIRLS! YOU REMEMBER YOUR OL' PAL, RAYMOND, DON'T YA? REMEMBER HOW I STARTED OUT JUST AN AVERAGE HUNCH-BACKED LABRATORY ASSISTANT WHO LIKED TO TELL SCARY STORIES & HOW MY MASTER 'SPERIMENTED ON ME TO MAKE ME A 100% PERFECT COMPUTERIZED STORYTELLER? AND THEN EVERYTHING WENT TERRIBLY WRONG & I WAS BEING HELD HOSTAGE BY MY COMPUTER BRAIN'S BACK-UP SQUIRREL? REMEMBER?!? WELL, GUESS WHAT! MY MASTER FIXED EVERYTHING BY INCREASING POWER TO THE COMPUTER HALF OF MY BRAIN & TRAPPIN' THAT NASTY SQUIRREL IN ITS ARTIFICIAL GROWTH! AND MY COMPUTER BRAIN'S STILL GROWIN' OUT, BUT WHO CARES 'BOUT THE REST OF THE WORLD AS LONG AS I'M A MORE EFFECIENT STORYTELLER--tell the story! you're driving me nuts!... ANYWAYS, HERE'S

THE MARS BROTHERS IN... "A DAY ON PLANET EARTH" ...



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Minnesota Technolog is looking for writers for the 1995-1996 school year. We're seeking IT undergraduate and graduate students who'd like some experience writing for publication! We have several beats in mind, including environment, ethics, new technology, personal profiles and features, editorials, and personal reports on the specific projects you're working on for school.

Although our editorial board mainly consists of creatures from outer space, we've been known to work well with humans. If you'd like more information, or would like to come in for an informal interview with the editor, please leave a cover letter, a resume and any available writing samples in an envelope outside the *Technolog* office in Room 5, Lind Hall.

And, if you're not quite up to writing, but have interesting ideas for stories you'd like to see in upcoming issues of the *Technolog*, please jot them down on this form and drop it by the office.

MINNESOTA TECHNOLOG

Description of story idea(s):

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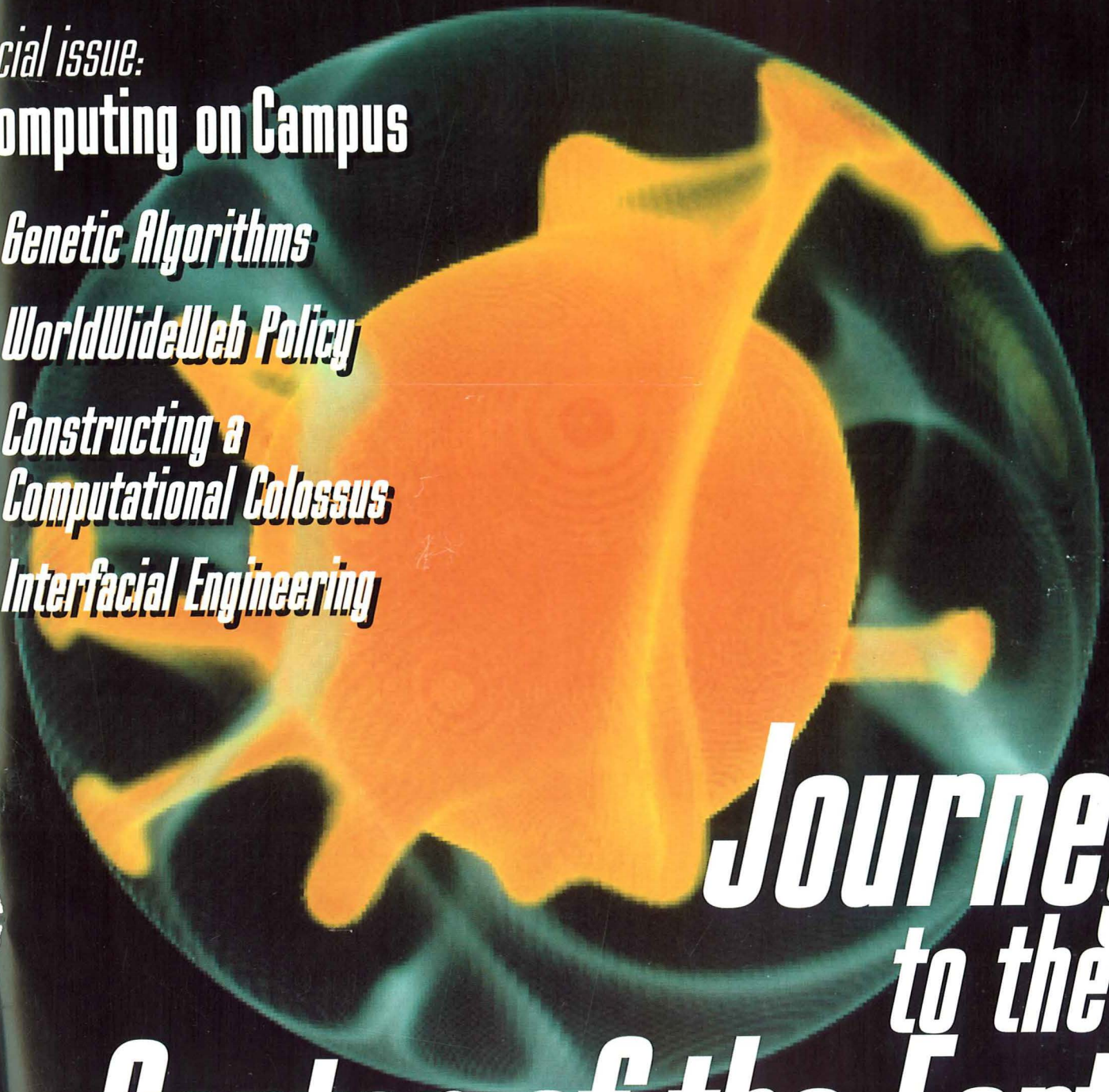

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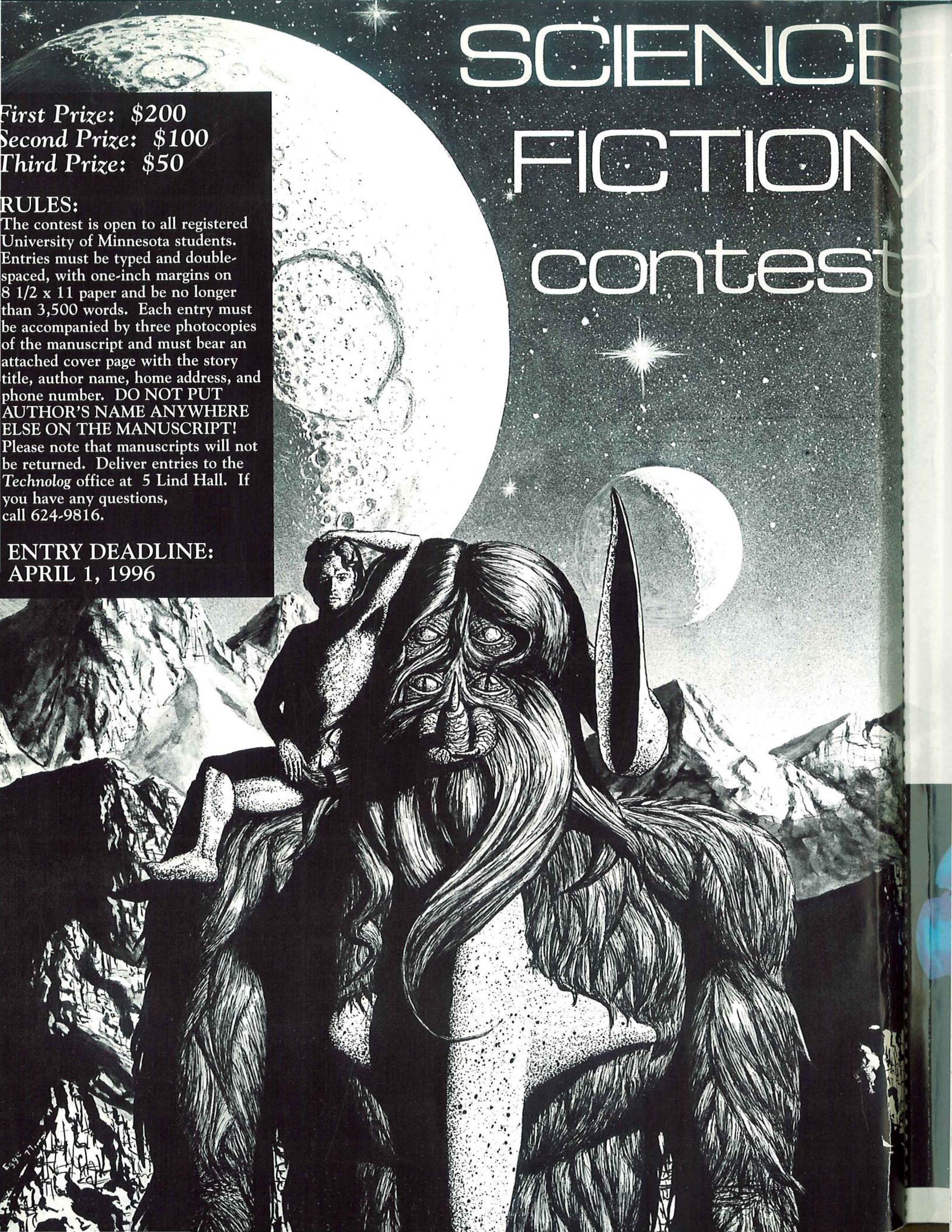
Computing on Campus

- Genetic Algorithms
- WorldWideWeb Policy
- Constructing a Computational Colossus
- Interfacial Engineering

Journey to the Center of the Earth

Computationally Modeling Mantle Convection



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Volume 76 Number 2 • January 1996

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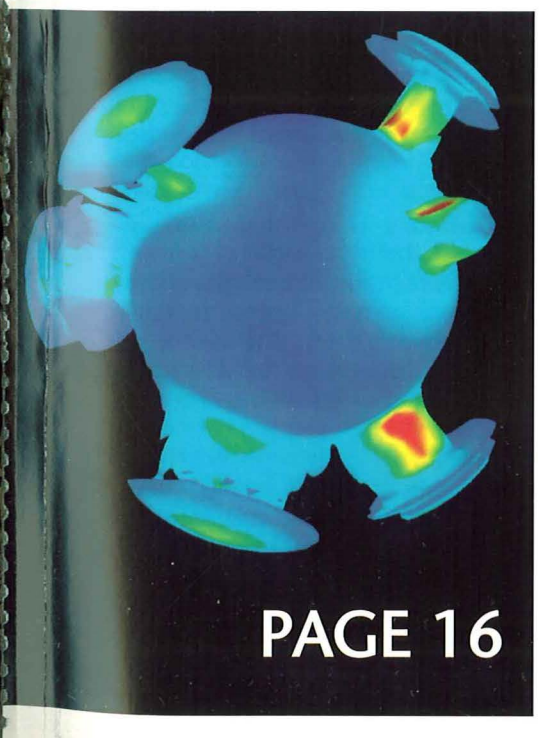
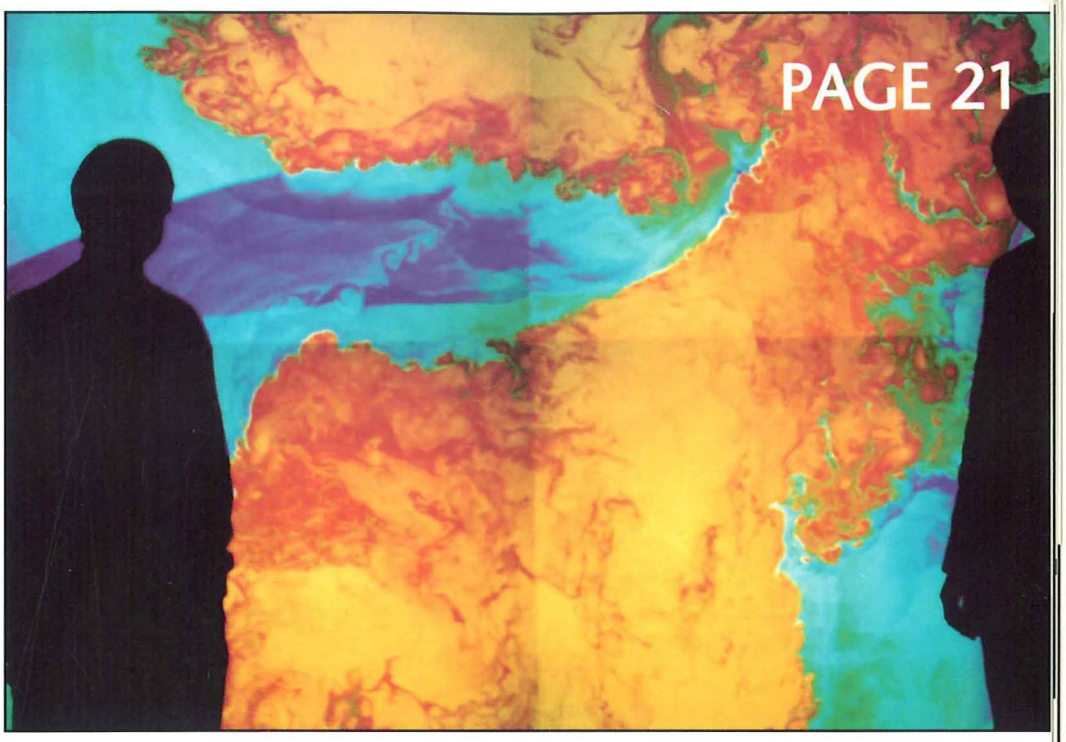
COVER STORY

FEATURES





About the Cover

Mantle convection deep inside the earth is modeled using a spherical shell representation. This scheme is more representative than conventional Cartesian models and better represents the geometric characteristics of the Earth. The orange-ish plumes represent hot upwellings of material inside the mantle. Research like this may someday better explain the drift of the continents, the causes of earthquakes and volcanic activity, and the nature of topographical features. The cover story begins on page 16.

Cover graphic courtesy of Shuxia Zhang

EDITORIAL by Gregory Lauer

Searching for an Exit on the Information Superhighway

The Baby Boomers of today grew up in a world devoid of personal computers, fax machines, and pagers. To most of our parents, silicon was associated with sand on the beach, not the inner workings of a digital watch or an answering machine. The advent of electronics has fundamentally altered human interaction over the course of a generation. At the forefront of this revolution is the Internet, a free-wheeling, self-service convenience station distributing information and ideas to wayward electronic travelers.

An outgrowth of a defense project spawned in the early '70s, the Internet has evolved into a society of its own spanning all geographic, social, and economic constructs. It is a communication medium with no out-of-bounds, no guidelines and no rules. To shamelessly borrow from Emma Lazarus, it is a place for all those "yearning to breathe free." With thousands of news groups, numerous IRC channels, and a countless array of WorldWideWeb sites, the Internet offers something for everyone.

Amidst all of this hype and hyperbole, it's hard to avoid jumping onto the electronic bandwagon. Commercial network providers like CompuServe and America Online are experiencing phenomenal growth as millions rush to plug in. *Newsweek* recently went so far as to declare 1995 the "Year of the Internet." I can't help but question, however, this maddening stampede of digital cowboys as they race towards their keyboards and modems.

Most troubling, the Internet reduces human interaction to a mere string of ones and zeros. In cyberspace, smiles, winks, and nods are reduced to a cryptic series of emoticons that trail sentences like an undigested Big Mac. In our technology-driven culture, the computer is becoming man's new and improved best friend. Clifford Stoll argues along similar lines in *Silicon Snake Oil: Second Thoughts on the Information Highway*.

"I can't help but question, however, this maddening stampede of *digital cowboys* as they race towards their keyboards and modems."

In the 1950s, urban planners, engineers, and politicians envisioned a national network of roads that would bring citizens closer together. Proponents hailed the transportation act authorizing the construction of America's freeways as a giant leap forward. Progress, however, introduced congestion and pollution, suburban sprawl, and the decay of America's inner cities. Most damaging, though, this transportation network pushed people farther apart. Today, freeways make it possible to drive across the country without seeing anything or anyone.

The Internet is just as dangerous. Travelling on the Infobahn, human interaction is translated into a few keystrokes or a click of the mouse. The computer is now a cocoon enabling Internet afficionados to withdraw from a world filled with real sights, real sounds, and most importantly, real people. The cyber communities of tomorrow can never replace a parade on the Fourth of July, a Little League baseball game, or a family feast on Thanksgiving Day.

In a recent wave of commercials, AT&T rhetorically asks if you can send a fax from the beach or water your lawn from the Grand Canyon. You will, the smooth-talking spokesperson says assuringly. In *The Road Ahead*, Bill Gates writes even more fanciful prophecies. The Internet, he says, will offer everything from groceries to autos to consumers with electronic money. For the more cultured Net surfer, performances of Shakespeare's complete works may someday be available online. Forgive my nostalgia and backward thinking, but I'd rather spend my time at Rosedale and the Guthrie.

The Internet offers an undeniable array of benefits to society. Lost in the fanfare, unfortunately, are the associated costs of "going digital." In its present form, the Net is a technical innovation in desperate need of some social engineering.

As Bob Dylan wryly observed, "The times, they are a-changin'." As America plunges head first into an electronic ether world, however, I wonder if the times are changing for the better. ★

NEWS

Reprinted from other members of ECMA, Engineering College Magazines Associated

Charting the Double Helix

The Human Genome Project is a grand attempt to completely map the 23 pairs of chromosomes that uniquely determine the genetic blueprint of a human being. The sheer scale of this endeavor is a daunting challenge to researchers in the field. Dr. Chris Overton, a biologist at the University of Pennsylvania, explains, "Each chromosome contains a single molecule of DNA—a string of text made up of four different nucleotide characters." The DNA text inherited from each parent is more than three billion characters in length. Working in collaboration, groups of scientists around the globe are attacking different segments of the human genome. The raw data, essentially a long text string, is transferred into databases. However, no standard presentation format is in place in the scientific community today. Overton and others here are developing an interface capable of connecting the many existing databases in the field. The relational model, the most popular choice in business and administrative settings, was unable to handle the needs of a scientific database, such as arrays, lists, bags, and more complicated data types. In response to this, Overton's team developed Collection Programming Language (CPL), a lower-level language that exploits the commonality of data types found in databases. Dr. Susan Davidson, another researcher in the group, concludes, "It is capable of handling arbitrarily complex databases. We haven't seen anything yet that we couldn't really handle."

—El Smith
Pennsylvania Triangle
Fall 1994

The Army Ant Project

Group coordination of many different robotic units has recently become an area of intense research. At Virginia Tech, students in electrical, mechanical, and computer engineering are concentrating efforts in robotic design and development. The product of their research is the army ant, a low-cost, sensor-oriented robot capable of completing "team-oriented" tasks. With the support of Martin Marietta and Delco Electronics as well as funding from the National Science Foundation and the Office of Naval Research, students are building a new breed of robot. The army ant is approximately 18 inches long and one foot wide and is capable of lifting more than one hundred pounds. It relies on two principle control systems: one module handles programmed responses to specific data from sensors and communications, while the second controls the motor. One of the most difficult issues confronting the designers of the army ant is the coordination of several duplicate robots. In theory, the army ant is capable of working with as many other units as necessary to complete an assigned task. In practice, however, enabling a group of army ants to act as one machine is very challenging. Numerous benefits favor this approach to robotic "group activity." Companies may quickly and easily replace broken units, and the machines are very adaptable. Furthermore, once the technology is in place, projects may easily be scaled up in size by merely adding more robots. The Army Ant Research Group can be found on the WorldWideWeb at http://armyant.ee.vt.edu/armyant-project.htm/.

—Nathan M. Phillips
Engineer's Forum (Virginia Tech)
December 1994

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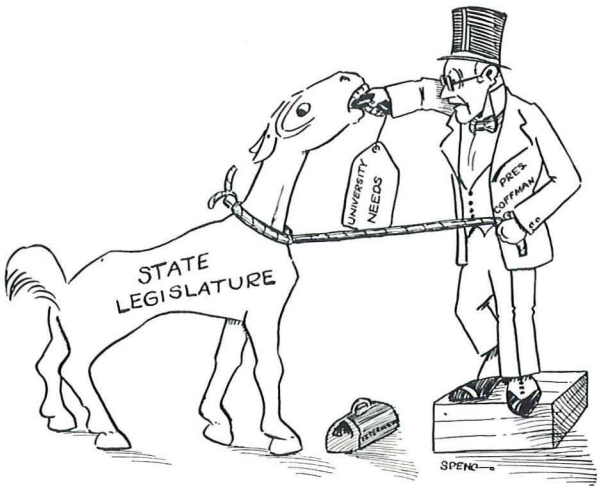
From the *Technolog* Archives

Life Before Hockey?

Several students have recently indicated interest in making hockey a major sport at Minnesota. Many Canadian universities and eastern schools already have high-profile hockey programs, and the climate is no less favorable in Minnesota than in those regions. Minnesota has the resources to support a hockey team: the Armory rink and a group of talented players.



The more things change, the more they stay the same? A political cartoon from the January 1921 issue of the ***Minnesota Techno-log.***

Adding hockey would be beneficial to both the players of the sport and the university. The program would provide another outlet for fame and success at Minnesota, and it would offer those who excel at hockey rather than football or basketball a chance to hone and demonstrate their skills.

Hockey is capable of generating as much interest and excitement as any other sport. Minneapolis citizens enjoy winter sports of all kinds. As evidenced by Minnesota's performance in last year's intercollegiate hockey league, a hockey team here could produce impressive results within a short period of time.

Unfortunately, the university lacks a suitable rink size, publicity, and organization for a hockey team. Each of these problems, however, could be solved inexpensively. With effort, Minnesota could field another successful athletic team.

—February 1921

Making the Grade

The president of American Telephone and Telegraph Company, W.S. Gifford, recently wrote an article published in Harper's Magazine and entitled "Does Business Want Scholars?" It examined the relationship between scholarship and progress in the Bell System, a large organization. The scholastic records of 3,806 employees were acquired and divided into four groups: top 10 percent, top third but not top 10 percent, middle third, and bottom third of their respective classes. The employees were tracked by salary because pay is a reliable indication of high performance and advancement within the company.

It was noted that a strong correlation existed between college scholastic achievement and subsequent career success. Ten years after graduation, the median salary of the employees in the top tenth of their class was over 10 percent higher than the median salary of the entire group. After 20 years, it was 30 percent higher; after 30 years, it was 55 percent higher.

The level of extracurricular activity of the workers was also studied as a determinant of prosperity. The study found that those who had some, but not too much, extracurricular involvement tended to have the best job performance. While it was found to be a fair indicator of success, participating in collegiate activities was not as key as scholarship. In addition, students who pursued literary, editorial or managerial fields enjoyed greater workplace achievement than those involved in art, music and drama. Students who worked to pay for their education suffered negative consequences in their careers, most likely due to their tendency to be low achievers because of time constraints.

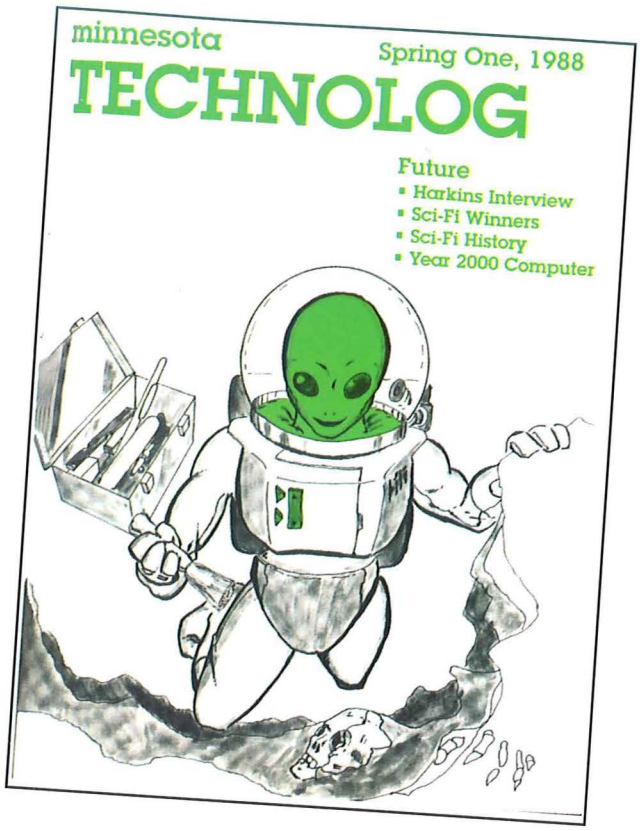
Although employers often weigh all three factors, they usually consider scholastic success to be most important. The message to students: Study, get involved to a moderate degree in extracurricular activities, and avoid working an outside job if at all possible.

—October 1930

Deferment and Draft-Dodging

As an engineering graduate, what are your best options for deferment of military service? One resource is your employer, who can request that you be deferred for up to one year while a replacement is found. The period of deferment can be extended if no replacement is available. Another choice is to join the Reserve Officers' Training Corps (ROTC). In addition to receiving college credits and a commission upon graduation, you may receive a deferment if you complete your ROTC training before you graduate. After graduation, you will be required to complete two years of active and six years of reserve duty. If you wait to be drafted, however, you will be a private and paid $78 per month, less than a third of the $250 paid a recent ROTC graduate. You may enter Officers Candidate School, but your service time will be extended by at least a year. Your final option is to enlist. The author of this article advises college students to find as many deferments as possible. "Getting it over with" may not be necessary if the circumstances of the war change, making the draft unnecessary or limited in scope.

—January 1954



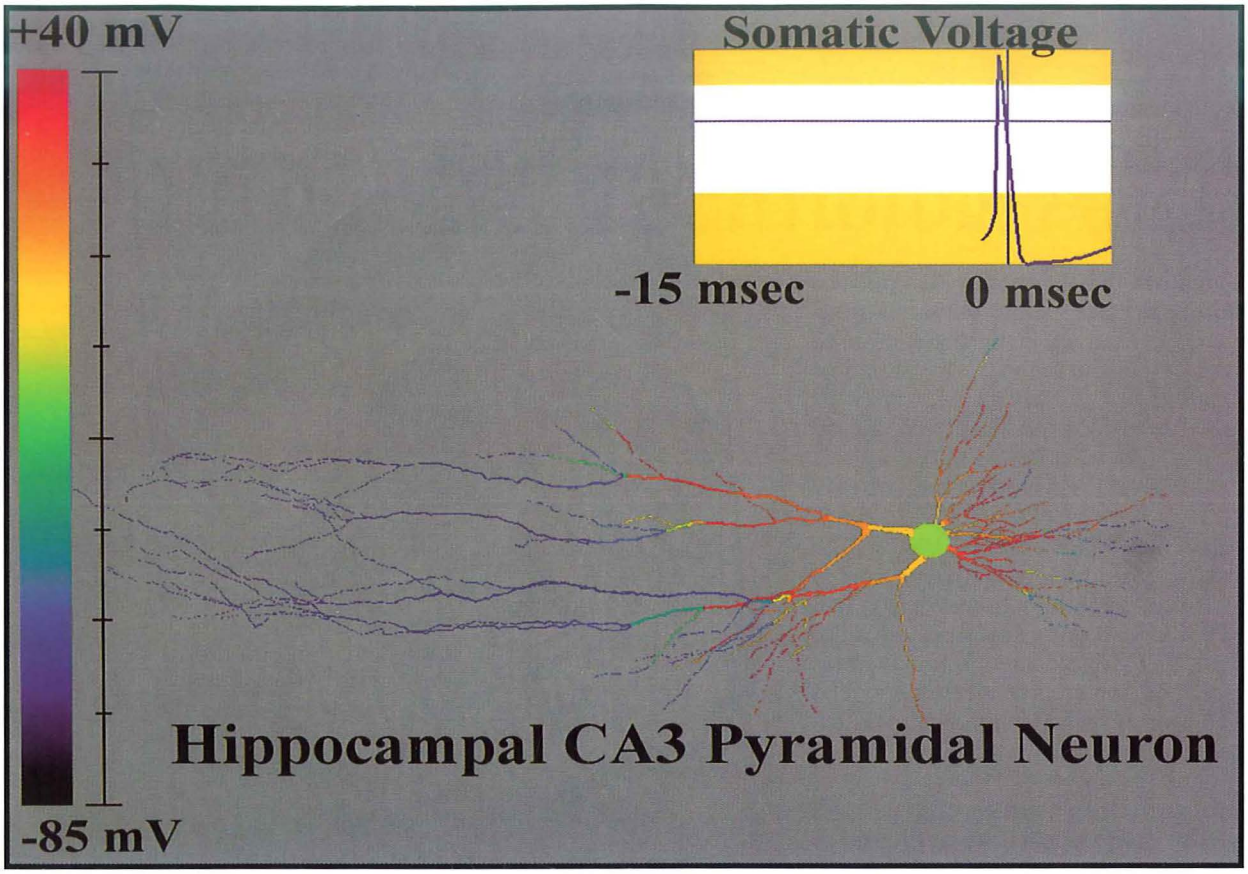
Cover of the spring 1988 issue (Vol. 68, No. 5)

Dreams of a User-Friendly Interface

As computers become more commonplace, an increasing number of people desire and need access to their capabilities. Most of them, however, lack the knowledge of computers and non-intuitive programming languages necessary to manipulate them. A reasonable solution is the development of a programming language in which the user could type commands written in standard English. Although this seems possible in theory, it is largely unrealistic in practice. Current computers are limited by their relatively small memory capacities, and an English-based programming language would require vast amounts of space to store not only the words but also the algorithms for the interpretation of sentences. Even if enough memory existed, searching the memory for a word or performing an interpretation would take a great deal of time, too much for practical purposes.

It is possible, however, to create a limited atmosphere in which the computer can handle queries and commands in English. When a specific task is performed repeatedly, it can be programmed to handle typical conversational communication regarding that topic.

—December 1967



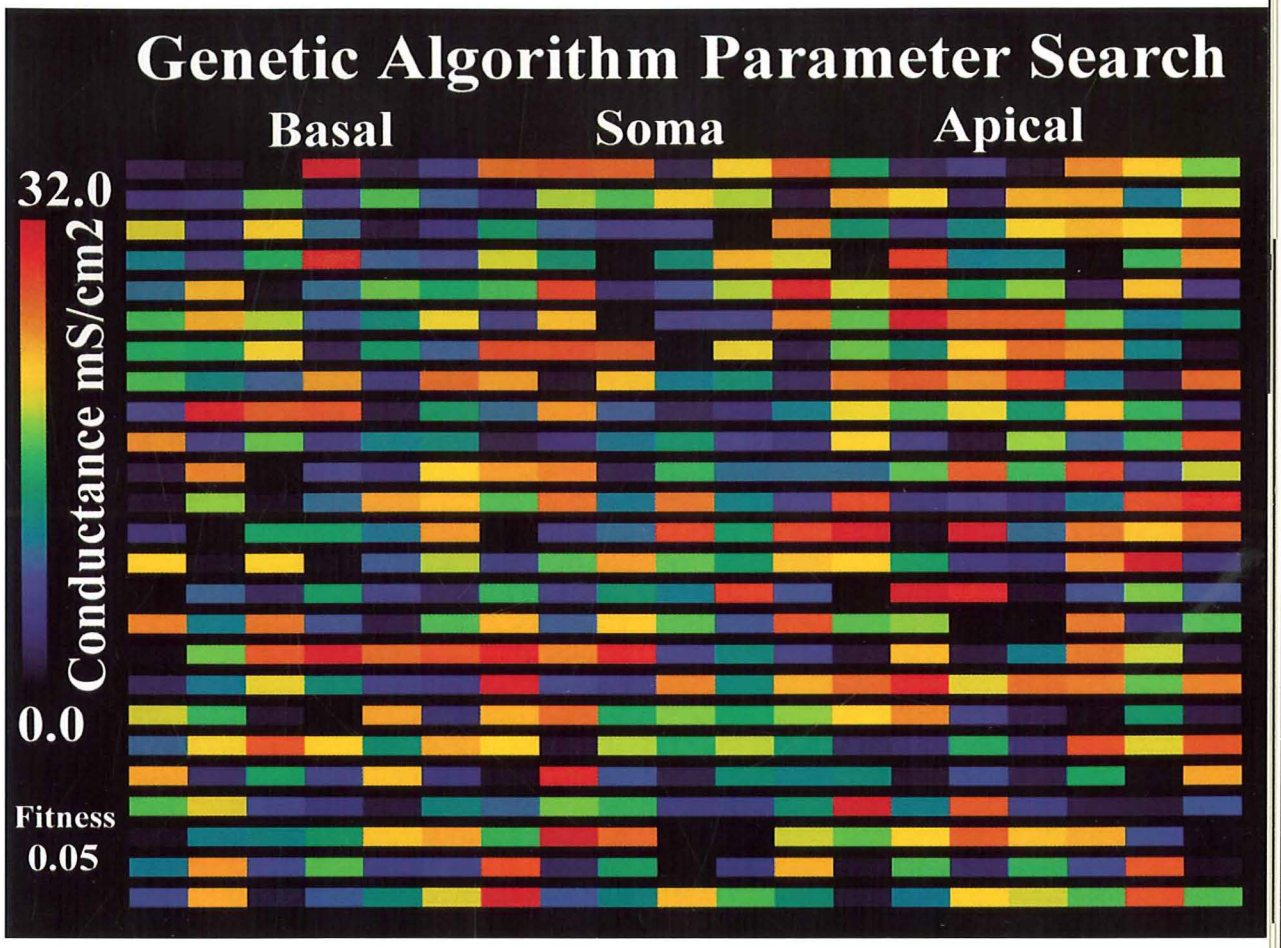
Above: A CA3 hippocampal neuron can be computationally simulated by solving a partial differential equation known as the cable equation. The spatial domain is defined using experimentally obtained 3-D morphologies. The challenge is to determine a basis for the spatial distribution of the non-linear control units (membrane-bound ion channels) that produce appropriate electrical signaling behaviors. ***Graphic courtesy of Rogene Eichler West.***

Genetic Algorithms: Survival of the Fittest

Applying computers to problems in neuroscience that are unsolvable by experimental methods.

by Laura Walbrink

Researchers of areas as diverse as circuit design and inventory control systems share a common problem: Devising a computational model to efficiently optimize the performance of high-dimensional non-linear systems. High-dimensional systems consist of a large number of variables (parameters). The vast number of possible combinations of the parameters within these systems renders the determination of an optimal parameter set impractical, if not impossible, by conventional means: enumerative, trial-and-error, hill-climbing, and calculus-based techniques.



Genetic algorithms evolve a population of parameter sets such that a desired behavior is achieved. The initial conditions are randomly selected. ***Graphic courtesy of Rogene Eichler West.***

The time needed to evaluate all potential sets of data in high-dimensional systems increases exponentially with the number of parameters. Consider, for example, a system containing 100 parameters. If each parameter had two possible states, and if each evaluation took just one second, evaluating all of the sets would take $4 * 10^{20}$ centuries (2^{100} seconds). Incidentally, the universe has only existed for approximately $2 * 10^{8}$ centuries. Enumerative, or combinatorial, algorithms, used in low-dimensional systems but impractical for high-dimensional systems, rely on testing each possible combination and are undesirable for that reason.

Trial-and-error, hill-climbing, and calculus-based techniques have also been used to solve optimization problems, but each method has drawbacks. With trial and error, a guess is made as to the correct parameter set based on experience with the system. The parameters are then manipulated after each evaluation until an acceptable combination is found. The trial-and-error method requires fewer evaluations than the enumerative approach. However, the optimal solution set may never be found.

The hill-climbing method begins with a set of random parameter values. While the other parameters remain constant, a "step" is taken along one dimension (parameter). The surrounding parameter sets are evaluated for optimal performance with the changed parameter. The set yielding the most improvement is chosen to become the new set of parameters. The process is repeated until no further improvement is achieved; the final set is the optimum. Hill climbing works best for parameters that are not highly interdependent. Unfortunately, this technique can become mired in local extrema and result in the discovery of an inferior solution. For this reason, several searches are conducted from unique random initial conditions, and their results are compared to verify that a global maximum has been found.

Calculus-based techniques search for the parameter value at which the solution manifold bifurcates. These routines, however, can only be applied to systems whose derivatives are both defined and continuous. In addition, the output might not correspond to the salient behaviors of the system. Efficiency is comparable to that of the enumerative method because software tools

What's a Genetic Algorithm (GA)?

The Genetic Algorithm (GA) is a model of machine learning which derives its behavior from a metaphor of the processes of evolution in nature. This is done by the creation within a machine of a population of individuals represented by chromosomes; in essence, a set of character strings that are analogous to the base-4 chromosomes that we see in our own DNA. The individuals in the population then undergo a process of evolution.

The following is a brief outline of the structure of the genetic algorithm in computer-related terms:

PSEUDOCODE:

```
Algorithm GA is
// start with an initial time
t := 0;

// initialize a usually random popula-
   tion of individuals
initpopulation P (t);

// evaluate fitness of all initial individu-
   als of population
evaluate P (t);

// test for termination criterion (time,
   fitness, etc.)
while not done do

        // increase the time counter
        t := t + 1;

        // select a sub-population for
           offspring production
        P' := selectparents P (t);

        // recombine the "genes" of
           selected parents
        recombine P' (t);
```

limit exploration to only one or two dimensions at a time.

The genetic algorithm, by comparison, is far more robust and efficient than any of the above methods. The method, based on the principles of natural selection, was conceived by John Holland in 1975. His Schema Theorem states that the genetic algorithm will consistently improve the overall fitness of an initially randomly chosen population of parameter sets.

Rogene Eichler West, a Ph.D. candidate in neuroscience at the University of Minnesota
(Photo by Reed Lauer)

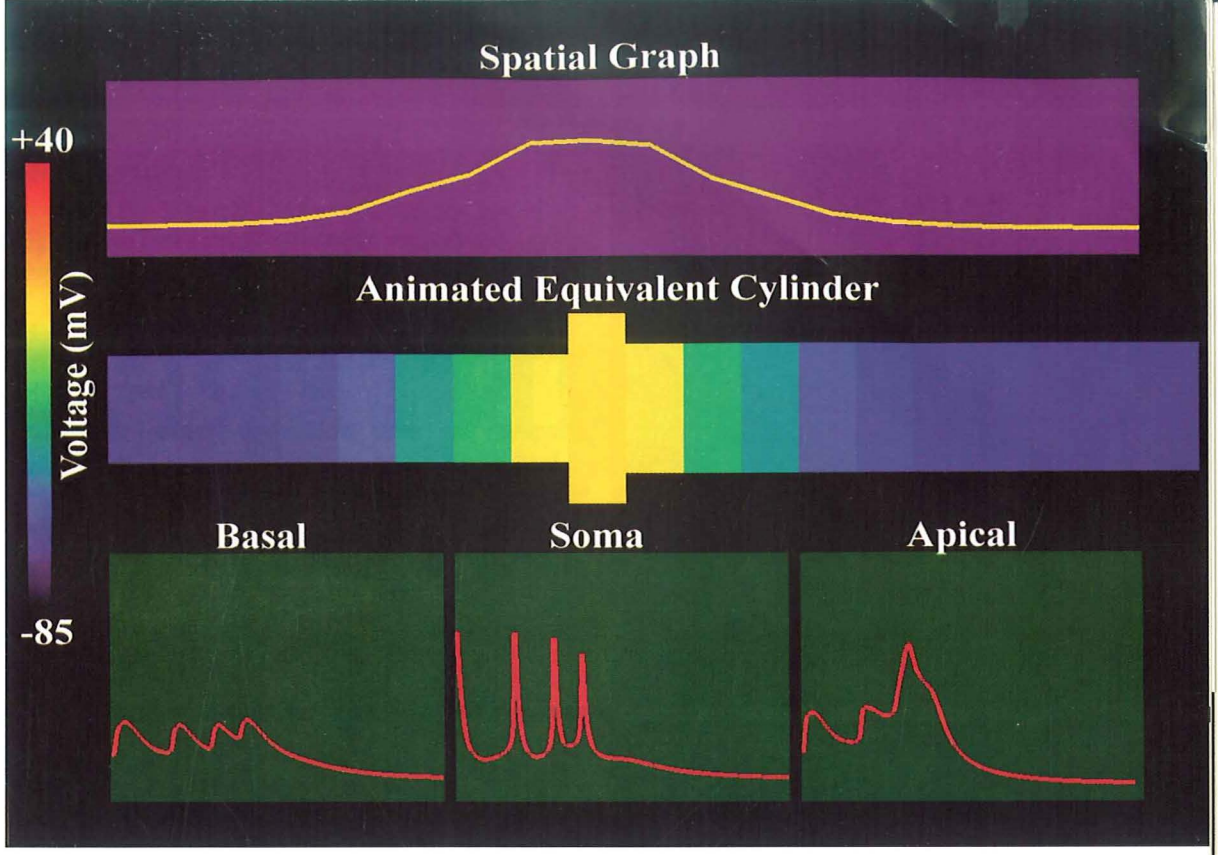
The structure of the computational model is analogous to its biological counterpart. In the computational model, a chromosome is represented by an array of data which contain the parameters corresponding to the optimization problem. The chromosomes can be combined using techniques such as crossover and mutation. Crossover involves pairing selected parameters of one chromosome with others of a second chromosome. In small-bit mutation, one parameter is randomly selected and changed.

The efficiency of genetic algorithms is derived from their use of a random population base of relatively small size. Each individual combination is evaluated and assigned a fitness score to indicate its correlation to the optimal solution. In Darwinian fashion, an extinction threshold is applied to determine which individuals survive the generation. Those that live are combined with other survivors through crossover, mutation, or reproduction to produce the next generation. The unfit population is removed and the process repeated using the new generation. Each generation is increasingly fit and approaches the optimal solution.

Rogene Eichler West, a Ph.D. candidate in neuroscience, has applied the genetic algorithm to solve a problem currently irresolvable by experimental methods: extracting an accurate simulation of the behavior of a neuron from randomly selected potential data.

Proteins embedded in the cell's membrane serve as the non-linear control units that determine the neuron's response to incoming information. The conductances of the ion-permeable channels formed by the proteins vary with the voltage level and calcium concentration. Because ions pass through them into and out the cell, the channels themselves are the main source of changes in the calcium concentration and voltage level. If the voltage level rises above a certain threshold, an action potential (outgoing signal) transports information to neurons downstream; if the calcium concentration reaches a designated amount, biochemical changes occur. These changes are thought to comprise the molecular basis of learning and memory.

Neuroscientists discovered these channels over 40 years ago, and even more types have been identified recently due to advances in pharmacological tools and electrophysiological techniques. In some cases, the temporal behavior of these channels can be modeled through the derivation of kinetic equations. However, given a desired set of neuronal behaviors, the spatial distribution of channels with varied kinetics along the morphology of the neuron cannot be determined experimentally. Using Eichler West's genetic algorithm method, the distribution can be accurately predicted. Preliminary work involves experimentally obtaining and digitizing the three-



A simplified representation of a neuron is used to search a 114-dimensional space. The spatial and temporal data series are played back as an animation so that the "fitness" of the GA-produced solutions can be verified. ***Graphic courtesy of Rogene Eichler West.***

dimensional morphology of a neuron. A partial differential equation based on this data is defined to model the flow of voltage and calcium within the cell. The morphology is then divided into six channel conductances: sodium, calcium, and four types of potassium. In a simplified model of a hippocampal neuron, 19 compartments were used for a total of 114 parameters.

At the initiation of the simulation, approximately five hundred individuals (parameter sets) are randomly generated from the pool of potential combinations. Each individual is run through the neuron simulator, a partial differential equation solver. The waveforms of the resultant time series, which describes five seconds of neuronal activity in response to an appropriate stimulus, are compared to experimentally obtained waveforms and assigned a fitness rating based on the degree of correspondence. The fitness score is sent to the genetic algorithm, which chooses the highest-scoring individuals to produce the next generation. Eventually, a generation is produced with a 100 percent fitness rate, and the optimal solution is achieved.

Eichler West uses the resources at the Laboratory for Computational Science and Engineering and the Minnesota Supercomputer Institute to evaluate this system through genetic algorithms. Because each parameter set can be simulated independently, the routines are suited to parallel processing. Supercomputers are employed to handle the magnitude of the problem. Even with the considerable computing power provided by a cluster of twelve Silicon Graphics R8000 processors, searching for the optimal set of parameters can require the simulation of more than 100,000 parameter sets and over a week of continuous processing. Running the same number of simulations on a Sun Sparc 2 processor would take more than a year.

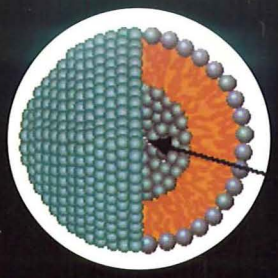
Eichler West's work benefits the fields of neuroscience, control theory, self-organizing systems, and nonlinear optimization. The results of her work will support and highlight genetic algorithms as a viable technique for fitting nonlinear parameters of computational models to experimental data. The method is efficient, reliable, and can be modified to change the number of parameters, the computational model, or the fitness measure.

In the future, the computational model could serve as a reference or complement to animal-based experimentation. Well-defined neuronal mechanisms could inspire adaptive systems such as robots and pattern recognition devices. Eventually, it could provide the impetus for the next development in the 40-year-old single cell modeling theory. ★

WorldWideWeb

For more information:

http://www.cs.cmu.edu/Web/Groups/AI...aqs/ai/genetic



INTERFACIAL ENGINEERING

Synergistic Partnerships between Industry and Academia

by Kari Siegle

Because funding for scientific research in higher education is declining, academia is joining forces with industry to create resources such as the University's Center for Interfacial Engineering.

Interfacial engineering focuses on the molecular interactions that occur at the boundaries of vapor-liquid-solid materials, which are present at every stage of microelectronic fabrication, as well as in optical and magnetic recording coatings. It also encompasses the processes, systems, and devices that work in the regions of these boundaries. Interfacial engineering pioneered the development of new composite systems offering materials with high strength-to-weight ratios for use in transportation and other fields.

The Center was founded in 1988 as a National Science Foundation Engineering Research Center. Supported by the University, the state of Minnesota, and industry, along with funding through 1997 by the NSF, it has an annual budget of over seven million dollars.

D. Fennell Evans, Center director and a professor of chemical engineering and materials science, said the Center exists to build a partnership between the University and industry and to more effectively educate students and carry out research between the two groups. The center focuses on three areas: research, industry and education.

Industry and Research

Over 50 companies, including 3M, Oak Ridge National Laboratory, Xerox, and Dow Corning, have formed industrial relationships with the Center. These partnerships support researchers who seek the answers to technical problems facing industry today.

Eighteen University of Minnesota faculty members serve as principal researchers at the Center. Participants in the Center's activities include members of the engineering departments in the Institute of Technology, researchers in the basic science departments of the Medical School, and clinical physicians. The Center's interdisciplinary approach, rather than the traditional individual or departmental involvement, makes it unique.

Matthew Tirrell, head of the chemical engineering and materials science department and program leader for the Center's bio-interfacial engineering program, noted that research at the Center is collaborative. Collaboration, he explained, also occurs in depart-

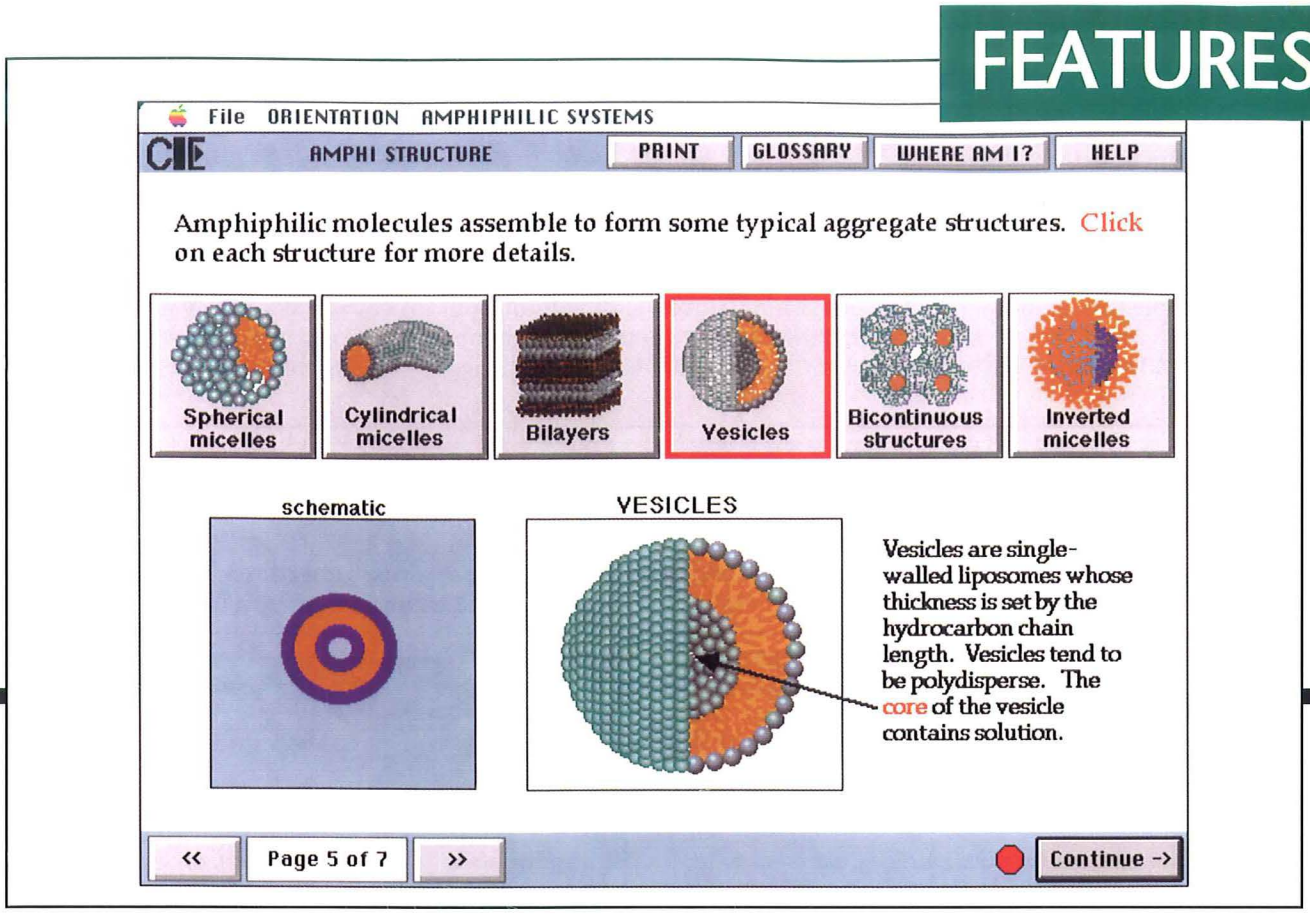


Illustration of the wide variety of structures into which amphiphilic molecules can assemble.
Graphic courtesy of the Center for Interfacial Engineering.

mental research, but it is generally applied to a specific aspect of the project late in its formation. At the Center, however, researchers begin to collaborate as soon as an idea is conceived. "It's not just 'where does our expertise run out?' but 'what can we really do?'" Tirrell said.

The biomedical interfacial engineering program studies medical devices and other specialty areas. Investigators are discovering how conditions at the tissues/implant interfaces affect biocompatibility, infection and bioactivation.

Jack Lewis, a professor of orthopedic surgery and mechanical engineering, said research at the Center involves a collection of people working toward a common goal: making the Center successful.

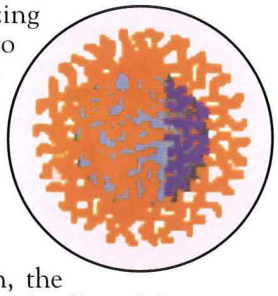
Lewis's group is studying how cartilage degenerates and how the cells reassemble it. Although he has worked at the Center for only three years, his research in this area dates back more than a decade.

"Most biological problems are so large and complex that it's difficult for one person to get far working on them on their own," Lewis said. Because group members have different techniques and areas of specialization, they can sometimes see what others have missed.

The Center also sponsors another group researching coating processes. Many products, including photographic and graphic arts materials and optical fibers, are dependent on these coatings. This group's goals include troubleshooting possible production problems, boosting production efficiency, computationally modeling coating processes, and producing coatings and films by liquid deposition and solidification. The researchers also study thin-film processing and investigate phenomena such as chemical vapor deposition.

The group studying polymer micro structures investigates interfaces that may be internal or external to the bulk structures. Internal interfaces are necessary in structures like membranes and polymer-impregnated ceramics; external interfaces are important in thin film application and adhesives. As a result of the molecular mechanisms and time-dependent processes associated with the construction of interfaces, current processing methods are not optimal. Research in this area is key to improving effectiveness and is relevant to industry.

In addition, the coating processes group studies surfactancy and self-assembly, which involve materials and processes such as detergents and lithography. Research areas include characterizing surfactant micro structures, developing a running computer simulation of the self-assembly, and process development.



Since its conception, the Center has invested 3.5 million dollars to create a state-of-the-art Characterization Facility, available for use by Center personnel. The

Facility houses electron microscopy, including a Scanning Transmission Electron Microscope (STEM) whose system allows for energy-dispersive spectroscopy and a video camera that allows magnifications of up to 10 million times actual size.

Also available are scanning probe microscopy, small angle neutron scattering and a neutron reflectometer, a high-speed video system, a coating process fundamentals laboratory, optical microscopy, and film characterization and x-ray scattering.

Because interfacial engineering is a specialization, it probably will not be an undergraduate major offering. "It's not a primary kind of engineering," Tirrell said, adding that it requires an extensive scientific background.

Education

"Recently they (NSF) have been more insistent with educational outcomes," said Karl Smith, an associate professor of civil engineering and the Center's associate director of education.

Evans believes that education should not rely on traditional lecture classes as it has in the past. "I think we should be doing something novel and providing a cutting edge where departments want to go," he said. "The challenge is how to use the teaching arena and use it in a way that preserves what is good and provides students with a richer learning environment."

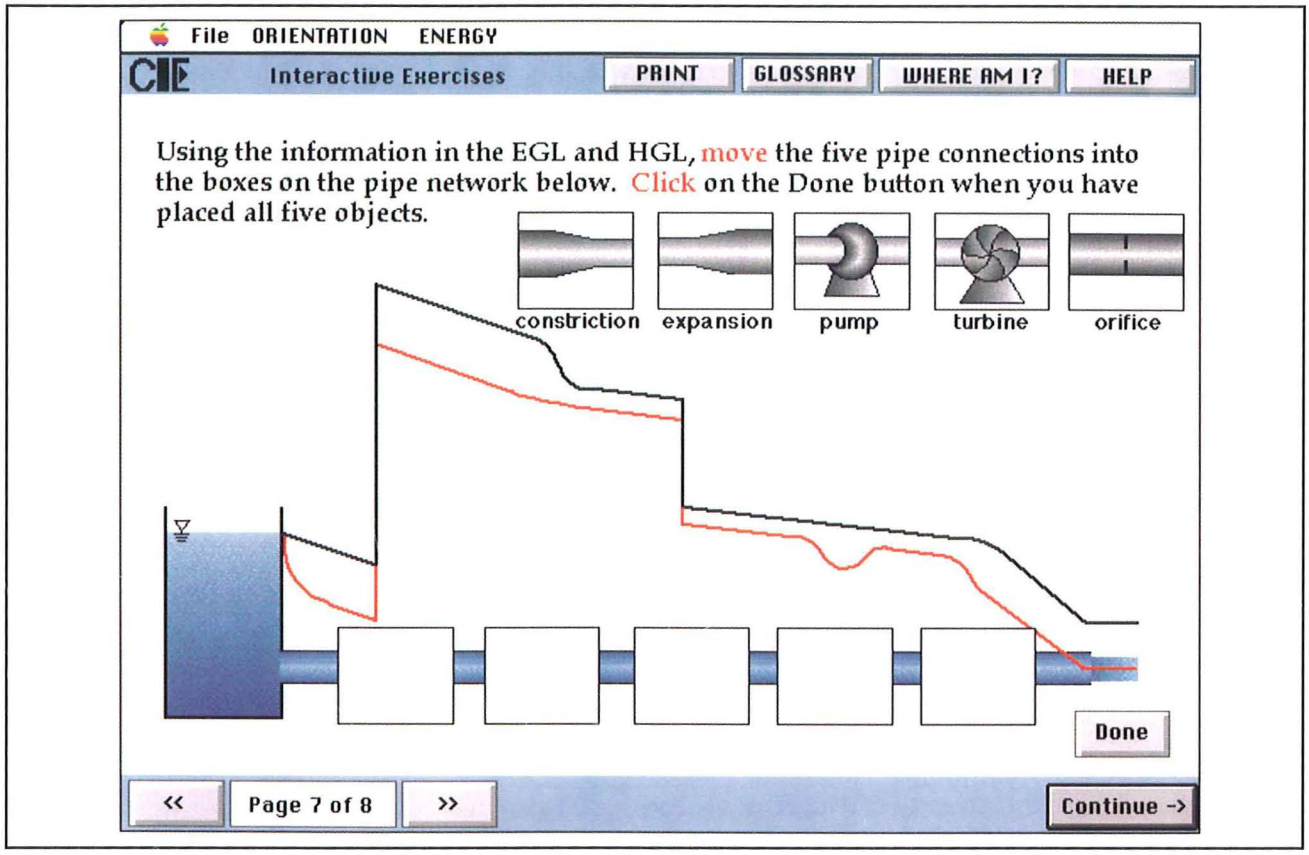
A lecture consists primarily of body language and signals given to students about what material is or is not important. "It's an effective way of transmitting information, but it's not an effective way of learning," Evans said.

Both Smith and Evans said that they think undergraduate students have a highly developed sense of visual learning, partly because they have grown up with television. "Words are the enemy and images are the friend," Evans said.

Using visuals is beneficial, Smith said. Evidence also indicates that allowing students to grapple with a problem and solve it before teaching them the underlying theory helps them to understand it better. The traditional approach, by comparison, is to teach the theory and applied science first before allowing students to practice solving problems.

Smith said the center is trying to integrate cooperative learning, in which small groups of students work together to solve problems. Problem-based learning involves giving students the problem first and then helping them find the solution to it. Using computer-based multimedia allows for a visual presentation of material that may otherwise be difficult to conceptualize.

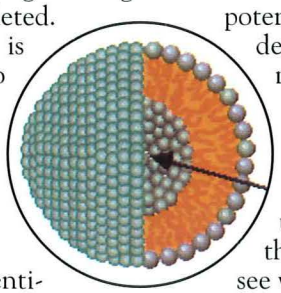
The Center is developing two projects, each with different aims and audiences in mind. One is an inter-



Discussion of the energy contained in fluids, a difficult topic to illustrate in static images.
Graphic courtesy of the Center for Interfacial Engineering.

facial engineering module intended for graduate students and engineers already working in industry. It is self-contained, meaning that it doesn't refer users to textbooks or other materials.

So far, eight modules of the upper graduate interfacial engineering project have been completed. The beginning module is the introduction to interfacial engineering. It explains the importance of and gives a general description of interfacial engineering.



The second module, entitled "Forces in Interfacial Systems", details fundamental concepts. After this module, the content is split into two sequences: fluid interfaces and solid interfaces.

Evans added that the modules could be used to complement a professor's lecture. The modules would provide the basic instruction, leaving more class time for discussion of projects and interaction between the students and the professor.

The program, which is icon-based, allows a story to be developed by putting required information in the icon and building off it. Key words are highlighted, and visuals dominate the screen. One module involves amphiphilic materials, which have polar and non-polar ends.

"There is a certain rock bottom of text and equations that are simply essential," said James Horswill, a Center consultant. Key concepts, he said, can be communicated entirely with pictures.

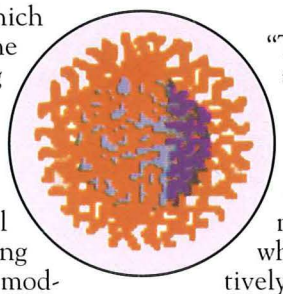
The modules are self-based, which means that viewers can proceed at their own pace. A paging routine allows viewers to back up to past information.

One limitation of the modules is the time needed to produce the material. Technology changes rapidly, and these modules alone have taken over two years to develop. Changes can be made to them, but they require a significant amount of time. The advantages, however, are also substantial. The second set of modules, whose subject is fluid mechanics, is programmed for the undergraduate sophomore level. Because all IT undergraduates except those majoring in electrical engineering and computer science must take a fluid mechanics course, "it has the potential for use by lots of students in lots of departments," Smith said.

Many students have difficulty understanding fluid mechanics, but using a computer allows them to guess and check to see what will happen with the information.

The module's introductory level assumes that the user has little previous knowledge. By clicking on any of eight images of pipe pieces, for example, the user can get a description of the parts. When new equations are introduced, previous equations are displayed to demonstrate the progression. In the future, the modules should have a practice problem for students that tests them on the material covered in each section. One exercise already developed involves placing different pieces of pipes into a row and observing one of the 12 possible outcomes.

These types of problems can be solved individually or by a group of students. Information on the screen can be printed, which eliminates for students the distraction of taking notes while trying to focus on the problem at hand.



Michael Mahler, a civil engineering senior working on the fluid mechanics module, said that its basic purpose is to allow users to choose the information they view. This freedom encourages users to explore and gives them a sense of control over what they learn.

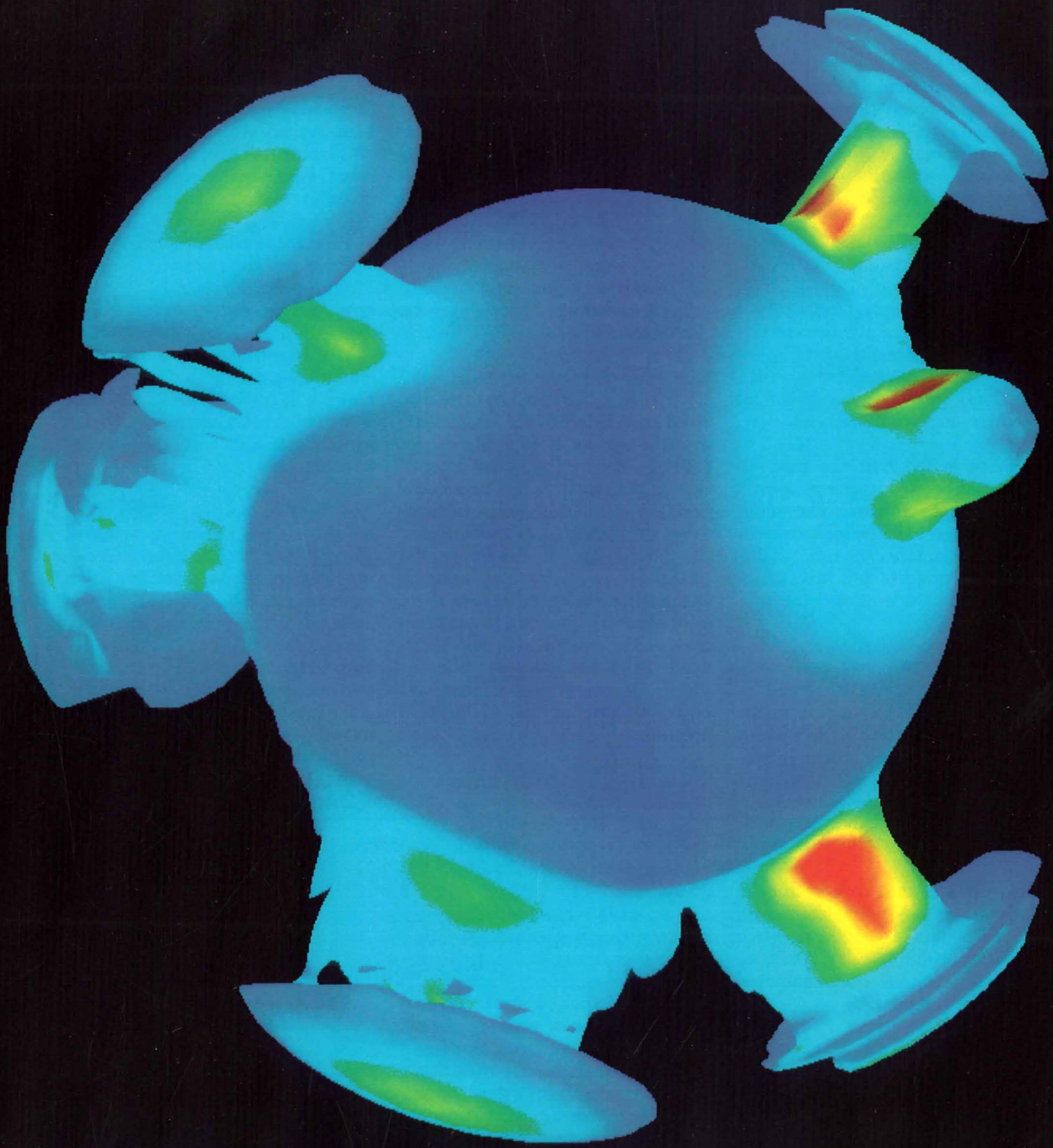
Mahler said that working with the modules offers him insight into the practical applications of the information he learns in his college courses, which tend to focus on theory. Evans said that the training undergraduates receive while working at the center helps them with their studies and later in life. He cited a review of 21 similar centers in the United States that compared the amount of time needed to find a job after graduation among students who worked in the centers and those who didn't. Of the students who worked at the centers, around 98 percent had jobs after they graduated, compared to just 60 percent of other students. Evans said that this research suggests that the centers have a considerable impact on students and their futures.

Future plans for the modules include developing a collection of chapters from which a program fitting the user's needs may be created, Evans said. Users would be able to indicate what they wanted to learn and at what level they needed to start.

This flexible learning system could be particularly useful in industry, where people need to learn information quickly for projects and other applications. Easy access to this material would improve their efficiency. At universities, this body of knowledge could also help eliminate one of the major barriers to undergraduate research: the time needed to teach essential background material. With this program, Evans said, a chunk of material specific to the undergraduate's needs could be found.

"That is not to say courses are not necessary," Evans advised. He said that some faculty like the new ideas while others don't, but instructors must ultimately choose whether and how to effectively use this type of technology in their courses.

"I'd a lot rather blow a million bucks and have an honest failure than have a lot of the same old stuff," he said. ★



Distribution of viscous dissipation along hot upwelling plumes. Viscous dissipation occurs due to the friction and shearing of moving masses in a fluid medium. The spherical shell model employed in this simulation considers the effects of phase transitions, fluid compressibility, and viscous dissipation. **Graphic courtesy of Shuxia Zhang.**

COVER STORY

Journey to the Center of the Earth

by Gregory Lauer

In a dimly-lit room cluttered with stacks of scribbled notes and scientific papers, candy wrappers and coffee mugs, researchers at the Minnesota Supercomputer Institute are quietly uncovering the secrets of the inner earth. Working with some of the most powerful computing equipment on the planet, the geological community is gaining a glimpse into worlds we cannot see with traditional tools and scientific methods.

The geologists of today are just as likely to be staring at the dull glare of a monitor as squinting at a sample of quartz or limestone. At the Minnesota Supercomputer Institute Dr. David Yuen, a professor of geophysics and scientific computation, and others are studying mantle convection.

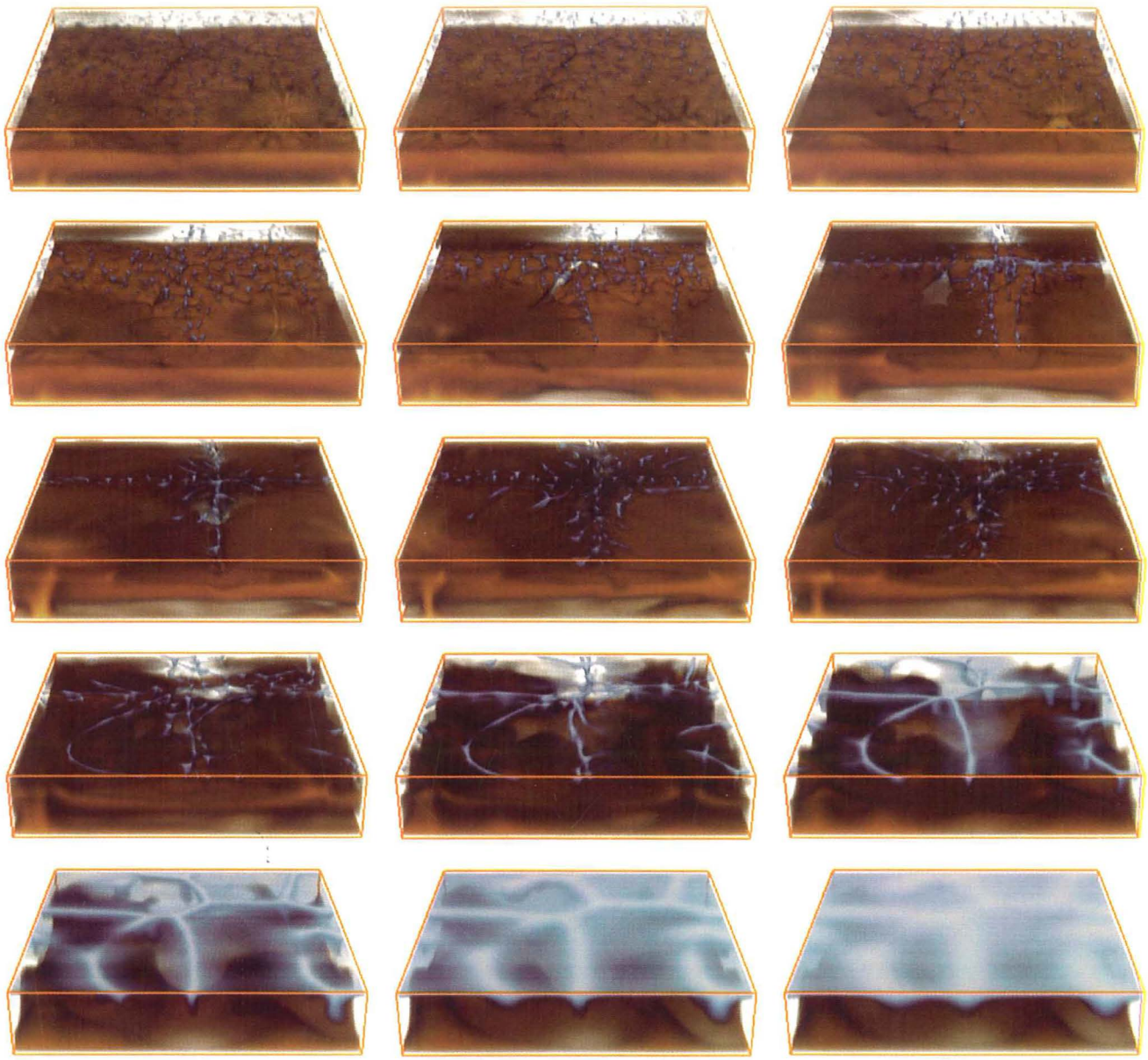
Background

As recently as the seventeenth and eighteenth centuries, it was believed that all of the Earth's features—mountains, valleys, and oceans— were formed as a result of several great catastrophes. Many thought these events had occurred relatively recently and matched the chronology of catastrophic events recorded in the Bible.

In 1795, James Hutton published *The Theory of the Earth* and proposed the Principle of Uniformitarianism. His revolutionary thinking laid the groundwork for a more scientific and rational approach to geology.

Then in the early 1900s, a virtually unknown German meteorologist introduced a new paradigm to the geological community. Alfred Wegener explained the appearance of similar fossils and rock formations on land forms separated by oceans, the jigsaw-like appearance of the continents, and several other puzzling phenomena with a theory now commonly known as plate tectonics. Wegener's ideas weren't completely accepted until the 1960s when mounting evidence from around the world supported his once-controversial thinking.

Using the theory of plate tectonics, scientists can explain the driving mechanism associated with the movement of the continents. It is believed that dense lithospheric plates containing the continents and ocean



Above: Time sequence of the development of the 3-D temperature fields in convection driven by a non-equilibrium coupling of the mantle temperature to the core-cooling and by time-dependent internal-heating. Sequence goes from left to right and from the top to the bottom row. The initial Rayleigh number was $2x10^7$ and the final Rayleigh number $2x10^4$. Internal-heating is effectively zero in the bottom two rows. The yellow hue indicates the hottest temperature, while the blue color denotes the coldest parts.
Graphic by Gregory Lauer.

basins "float" on the aesthenosphere. In a perpetual game of cat-and-mouse, the continents chase one another across the globe, powered by forces deep beneath the surface of the earth. Although the geological community has made giant strides in exploring and explaining parts of the Earth we can see and touch directly, our understanding of the Earth more than several miles beneath the surface is relatively shallow.

Investigating the composition, structure, and behavior of the mantle is one of the hot topics in geological research today. Because scientists can't study the mantle and the core directly, they must rely on other methodologies and techniques. Computer simulations and numerical models offer unique insights into processes we can't see or measure directly. Most promising, current modeling efforts may one day expand our understanding of continental drift and the cause of volcanoes, or even predict future earthquakes.

Computational Modeling

The computational models employed by Dr. Yuen and his researchers at the Minnesota Supercomputer Institute are based on the fundamental equations of physics—the conservation of mass, momentum, and energy. These mathematical expressions are repeatedly applied to a grid of data points representing a two- or three-dimensional model. After an initial condition is given, the solution is calculated with the aid of a finite element scheme.

The sheer size and complexity of fluid dynamical phenomena, such as thermal convection or the airflow past a Boeing 757, require substantial computational resources. With the supercomputers at the Minnesota Supercomputer Center, memory and speed are measured in hundreds of megabytes and billions of floating point operations per second respectively. Enormous amounts of data are generated from numerical simulations of mantle convection.

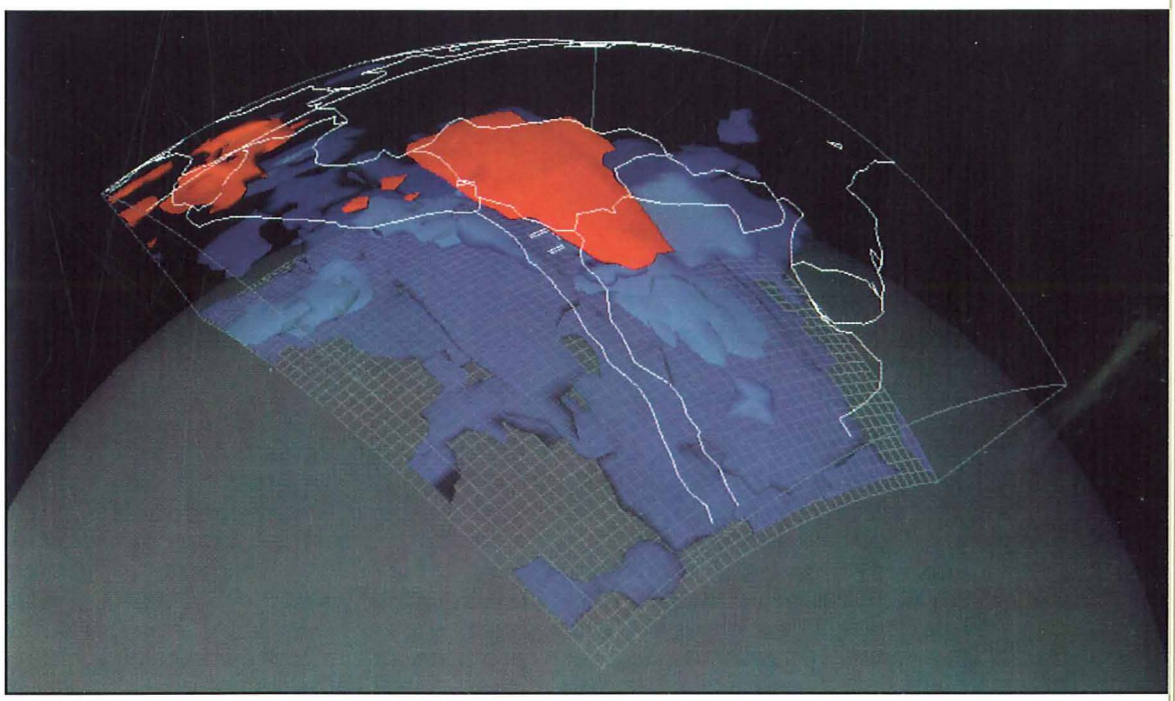
The computational models of Dr. Yuen et al. attempt to capture the salient details of the earth's mantle and core. Assumptions must be made, though, as the study of mantle convection is still in its infancy. Scientists simply don't know the rheological composition of the mantle, for example, or the details of the interface between the core and the mantle. Numerical laboratories like the Minnesota Supercomputer Institute offer researchers a unique opportunity to test hypotheses that cannot be investigated with more conventional experiments.

Many models of mantle convection rely on the assumptions of a constant core-mantle boundary temperature and a constant rate of internal heating. These simplified models, however, are not valid over a time scale of a few billion years because of the cooling of the core by mantle circulation. Additionally, the major radioactive elements in the mantle have a mean half-life of between one-fourth to two times the age of the present Earth. The heat emitted from the decay of these elements is an exponentially decreasing function; modeling internal heating as a constant may be a dangerous simplification.

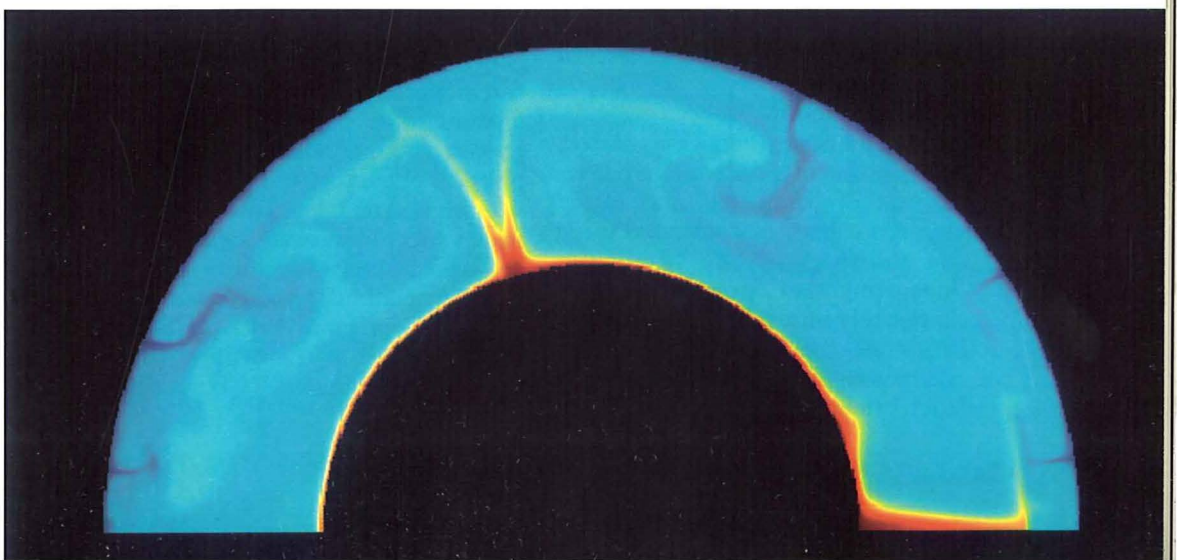
At the U of M, researchers are modeling the core-mantle boundary temperature and internal heating as time-dependent forcings of a mantle convective system. This non-equilibrium approach is considered more representative of the actual Earth, and results differ significantly from the behavior of models using standard equilibrium conditions. This method, however, is much more computationally intensive and difficult to implement.

The numerical grid representing the mantle is usually a non-dimensionalized Cartesian model, although recent efforts include the use of spherical shells. The depth of the mantle is typically estimated to be 2000 km.

From seismic analysis and other methods, geologists theorize the existence of two major phase transi-



Above: By carefully analyzing the velocities of P-waves generated from an earthquake, seismologists infer the composition and structure of the mantle near Bolivia. Red areas denote hotter material while blue hues represent colder, denser regions. ***Graphic courtesy of David Reuteler.***



Bottom: This model of convection in the earth's mantle reveals the process of megaplume formation (dark red areas). ***Graphic courtesy of Brigit Schroeder.***

Left: The powerful hardware at the Minnesota Supercomputer Center enables U of M reserachers to study computationally-intensive topics such as mantle convection. ***Photo courtesy of the Minnesota Supercomputer Center.***

tions. Material composition and properties and physical conditions such as heat and pressure change abruptly at these locations. The two principal phase transitions, olivine to spinel and spinel to perovskite, are located at approximately 400 and 670 km respectively. The buoyancy effect and the latent heat release at the phase transitions are modeled with an effective depth-dependent thermal expansivity. Using this approximation, the numerical model accounts for the background variation as well as the sharp variation in the zone in the immediate vicinity of the phase transition. The fineness of the model, i.e. the number of grid points, is increased in the vicinity of phase transitions to increase vertical resolution.

Once a numerical model is created, the response of a system to a particular set of parameters and initial conditions must be calculated using the resources of the Minnesota Supercomputer Center. Researchers do not rely on explicit equations to determine the behavior of mantle convective systems. Instead they "inch" their way towards a solution by calculating many intermediate points along the way.

At each timestep, the heat flux from the core is calculated and used in computing the new core temperature and the temperature drop across the mantle through an ordinary differential equation. A dimensionless timestep of 0.001 corresponds to approximately 127 million years in the evolution of the earth. These equations are applied repeatedly; in some of the cases, the number of timesteps required may run into the tens of thousands.

Results

Using advanced workstations like Silicon Graphics machines, researchers visualize the massive amounts of data produced in order to gain a better understanding of the physical phenomena of mantle convection and its related processes. A wide variety of software applications are used in preparing these materials. Specialized packages such as BOB (the program Brick of Bytes was developed at the nearby Army High Performance Computing Research Center) and more common spreadsheet applications like Excel are often used. The graphics contained in this article were all generated by researchers working under the direction of Dr. Yuen.

The efforts of Dr. David Yuen and his researchers at the Minnesota Supercomputer Institute offer a wide array of benefits. Work at the Institute is driving the development of ever more sophisticated and powerful computers. Most importantly, their work is expanding our understanding of geophysical processes deep inside the earth. ★

WorldWideWeb

For more information:

http://sop.geo.umn.edu

http://www.msi.umn.edu

Constructing a Computational Colossus

Above photo: Professors Tom Ruwart and Paul Woodward of the Laboratory for Computational Science and Engineering are silhouetted against the PowerWall. Four 1600-pixel by 1200-pixel resolution Electrohome video projectors display images in full color on a 6-foot by 8-foot screen. *Story begins on page 22.* ***Photo by Reed Lauer.***

A Visit to the Laboratory for

by Tom Ruwart and Paul Woodward

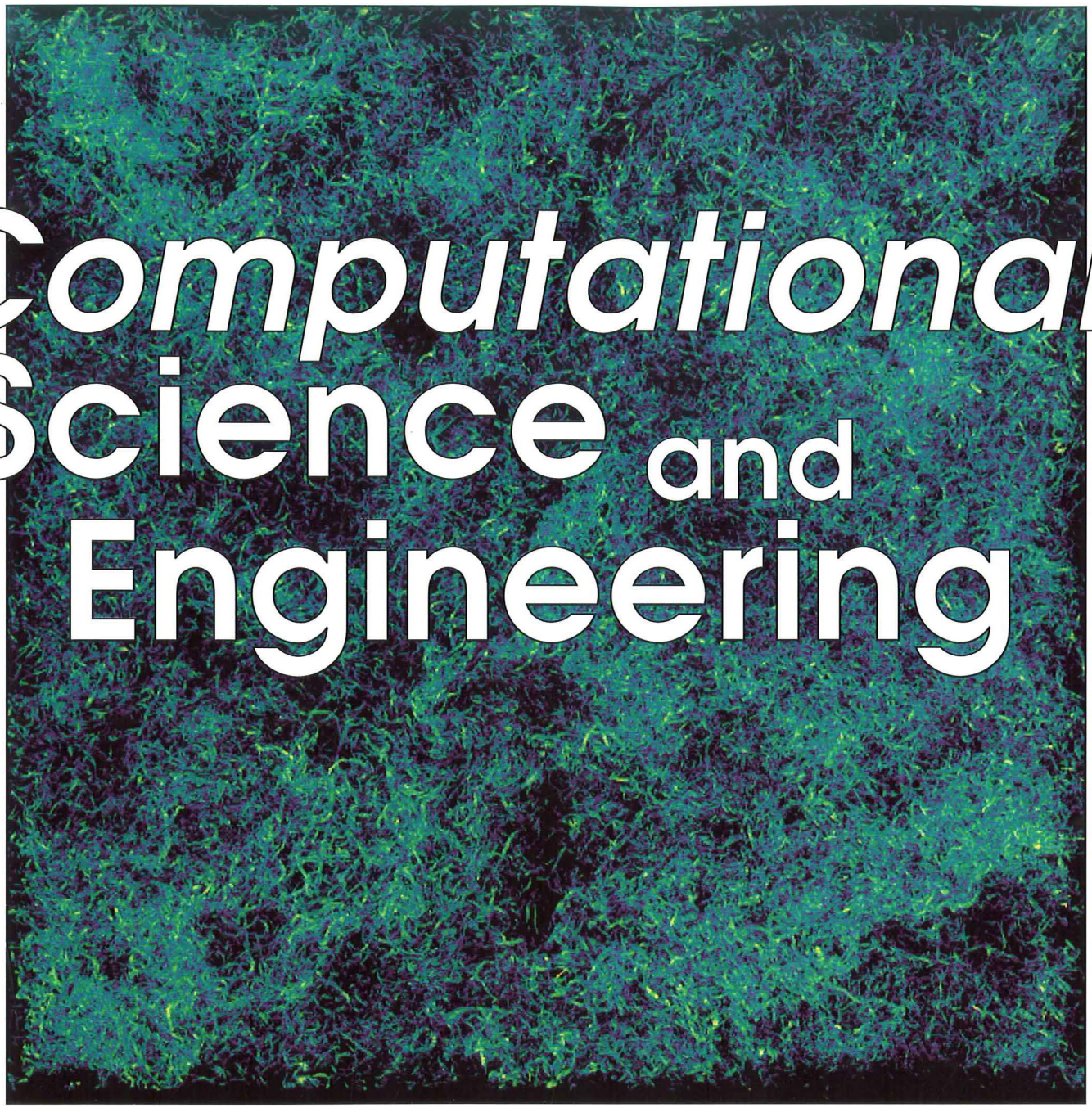
Ten years ago, in 1986, the state of the art in high-performance computing was defined by 1 GigaFlop/s supercomputer systems, 1 GigaByte 14-inch disk drives with 9 MegaByte per second interfaces, local area networks running at 10 MegaBits per second, and graphics engines capable of displaying images of 1280 x 1024 pixels on a single computer monitor at roughly 1 frame per second. A short 10 years later, the fortunate among us are now working with new computer architectures, storage subsystems, high-speed communications technology, and high-performance computer graphics capabilities which make the supercomputers of 1986 look like PCs. In the high-performance computing world of today, clusters of shared memory multiprocessors (SMPs) run at speeds in the tens of GigaFlop/s, 3.5-inch disk drives with dual 100 MegaByte per second interfaces hold 8.7 GigaBytes each and can be combined into single disk array subsystems with TeraByte capacity and 500 MegaByte per second transfer rates, local area networks run at 1000 MegaBits per second, and computer graphics systems display images with 3200 x 2400 pixel resolution at 15 frames per second. Researchers at the Laboratory for Computational Science and Engineering (LCSE) have played and continue to play an active role in the development of these technologies as well as applications and system software which exploit them.

The Laboratory for Computational Science and Engineering (LCSE) is a new facility located in the basement of the Electrical Engineering and Computer Science building on the University's East Bank campus. It is directed by Professor Paul R. Woodward, of the Astronomy Department, and by assistant directors Professor Matthew T. O'Keefe, Electrical Engineering, and Thomas M. Ruwart, Astronomy. Formed in June of 1995, the LCSE provides a facility in which innovative hardware and system software solutions to problems in computational science and engineering can be tested and applied. The LCSE is built around strong and long-standing collaborations between Laboratory researchers and the computer industry. It also has a mandate for outreach to industries which now use or would like to use high-performance computing to expand their capabilities. Although the Laboratory builds new combinations of computing elements and experiments with new computing paradigms, the LCSE combines these functions with applications of the new technologies, and thus provides significant high-performance computing resources to its users. The LCSE has a broad mandate to develop innovative high-performance computing technologies and capabilities in computational science and engineering.

The LCSE has a unique relationship with several leading-edge computer technology companies which provide the LCSE with state-of-the-art computer hardware and software on a loaner basis or, in some cases, as donations to the University of Minnesota. Loaned equipment is returned at the end of the loan period, typically in 9 to12 months, to be replaced by newer, current equipment. Although the University does not own this loaned equipment, these loans have distinct advantages. The equipment is continually upgraded, and it is maintained by the lending company. The benefit in this arrangement for the sponsoring company is the access which is provided by the LCSE to its environment for collaborative work. Such a collaboration might be a proof-of-concept demonstration of the capabilities of the new equipment for demanding applications from federally funded research projects of LCSE investigators. Those research projects benefit, in turn, from use of the latest equipment in the LCSE. This synergy of government and industry, catalyzed by the LCSE, can result in new research capabilities for the government and in new product concepts for the participating industries. This bringing together of industry- and government-sponsored research in a development lab rather than a production computing facility gives the LCSE its special flavor.

The LCSE has its roots in the research group of its Director, Paul Woodward, and in the associated work in the group of Assistant Director Matt O'Keefe. Research grants from the National Science Foundation (NSF), the Department of Energy (DoE), NASA, and the Office of Naval Research (ONR) provide the core applications which drive developments in the LCSE. A special research project with Silicon

Computational Science and Engineering



A volume-rendered image of the billion zone (1024x1024x1024) CFD simulation done by ***David Porter*** *for the CHALLENGE Array Project. This simulation ran for five days and produced 800 GigaBytes of data of which this image represents about 1 percent.*

Graphics and the Army Research Laboratory which involves Distributed and Virtual Shared Memory technology has resulted in a 12-processor Silicon Graphics Power Challenge machine with 2 Gbyte memory being provided in the lab. Recently, the NSF awarded to the LCSE a MetaCenter Regional Alliance grant which explicitly integrates the LCSE into the NSF Supercomputer Centers Program. In addition to industrial and K-12 outreach components, this MetaCenter Regional Alliance focuses on the new supercomputer architecture represented by clusters of shared memory multiprocessors (SMPs), like the LCSE's two major Silicon Graphics machines. The LCSE is open to suggestions from IT faculty for further collaborative projects which can leverage the lab's resources and enhance its activities. Some representative projects carried out by LCSE researchers in collaboration with the computer industry are described briefly below. These projects began before the founding of the LCSE and provided a major impetus for the formation of this new lab.

The CHALLENGE™ Array Project

The CHALLENGE™ Array Project was conceived in 1993 out of the need to perform a single

Computational Fluid Dynamics (CFD) calculation that was too large to fit on any computer on the planet at that time. The Woodward Research group worked with Silicon Graphics, Inc., to construct an array of 16 CHALLENGE™ computer systems each with twenty 100Mhz R4400 processors and 1.75 GigaBytes of memory, for a total of 320 processors and 28 GigaBytes of main memory. The computer systems were then connected together via a 3D torus using a network of 20 FDDI rings. A three-dimensional simulation of homogeneous, compressible fluid turbulence on 1024 x 1024 x 1024 mesh points, or more than one billion volume elements, was spread across this array of computers, and the calculation was set in motion. After five days of continuous computation, the simulation generated more than 500 GigaBytes of data and performed at a rate of more than 4.9 GigaFlop/s. Putting this into perspective, the same CFD code ran at roughly 7 GigaFlop/s on the 512-node Thinking Machines CM-5 at the University, the second largest supercomputer of its kind.

In an LSCE open house in December, 37 disk arrays were connected to a single Silicon Graphics machine to test read and write capacities. ***Photo by Reed Lauer.***

Research on the CHALLENGE™ Array continues at the LCSE with the Woodward Research Group as part of a project involving the Army Research Lab (ARL) in Aberdeen, Maryland, and Silicon Graphics. A 12-processor POWER CHALLENGE™ machine with 2 GigaBytes of main memory, provided for this research project by ARL, is a core part of the LCSE equipment infrastructure. Together with an 8-processor POWER Onyx on extended loan from Silicon Graphics, Inc., a small "array" of shared memory multiprocessor machines (SMPs) can be built and customized to research use in the LCSE. Work on SMP clusters in the LCSE is also directed towards support of this new computing paradigm at the National Center for Supercomputing Applications (NCSA), through the NSF MetaCenter Regional Alliance program, and at the Department of Energy's Los Alamos and Livermore laboratories, through the DoE Accelerated Strategic Computing Initiative (ASCI).

The M.A.X. Project

In April of 1994, the I/O Systems Research Group from Electrical Engineering, led by Professor Matt O'Keefe and Tom Ruwart, of the Woodward Research Group, constructed an experiment to test the Maximum Achievable transfer (Xfer) rate (MAX) of a Silicon Graphics Onyx computer system. For this test, 31 Ciprico disk array controllers were connected to an Onyx at the Army High Performance Computing Research Center (AHPCRC) on 31 independent 20 MegaByte per second SCSI channels. Each disk array was then turned on, one at a time, until all 31 were transferring data. The maximum sustained transfer rate was measured at 509.8 MegaBytes per second. Furthermore, the speedup was linear from 2 to 31 disk array controllers and showed no signs of dropping off.

The M.A.X. project was only one in a number of development projects involving fast I/O subsystems which have been carried out over the years by researchers now at the LCSE. The most recent of these projects involved the demonstration of a TeraByte disk file system at the Supercomputing '95 conference and in the LCSE in December 1995. This time 37 disk arrays, mostly from MTI, a sponsor company based in Chicago, were connected to a single Silicon Graphics machine. Disk reads of 520 MByte/sec and writes of 200 MByte/sec were demonstrated at an LCSE open house on the week before Christmas.

The applications driving these I/O system developments in the LCSE involve the interactive visualization of very large data sets either from computer simulations or from physical experiments. The computer simulations include turbulent convection in the sun (Woodward's group), circulations in the world's oceans (O'Keefe's group), and convection in the earth's mantle (Yuen's group). Observational data sets include the digitized Palomar sky survey, from Roberta Humphreys' Automated Plate Scanner project in the Astronomy Department, and digitized microscopy of the brains of rats and mice, from George Wilcox's Brain Project in the Department of Pharmacology.

The PowerWall

Developments, like those outlined above, in supercomputing power and in the I/O subsystems which store the data from computer simulations have made possible very high resolution simulations and the voluminous data sets which record the results. However, computer graphics display technologies have not kept pace with these trends. In the last decade, high resolution computer monitors have grown

The Laboratory for Computational Science and Engineering has a broad mandate to develop innovative high performance computing technologies and capabilities in computational science and engineering.

from 1280x1024 pixels to only 1600x1200 pixels, an embarrassingly meager advance for so long a time. The PowerWall Project addresses this issue by parallelizing the display of high resolution images and/or animation data across multiple computer systems running multiple graphics engines. These drive multiple rear projection monitors that illuminate a single large screen. The result is a single display with a resolution of 3200x2400 pixels (or more, given enough equipment).

The first PowerWall was demonstrated at the Supercomputing '94 conference in Washington, D.C., in November 1994. The construction and demonstration of that prototype system was a collaboration of the research groups of Woodward and O'Keefe with Silicon Graphics, with support from the AHPCRC, the DoE, NSF, NASA, and ONR. Since that demonstration, Silicon Graphics has included the PowerWall in its product literature, and a number of PowerWalls have been proposed or are in the process of being constructed at various sites around the country. The first of these PowerWalls is now in the LCSE, funded as part of a recent NSF CISE Research Infrastructure grant through the Minnesota Supercomputer Institute (MSI) and the Department of Computer Science. This PowerWall is available to all MSI researchers.

Current Projects

The three projects listed above serve to give a flavor of the work which forms the principal focus of the LCSE. Each involves extending the limits of high performance computation utilizing the combined efforts of University researchers and industry. In the SMP cluster computing project, a government lab, ARL, is also involved. Collaborations of industry, government labs, and the University are increasing in importance at the LCSE because of the effectiveness which can be achieved when all these resources are applied in a coordinated fashion to a technological problem. LCSE researchers have proposals pending for two such programs, the NASA Grand Challenge Applications program and the DoE Accelerated Strategic Computing Initiative. One active current project serves to illustrate this category.

Transcontinental Distributed Computing on Clusters of SMPs

In developing application software for SMP clusters like the Silicon Graphics Power Challenge Array, LCSE researchers have devised methods for restructuring more traditional application codes so that the relatively high latencies and low bandwidths of the SMP cluster network do not substantially reduce code performance. These methods, if aggressively applied, can lead to tolerance of latencies of 1/10 second and network bandwidths of as little as 5 to 10 MByte/sec. These relaxed network requirements could be used to allow the implementation of a very low cost network, or they could be exploited to allow extension of the SMP cluster network over transcontinental distances using ATM OC-3 channels with bandwidths above 5 MByte/sec. This second alternative is of great interest to agencies like the NSF, DoE, and DoD, which must distribute high-performance computing resources among widely separated centers, but which would nevertheless like to combine these resources upon occasion in order to achieve unique computing capabilities. In collaboration with NCSA, the Army Research Laboratory, and Silicon Graphics, the LCSE is working to demonstrate this capability on tightly coupled fluid dynamical simulations.

Summary

The LCSE is engaged in a wide range of research projects. This new lab focuses mainly upon collaborative projects in which government-sponsored basic research at the University of Minnesota can benefit from involvement of industry and the development of new high-performance computing technology at the LCSE. ★

If you are interested in becoming involved in the LCSE programs, contact Ms. Julia Sytine at 625-4097.

For more information:

Visit the Laboratory for Computational Science and Engineering's web site at

http://www.lcse.umn.edu

Threads of the Web: *Students, Staff, the U and the Web Policy*

by Alyson-Kathleen Riley

An integral component of every technology is the human factor, the way humans think about, regulate and use their technologies No technology can exist without social or political implications, and recent University of Minnesota policy decisions illustrate the ways in which hard technology is tied to greater social issues. In response to recent government action and proposed legislation, the U recently adopted a WorldWideWeb (WWW) policy that outlined standards for individual and departmental pages supported by University servers. But the policy did not go unquestioned. As U staff and students reexamine their webpages, technology is once again forced into the spotlight of public discourse; issues of freedom of expression, academic responsibility and the role of government are discussed in conjunction with the development of this relatively new technology.

WebHistory: The University

"The initial WWW server was in prototype in December 1993," said Frank Grewe of Central Computing Services (CCS). "Over the course of the first several months, it became clear that the technology was one with a huge future potential for serving the University community." To begin integrating the WWW into campus computing services, Grewe organized the first meeting of the Twin Cities campus WWW Advisory Committee on May 4, 1995. "My motivation for that first meeting was to involve the experts at the University for the design of our Web structure and content," said Grewe. In a lengthy collaborative effort, CCS technical experts, library personnel, and individuals from University Relations began to orchestrate webpage structure and style for the U. A little under a year later, the committee created system-wide homepages for the University of Minnesota, promoting use of the WWW on campus with the help of Distributed Computing Services (DCS). DCS was also to play an integral role in the next step with the WWW Advisory Committee: The creation of the University's WWW policy.

On September 27, 1995, *The Minnesota Daily* published the first article in a series that focused on the newly-created University Web policy. The article detailed a university student's negative response to the first version of the policy. The original policy included a clause that mandated placing disclaimers at the top of every individual and departmental homepage and a ban against webpage content that included material or links deemed "offensive" by University administrators. This section of the policy in particular sparked what would become a serious debate campus-wide over issues pertaining to policy semantics, freedom of expression and individual responsibility.

The most visible argument against this Web policy could be found in *The Minnesota Daily*, which featured a story on October 25 that focused on one professor's claim that the University Web policy at that time was unconstitutional and illegal. One month later, on November 27, the *Daily* announced that the WWW Advisory Committee had rewritten the University Web policy. The word "offensive" was omitted in favor of less politically volatile wording. Simply put, the new policy states that all University-supported homepages must comply with University policies and all federal, state, and local laws.

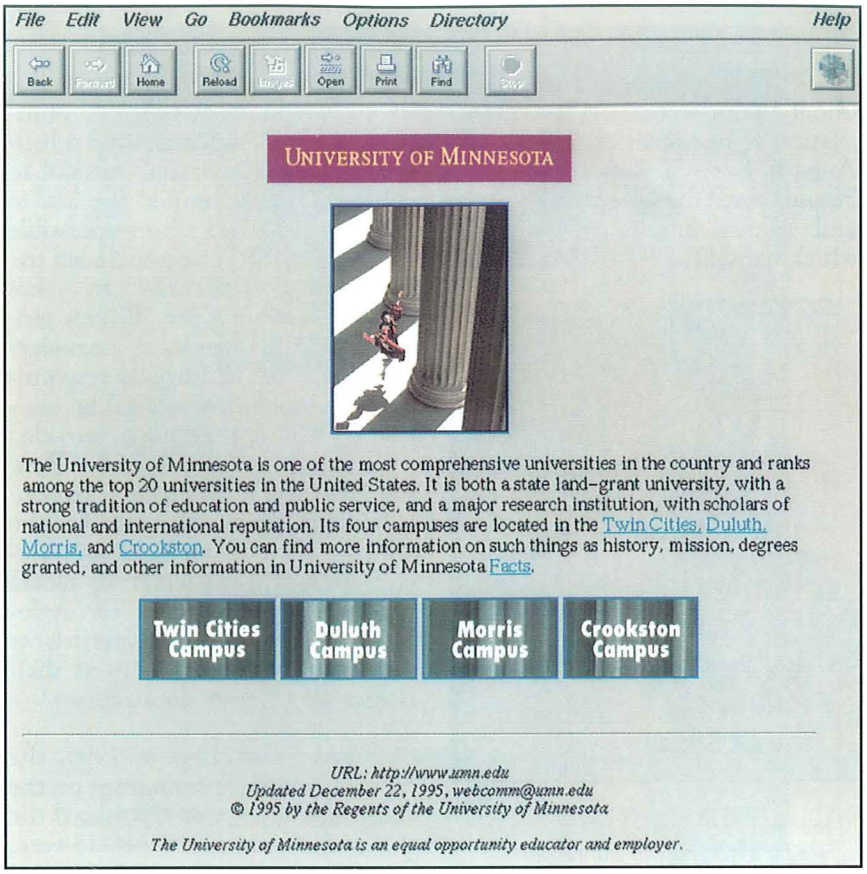
WebHistory:
The Federal Government

So what are the federal, state, and local governments saying about the legal issues connected to the WorldWideWeb? That remains to be seen. There are several proposed amendments to the Telecommunications Bill facing the Senate that will have a profound effect on the University's Internet policies services.

In the summer of 1994, Senator Jim Exon (D-Nebraska) attempted unsuccessfully to pass a Communications Decency Act that would have allowed the federal government to censor online material. After this attempt failed, Exon reappeared the following February to tack his Communications Decency Amendment onto the Telecommunications Bill, equipped with a collection of "obscene" pictures and other materials he had collected through some extensive web-surfing on his own. During this time, Senator Patrick Leahy (D-Vermont) offered counter-legislation that proposed implementing a joint study between the Department of Justice and the Department of Commerce that would research the ways in which users might be able to determine which materials they receive from the Internet, as well as determine to what extent laws are necessary to govern individual behavior in cyberspace. Leahy's proposals were unsuccessful.

On July 14, 1995, the Senate passed Exon's Communications Decency Amendment S.314 to the Telecommunications Bill, mandating fines of up to $100,000 and prison terms of up to two years for individuals found placing "obscene, lewd, lascivious, filthy or indecent" material on the Internet. Content deemed "harassing" in nature was also prohibited. In addition, the Federal Communications Commission (FCC) would be given broad powers to regulate the content of the Internet and hold Internet service providers responsible for illegal material posted by their clients.

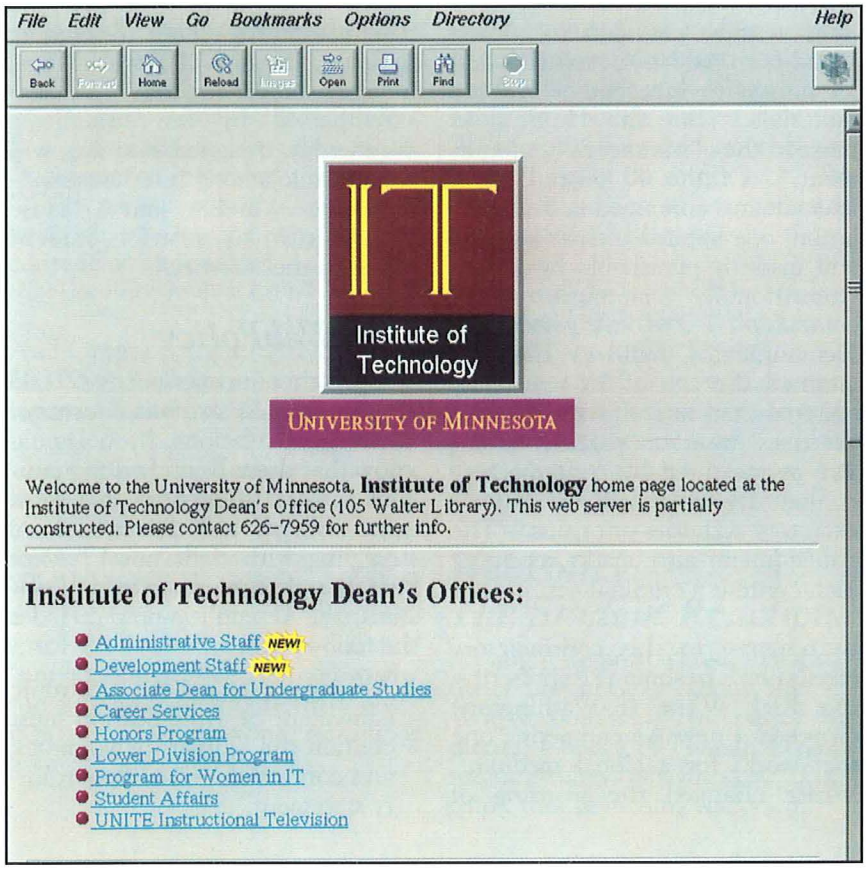
Once Exon's Amendment reached Congress, however, Speaker Newt



Taken directly from the WorldWideWeb

Above: The University of Minnesota's homepage.

Below: The Institute of Technology homepage.



Gingrich declared the proposed legislation to be unconstitutional. On August 4, in a 420-4 vote, the House passed the "Internet Freedom and Family Empowerment Act," which barred the FCC from regulating the Internet (and other interactive media) and removed the responsibility from online service providers for Internet content as long as these providers had made "good-faith" efforts to restrict access for minors to indecent or obscene materials. But the House also passed the "Manager's Amendment." Of the 40 miscellaneous amendments contained in this legislation, one applied to Internet use, and made it punishable by law to "intentionally communicate by computer . . . to any person the communicator believes has not attained the age of 18 years, any material that, in context, depicts or describes, in terms patently offensive as measured by contemporary community standards, sexual or excretory activities or organs." The Amendment also made receiving such content a criminal act.

Don Riley,
interim Chief Information Officer
for the University of Minnesota.
(Photo by Reed Lauer)

In response to this contradictory legislation, freshman Representative Rick White (R-Washington) proposed a new Amendment, "one that works for a global medium." White changed the wording of Exon's original amendment, omitting the word "indecent" and substituting it with "material harmful to children." This limited the law to content published for or accessible to minors. White also included the "good-faith" clause in his Amendment. Under White's proposal, online service providers would not be held legally responsible for violations occurring as a result of client activity provided they meet two requirements. First, the providers must make a "reasonable effort" to prevent minors from viewing harmful material and second, they must attempt to create "parental empowerment technologies" that would allow parents to regulate what material enters their homes via Internet connections.

On Wednesday, Dec. 6, 1995, the House conference committee on the Telecommunications Bill passed the White Amendment in a 20-13 vote, but with some important changes. It allowed for the original $100,000 fine limit and the two-year prison terms for offenders, and rewrote "harmful to children" to read "indecent." Now this metamorphosed White amendment is facing the Senate, awaiting a vote. According to Steve Pizzo of Web Review News, industry sources say that "the measure passed by the committee Wednesday, if signed into law, will create panic among Internet service providers and may cause Universities to restrict student access to the Internet."

The WebPolicy

"To put this into perspective," said Sharon Grimes, assistant director of University Relations, "you should know that these issues [writing policies] . . . are something that most other colleges and universities are struggling with right now." After having undergone some initial revisions, the U's policy now includes the following:

- All pages that are the electronic equivalent of a publication must contain the University wordmark and contain the equal opportunity statement.
- All copyright laws apply to electronic pages.
- University-supported Web pages may not be used for personal business or personal gain.
- The following statement must appear on all personal pages and student organization pages: *"The views and opinions expressed in this page are strictly those of the page author. The contents of this page have not been reviewed or approved by the University of Minnesota."*

It is the following section of the policy, however, that seems to be causing the greatest deal of concern among members of the University community: *"Units may create electronic home pages . . . that . . . support . . . the University's mission. Contents of all electronic pages must be consistent with University of Minnesota policies and local, state, and federal laws. This includes links to other pages or computers. In other words, a page may be considered in violation if it contains links to a page that violates the policy."*

WebPolicy: The Official Position

University administrators have been quick to respond to the issues surrounding the recent implementation of the Web policy. A publicly-accessible University Web site outlines the policy in its entirety and explains the rationale behind policy decisions. The main goal of the policy is to protect the University of Minnesota legally and to set "minimal standards that are meant to ensure that information published electronically is visually appealing and well written and follows the same high standards as other forms of published information." Administrators recognize that the quality and content of webpages supported by its servers reflect and represent the University as a whole. "I'm happy to see the Web viewed as simply another media for publication and as such subject to the same rules as traditional media," said Grewe. "This 'keeps it simple' for

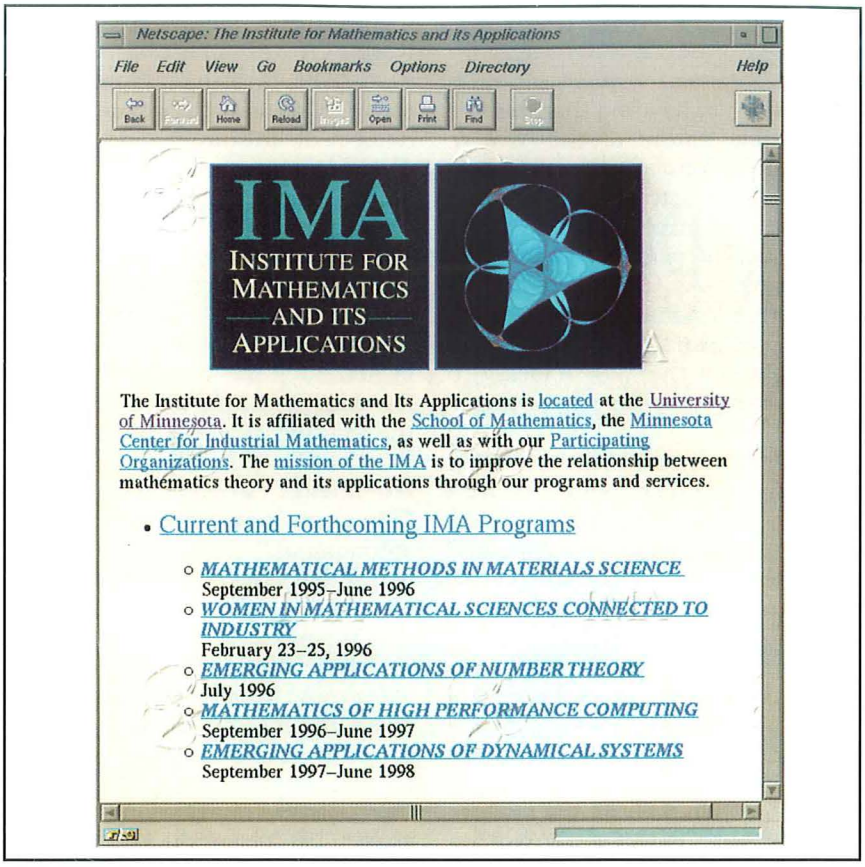
departments and other official groups in determining the approach they use for Web development."

According to Grimes, the University Policy Development Office followed several principles in the construction of the current Web policy. The end goal of the policy was to promote use of the WWW on campus that supports the mission of the University of Minnesota, that encourages freedom of expression and inquiry, that is consistent with all laws and applicable University policies, and that finds a balance between the above three principles.

The official University standpoint on electronic publishing is positive. The policy itself states that the "University of Minnesota recognizes the value and potential of publishing on the Internet, and so allows and encourages students, staff, and faculty to publish electronic information." The goal of the policy is not to prohibit, but to protect. Interim Chief Information Officer for the University of Minnesota, Don Riley, concurs. The U provides "E-mail and Internet services in support of . . . education," he says, but "ultimately, with privileges . . . come responsibilities."

The University currently does not review the contents of webpages supported by its servers. It is a webpage author's responsibility to ensure that all contents meet the U's Web policy specifications. "There has been a lot of concern in the academic community about the impact of the proposed bills. But we don't want to have to worry about being put in the role of policemen," Riley observes. "The University has thrived on the concept of freedom of speech and academic discourse and we really don't want to have to be watchdogs."

The legalities of Internet use are the most ambiguous. "There are enormous liabilities potentially for [Internet] service providers," Riley notes. "To the extent that we provide an email account and Web



Taken directly from the WorldWideWeb—the Institute for Mathematics and Its Applications (IMA) homepage.

URLs . . . for students and faculty, that allows us to potentially be considered a service provider and to be held legally responsible for the content of those pages."

Grimes agrees. "My understanding is that the online service [provider] that says it DOES review contents might be held liable if someone objects to the content of information . . . . One that does not review isn't."

And Grimes is right. A November 28, 1995, *Wall Street Journal* article reported that a federal judge recently ruled that Netcom Online Communication Services may be liable for copyright infringement because it failed to remove copyrighted material posted by a client. While Netcom lawyers argued that the service was merely "renting" space to clients, the judge ruled that "providing a service that allows for the automatic distribution (of postings) goes well beyond renting a premises" (Section B1).

For many critics of the U's WWW policy, the main concern is censorship. But Riley is convinced that is not the point. "You are free to speak or do whatever you want; you're just not free to speak or do whatever you want on publicly-funded facilities. We're not telling students they can or can't say or do things . . . . We reserve the right to set standards, not to censor," Riley asserts.

In the end, the issue will be resolved by federal legislation. "I don't know what impact future legislation will have on this," Grimes comments. "The University does have to comply with applicable laws." Until that time, the University of Minnesota's Web policy stands.

WebPolicy: The Student Reaction

As might be anticipated, many students are nervous about the U's WWW policy. "The policy has merit," College of Human Ecology senior Andrew Jenkins says. "But I think they're missing the point."

For Jenkins and others like him, the idea of placing limits on the capabilities of Internet communication is frightening. They find that the free and public nature of the WWW communication forum is one of its strongest characteristics. To try to restrict the Internet would be a major loss of personal freedom of expression. As College of Liberal Arts senior Valéria Storch observed, "Once you start putting limits on some parts of the Web it's easy to start putting limits on other things."

One of students' main concerns with the U Web policy centers around the section that prohibits "links to other pages or computers" that themselves "violate the policy" (for example, linking to a page whose content is considered to violate the University sexual harassment policy is a violation of University policy). This could have a ripple effect. In a web-like, interconnected environment, it is not hard to accidentally link a page to another page that covertly violates the policy by containing another link to a page violating the University Web policy.

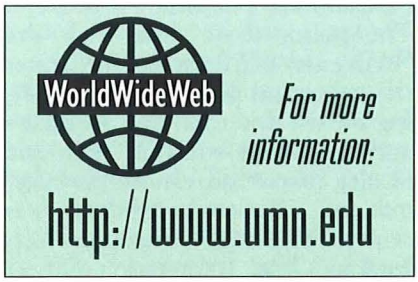
College of Liberal Arts senior Rogers George notes that "the policy can be recursively applied. If there exists a path involving any number of links from your pages to an offending page, then again, technically, your page is in violation. The policy, as it is currently written, effectively prohibits links to any outside pages. From a link to Yahoo [a search engine] you could go anywhere. I know that's not what they meant, but if the wording of the policy doesn't match intentions then the wording should be fixed."

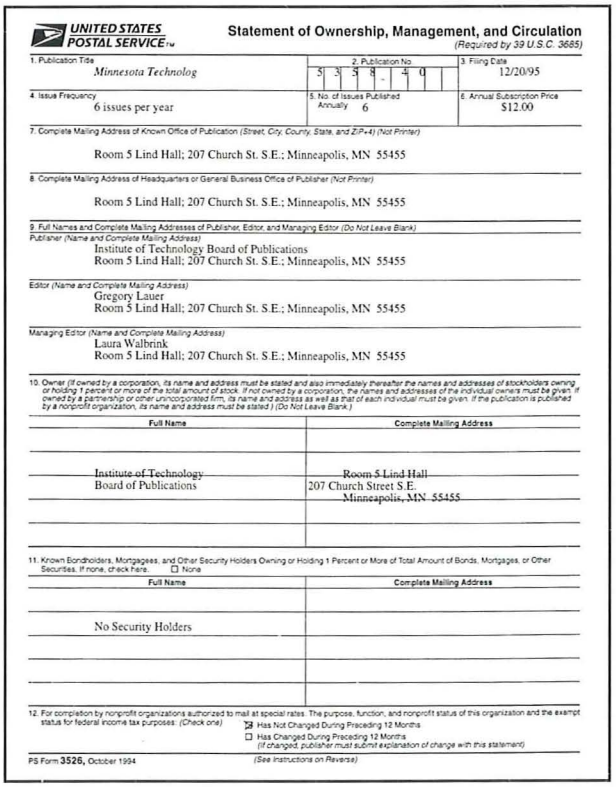
"It doesn't stop," says Jenkins. "Sites are not self-contained or autonomous." And for these students, that's the beauty of the Web.

But there are other students who feel that the policy is necessary. "More and more cases are arising where the Internet or Web provider is being held accountable, legally, for the actions of the users . . . . With this in mind, I don't see how anyone can blame the U for setting up some policies. If they are to be held accountable by district judges for the content of the students' webpages, then they would be idiots not to establish some serious rules pertaining to that content," said rhetoric student Joe Little.

Grewe observed that "placing the disclaimer on personal Web pages seems to me to be the proper balance between academic freedom, personal rights to speech and the need for the University to protect its public image."

"For my intent and purposes," observes College of Agriculture, Food, and Environmental Sciences senior and Board of Governors member Carlos A. Brooks, "it's okay. I'm using to being 'in congruence' with the University policies and mission. [The Web policy] is a natural progression of what already exists." ★





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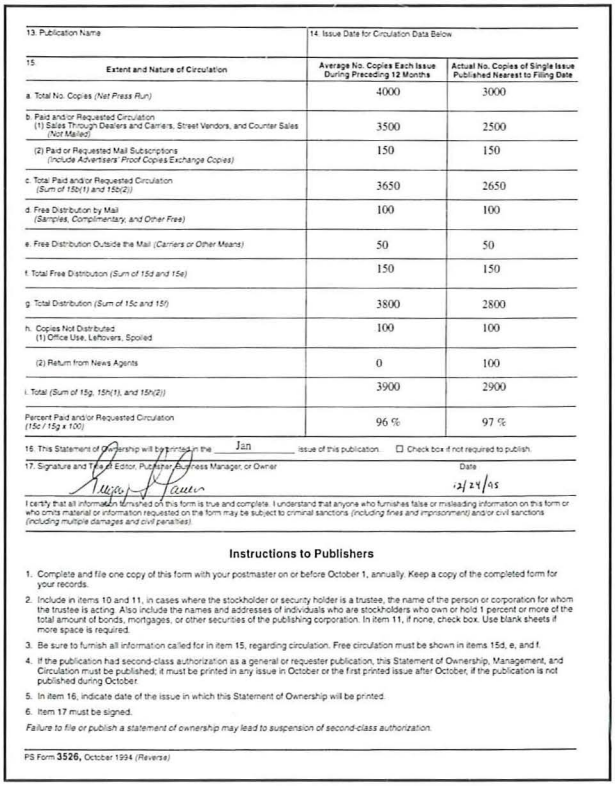

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3. Be sure to furnish all information called for in item 15, regarding circulation. Free circulation must be shown in items 15d, e, and f.
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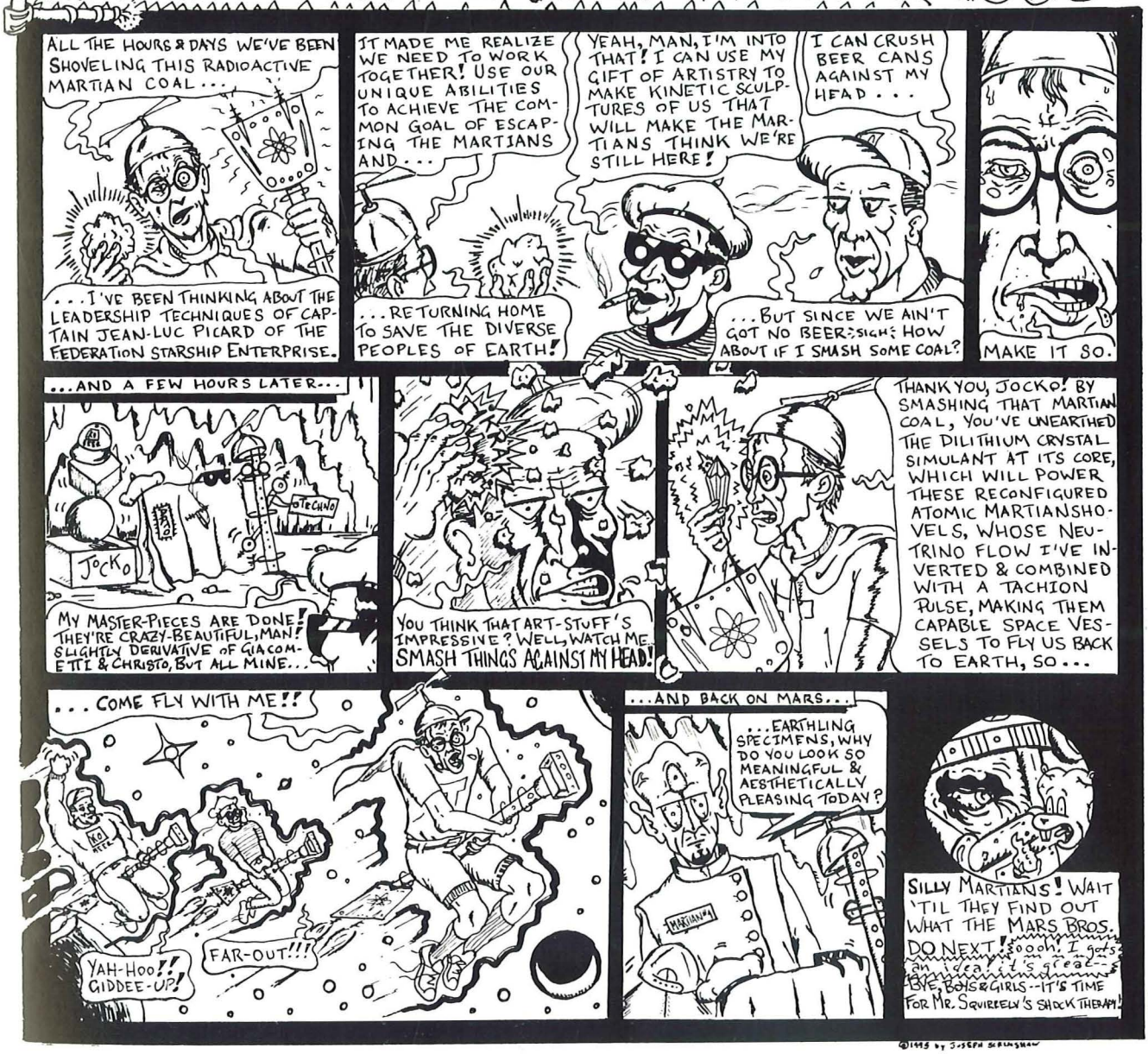
Tales of technology...

by joseph scrimshaw

HELLO THERE, BOYS & GIRLS! YOU WANNA KNOW WHY TODAY'S STORY IS SO EXTRA-SPECIAL STRANGE & SCARY? IT'S CAUSE THE MASTER'S BEEN 'SPERIMENTING ON MR. SQUIRRELY, AND HE FOUND OUT THAT IF HE GIVES HIM AN ELECTRIC SHOCK, MR. SQUIRRELY JUST GETS ALL CROSS-EYED & DROOLS A LOT, BUT IF THE MASTER GIVES HIM SALTY-NUTS, MR. SQUIRRELY COMES UP WITH SUPER-GOOD STORY-TELLIN' IDEAS, LIKE - shut up & tell 'em my story!! ANYWAYS, HERE'S MY, um, I MEAN OUR EXCITIN' STORY. WHAT SHOULD WE CALL IT, MR. SQUIRRELY? ...oh! how about... the Mars Bros. in the Salty-Nuts!!!



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Minnesota Technolog is looking for writers (as well as illustrators) for the 1995-1996 school year. We're seeking IT undergraduate and graduate students who'd like some experience writing for publication! We have several beats in mind, including the environment, ethics, new technology, personal profiles and features, editorials, and personal reports on the specific projects you're working on for school.

Although our editorial board mainly consists of creatures from outer space, we've been known to work well with humans. If you'd like more information, or would like to come in for an informal interview with the editor, please leave a cover letter, a resume and any available writing samples in an envelope outside the *Technolog* office in Room 5, Lind Hall.

And, if you're not quite up to writing, but have interesting ideas for stories you'd like to see in upcoming issues of the *Technolog*, please jot them down on this form and drop it by the office.

MINNESOTA TECHNOLOG

Description of story idea(s):

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Would you like to write the story? _____

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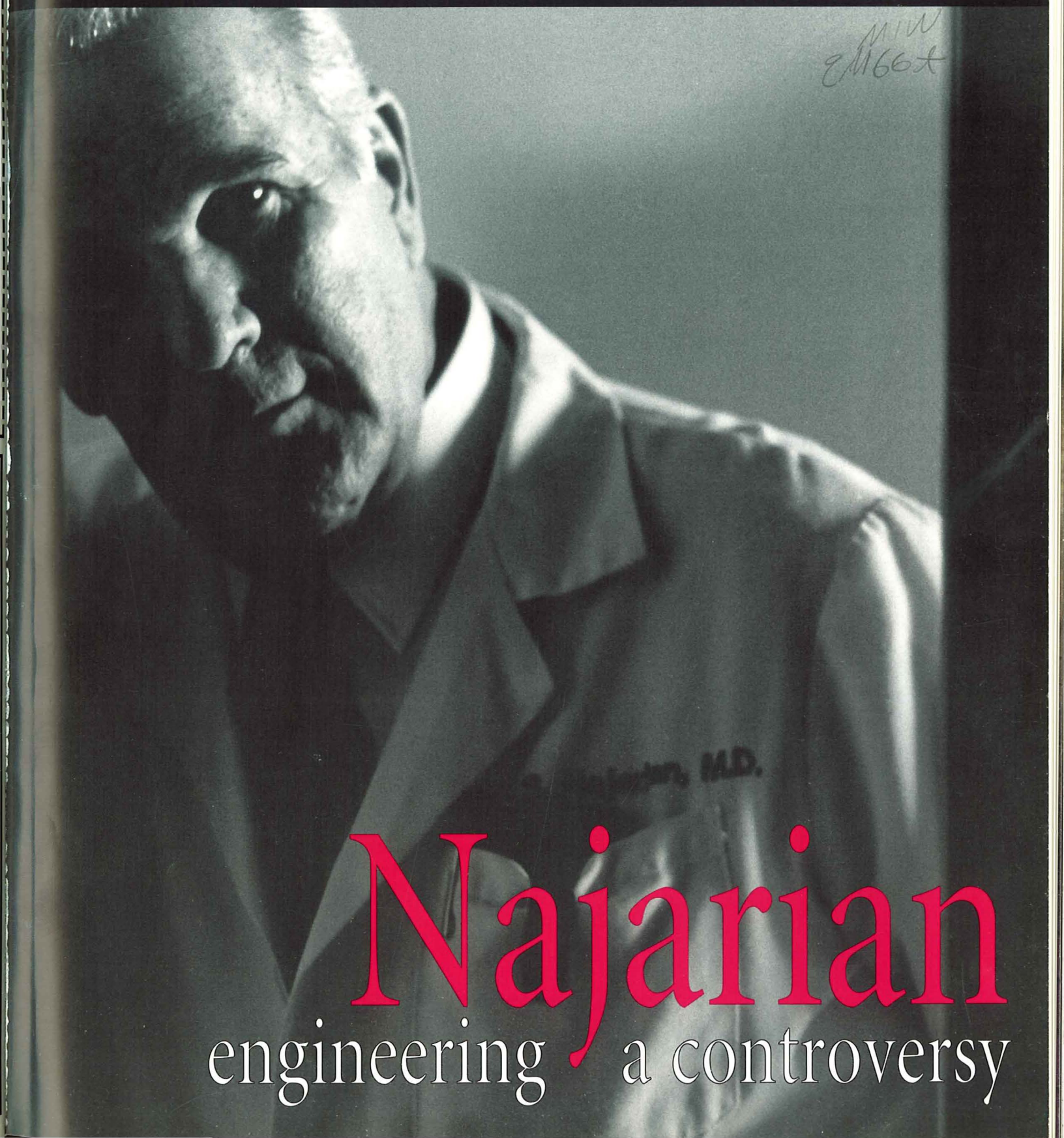

Najarian
engineering a controversy

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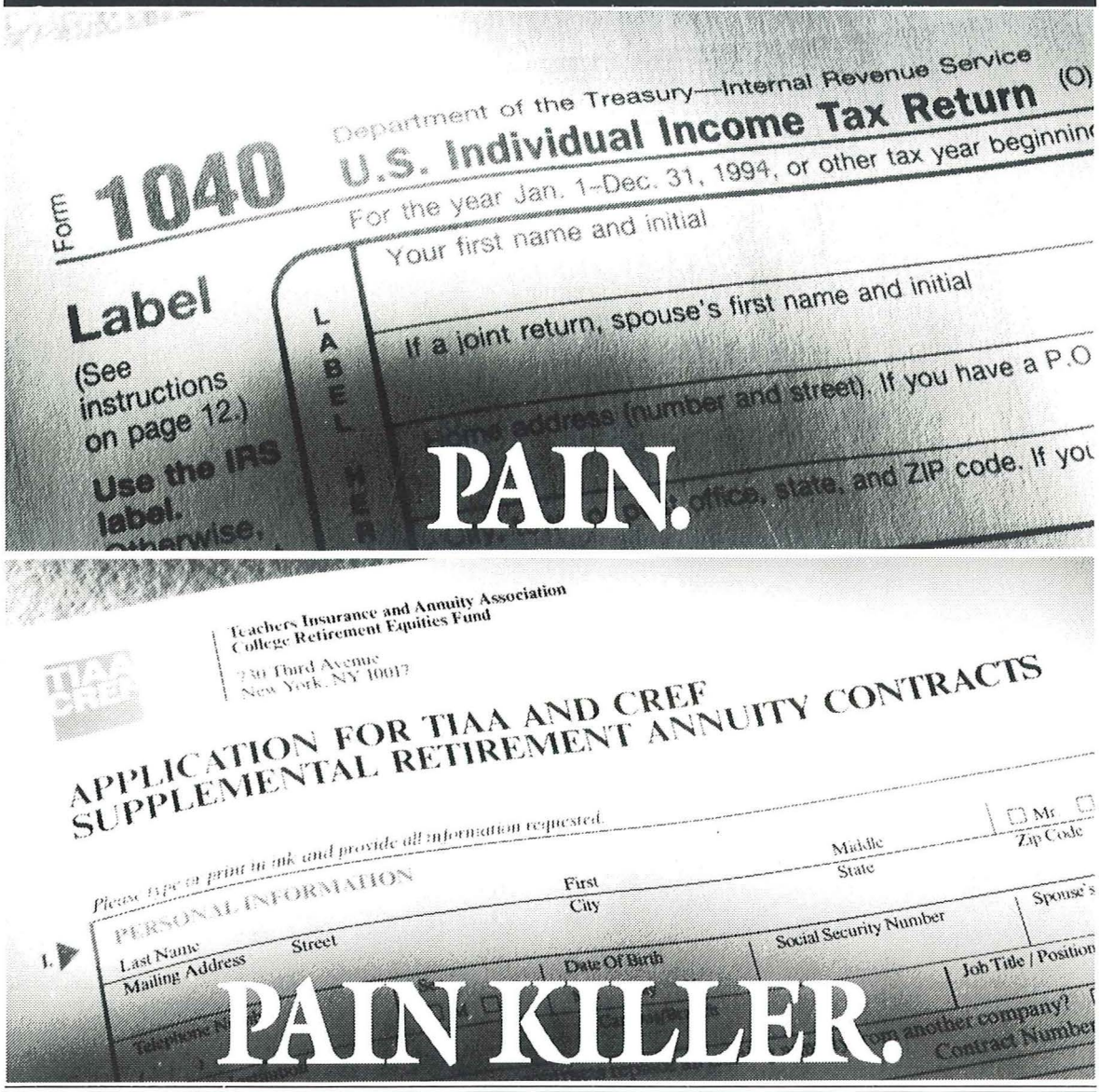

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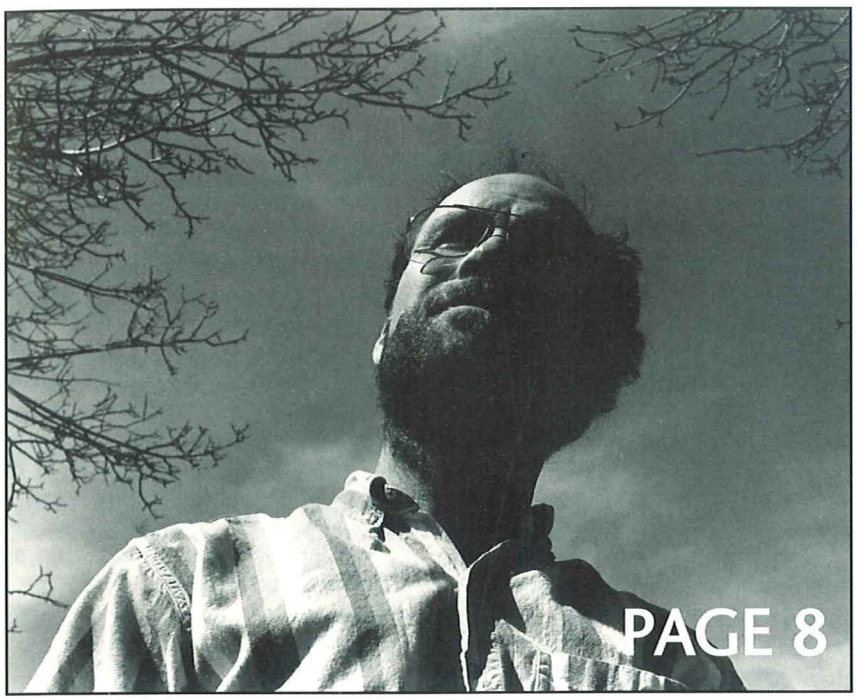

COVER STORY

Surgeon General's Warning:
Practicing Medicine May Be Hazardous to Your Health

Dr. John Najarian, the pioneering University transplant surgeon who developed the anti-rejection drug ALG, was hauled into U.S. District Court on January 17 on 21 counts of embezzlement, mail fraud, tax evasion, obstruction of justice, and medical fraud. The five-week trial marked the end of a saga that began in 1992 when the FDA shut down the ALG program and a federal grand jury started examining program records.

—by Jodi Compton

PAGE 12

FEATURES

Just Patent It:
Bringing the Fruits of Academia to the Marketplace

The University's Office of Technology Transfer Administration files about 40 patent applications every year—everything from crispier apples to waste treatment technology to rapid transit systems.

—by Kari Siegle

PAGE 8

Inventing Tomorrow:
Reengineering the Institute of Technology

IT is making *a lot* of changes in hopes of improving undergraduate education. The *Technolog* interviews Dean Peter Hudleston, investigates innovative teaching techniques like the new math sequence and cooperative learning, and profiles Samuel Moore, Director of the Program for Multiculturalism in Science and Engineering.

—by Laura Walbrink

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engineering a controversy

EDITORIAL

Should we mandate continuing education for practicing engineers?

—by Gregory Lauer

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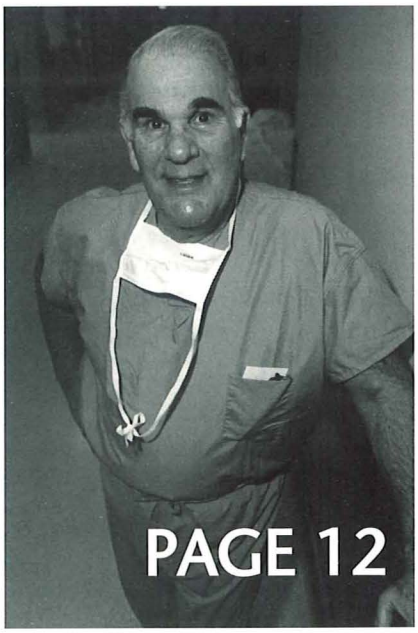
Cover photograph of Dr. John Najarian by ***Teddy Maki.***



EDITORIAL

by Gregory Lauer

Continuing Professional Development:
A Mandating Must for the Engineering Community

In the 1970s classic, *Animal House*, John Belushi et al. persuasively argued in movie theaters across the nation that formal education isn't necessarily a prerequisite to success in later life. For those who do survive the rigors of four (or more) years of microwave dinners, late-night cram sessions, and an endless parade of midterm and final examinations, who wants to bother with continuing education?

The need, however, for professional development in today's ever-evolving business climate is critical.

Continuing professional development is a must if we hope to remain in control of our techno-driven society. The National Research Council recently declared, "Technology is changing and interdisciplinary approaches to engineering are becoming more and more common. Thus, new science and mathematics must be regularly introduced to engineers." It is not enough nowadays simply to graduate from a college or university and assume that the learning curve has flattened out.

Additionally, engineers are now being asked to perform more duties outside the traditional realm of the profession. Not only must we wear a construction hard-hat or churn out drawings in the office, but in many instances engineers must also be persuasive writers and engaging speakers. Training in the arena of public relations usually isn't contained in the curriculum of engineering colleges, and continuing education is the best mechanism to deliver these much-needed skills to the engineering community.

An increasingly litigious society also demands continuing professional development if for no other reason than to save ourselves. In *The Death of Common Sense: How Law is Suffocating America*, Howard Philip convincingly argues that the burgeoning bureaucratic nightmares of regulation are causing many sleepless nights for those in business and industry. This is especially true, for example, in environmental engineering where the genesis of law is experiencing exponential growth at rates not seen since the seven days of the Creation. No engineer can afford to not remain current on the latest statutes, yet no one with professional obligations and responsibilities has time to keep up with the flood of legal documents emanating from Washington. Short courses for engineers in the field are the only viable option if we intend to safeguard the public and protect our pocketbooks.

Increasing our professional stature in the eyes of the public is another justification for continuing training and development. Nationwide, states are steadily moving towards mandatory continuing development for all types of professions such as certified public accountants, lawyers, pharmacists, social workers, etc. The general trend of other professions is to "emphasize competency and currency of material" by mandating some type of continuing education program. By not opting for a similar course of action, engineers are relegating themselves to the ranks of second-class professionals; this is clearly not in our best interest.

And the bottom line *is* the bottom line. Employers are demanding continuing education because it shows up in the profit margin of the corporate balance sheet. In a survey of urban and non-urban engineering employers, respondents identified the two most important reasons for continuing education: preparation for increased responsibility and increased performance of present job assignments. Continuing education makes sense because it makes dollars for the companies and engineers involved.

Consider the case of federal and state controls on surface drainage systems and water quality. In the early to mid-1970s, coal became a popular energy source in response to the oil embargo, and subsequently surface mining practices became widespread. Unfortunately, much of the existing knowledge used in the design and construction of drainage systems and sedimentation basins utilized theoretical models and numerical algorithms originally developed for agricultural applications. It was not only problematic but simply wrong to extrapolate agricultural methods based primarily on flat topography to mining areas typically characterized by great topographical relief. Extensive research was conducted in order to adequately modify the agricultural methods currently in place, and this information was then integrated into a series of computational models, nomographs, charts, and procedural rules. Short courses were offered, and mining engineers began constructing proper temporary stream channels and storage basins that met federal and state regulations regarding stream loads and erosion-deposition standards.

Continuing professional development is an urgent need if we as engineers intend to provide high-quality services to the society of tomorrow. If we are to increase the stature of our profession, protect ourselves from Shakespeare's "damn lawyers," and ensure the technical and non-technical competence of today's engineers, we must mandate formal education and training programs beyond the level of the B.S. degree. Finally, if we don't embrace continuing education, we may find ourselves the subject of Al Franken's next New York Times bestseller, *The Engineer is a Big Fat Idiot*. ★

ECMA NEWS

Reprinted from other members of ECMA, Engineering College Magazines Associated

Crawly Critters Can Communicate

Although you're unlikely to hear a couple of cockroaches chatting with one another, that doesn't preclude the possibility of critter communication. Researchers at Cornell have fully identified the exact molecular shapes of pheromones, the chemical walkie-talkies of the biological world, used by the brownbanded cockroach and the longhorn beetle. Scientists uncovered the chemical composition of the cockroach pheromone in previous studies, but until now the stereochemistry, or three-dimensional structure, remained a mystery. Last fall, components of the pheromone were first separated by gas chromatography. Next, the response of the insect's antennae (its olfactory senses) was monitored with an electroantennographic detector capable of recording minute electric signals, and this work led to a chemical roadmap of the pheromone. In order to ascertain the stereochemical composition of the pheromones, a team led by Professor Jerrold Meinwald of the chemistry department developed a synthetic method to produce stereoisomers. These stereoisomers were then compared to the original structure of the pheromone until a match was found. A heightened concern for the environment is driving the recent research in pheromones, and the results may lead to a more bio-rational pest control. Explains Prof. Meinwald, "This approach to pest control is based on understanding and using the species' own communication system. It is not toxic, not dangerous, and will not affect other species."

—Susan Chien
Cornell Science and Technology Magazine
Summer 1995

It's That Vision Thing . . .

The College of Engineering at the University of Wisconsin is jumping on the slogan bandwagon with the Vision 2000 plan (gee, does this sound familiar?). The proposal outlines nine broad policy planks with a total estimated price tag of approximately $100 million. The *Building for the Future* mandate attempts to address the chronic shortage of space on campus by constructing an Engineering Centers Building with more than 140,000 square feet of labs, classrooms, conference rooms, and a student commons area. Expanded funding for extracurricular activities will encourage the development of leadership, teamwork, and entrepreneurial skills. Roughly $22.5 million will be allocated towards undergraduate scholarships and graduate student fellowships, and another $24 million will be dedicated to improving opportunities for underrepresented groups on campus. More endowed professorships will be offered in an attempt to recruit outstanding faculty, enhance research, and attract additional grant support. The *Revised Professional Curriculum* plank addresses the need for training faculty and administrative staff in the areas of Total Quality Management as a part of the TQM University Challenge. Last, but certainly not least, campus aesthetics will be considered, and steps will be taken to "beautify the campus." Just four years before the turn of the century, the Vision 2000 plan is still more of a lofty vision than a concrete reality, but the University of Wisconsin Foundation and Dean John G. Bollinger are attempting to change that.

—Ryan Mathus
Wisconsin Engineer
February 1996

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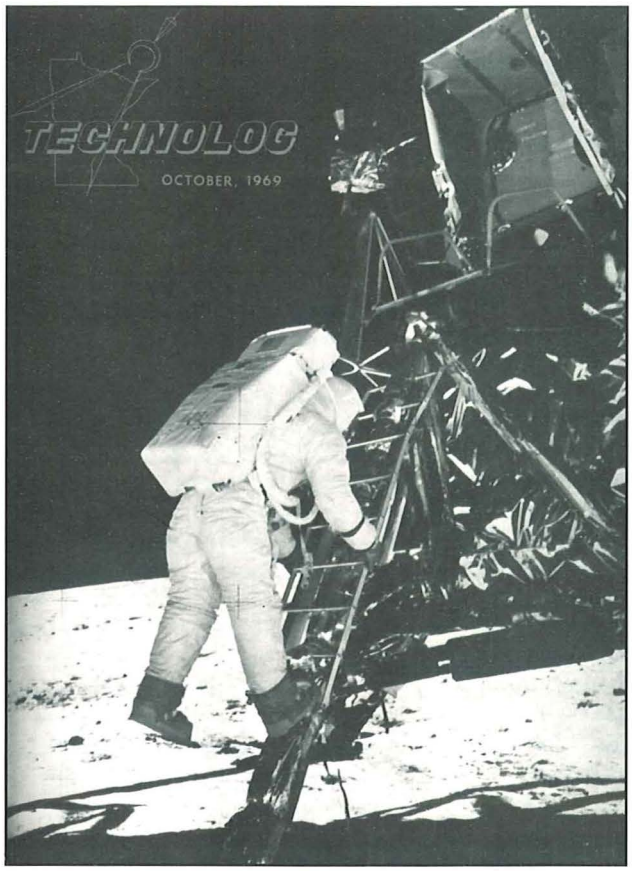


Out of the Past

Cover of the October 1969 issue, Vol. 50, No. 1

Not Enough Technology (Classes) for Everyone

The emphasis on technology in today's society has resulted in unprecedented enrollment in IT math and science courses. The heightened popularity is frustrating students, many of whom find themselves unable to get into required courses. Chemistry, computer science, math, and physics have seen dramatic enrollment increases. Part of the problem stems from the dual populations that IT serves: IT major students and students from the rest of the University who take basic math and science courses as electives. Because many of the second group are eschewing other subjects in favor of IT courses, IT suddenly faces an influx of students that it is unprepared to handle.

The administration has tried to reduce the impact of the situation by offering priority enrollment to students who have previously been unable to register for required courses. Dean of Student Personnel Services Paul Cartwright hopes to implement a system under which students would submit a tentative course schedule during spring quarter. The results would help planners better allocate faculty and sections to courses.

Undergraduate enrollment has been increasing slowly and steadily except in the computer science and environmentally-oriented programs, whose enrollments have risen rapidly because of heightened interest among students this decade.

—Fall 1977

Troublesome TAs

Using teaching assistants in courses, a widespread solution to the lack of teaching personnel, has lowered the quality of the University. These instructors are usually graduate students working toward a degree of their own. Mentally strained and financially troubled, they tend to value their faculty positions mostly for the salary.

Teaching assistants often come to class unprepared for lecture. They spend even less time on the courses they teach when they have their own exams to study for or theses to write. Students suffer from their instructor's unavailability.

The current system should be eradicated. Education is a vital tool, and teaching assistants must accept their responsibilities. If they can't, then they don't belong at the University in an instructional capacity.

(Excerpt from an editorial)
—November 1962

Looking for a Few Good Engineers

The demand for agricultural engineers is likely to increase as farming moves toward mechanization. Agriculture boosts its productivity rate by 6% per year, highest of any industry. To continue this trend, agriculture will require engineers to design and produce machinery and irrigation systems.

IT's Department of Agricultural Engineering is located on the St. Paul campus. Students enrolled in the agricultural engineering program follow the traditional engineering curriculum for two years and then train specifically in the agriculture field. Because demand for agricultural engineers is high, several scholarships are available to prospective majors.

Diverse opportunities exist for agricultural engineers. In addition to farm implement manufacturers, many work for companies that handle the storage, preservation, processing, and refrigeration of agriculture produce. The Soil Conservation Service and Department of Agriculture also employ agricultural engineering graduates. Some graduates work as contractors in land surveying and irrigation; others teach college courses.

—January 1956

Book Crooks Earn Less in '33

The Engineers' Bookstore has been a profitable student corporation for 13 years. In the early 1920s, the success of the Engineers' Bookstore led members to open a branch in the business school. That store was later closed due to financial woes. Since then, however, dividends have risen to a high of $8,579 in 1931.

A Board of Directors determines financial policy and operating procedure. Board members include three faculty members, a manager, and elected representatives from each college in the technical school.

All University students are eligible for membership, but only students in the College of Engineering and Architecture and the School of Chemistry can participate in its government. Students who wish to become members deposit $5.00 to be used as working capital until they leave school, at which time the deposit is returned.

Each fall, members have received a dividend of 16% based on the operating profits and the purchases made by each member. Dividends distributed to members have ranged from a low of $2,127 in 1921 to the 1931 figure. Recent dividends have been somewhat less impressive: $6,854 in 1932 and $4,749 in 1933.

—October 1933

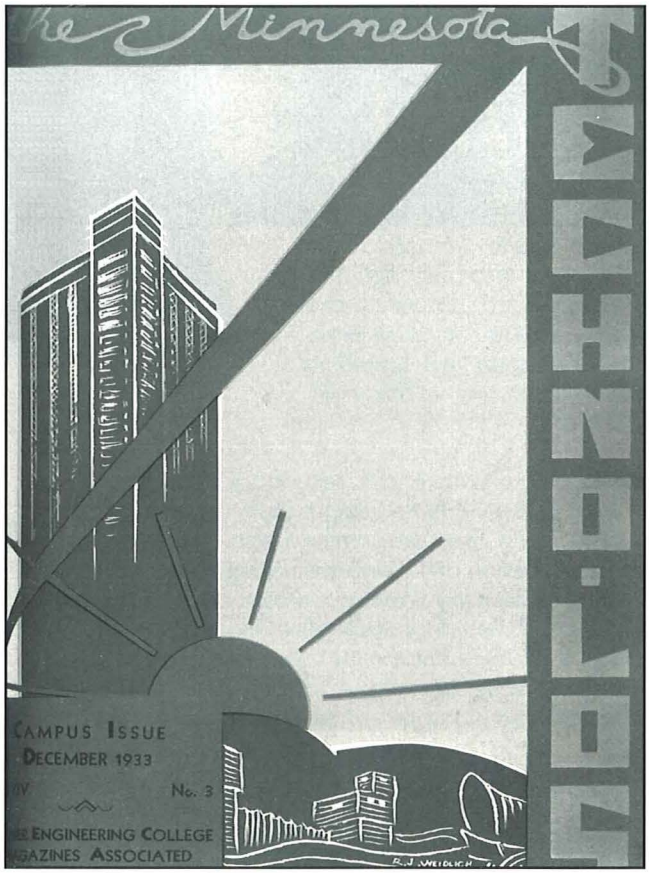
Early Beginnings for the Extension Department

Last June, the University graduated its first class of evening students. Among the 39 graduates receiving diplomas were 13 engineering students. Although many students assume that the day ends when the 5:20 bell has rung, hundreds of students take evening courses. Enrollment has climbed to 660 this year, and the Electrical, Experimental, and Main engineering buildings are open five nights per week.

Evening classes are growing in popularity, particularly among Minneapolis students. The Extension Division reports a 15% increase in Minneapolis enrollment this year, with the number of students in Duluth and St. Paul night courses decreasing slightly from last year.

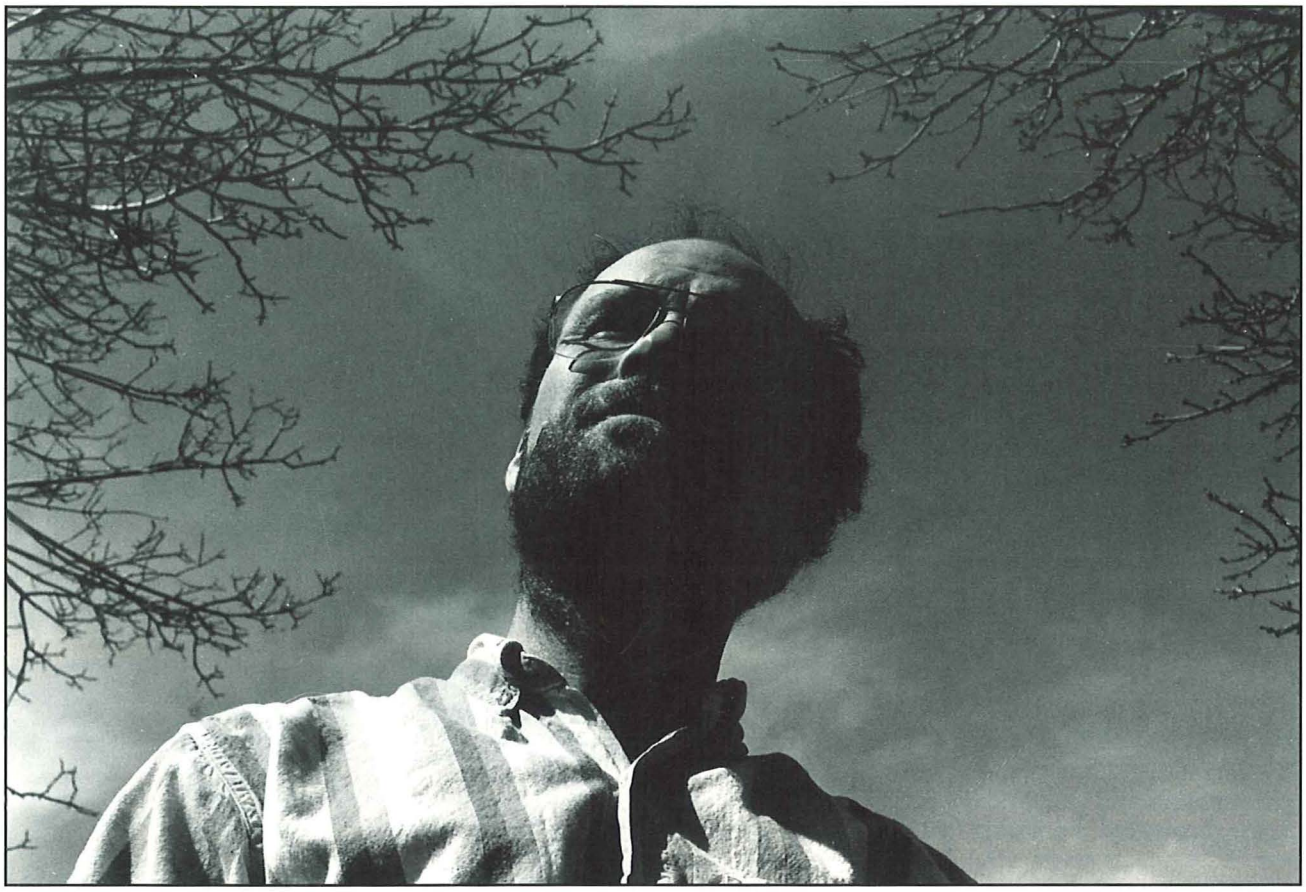
The University conducts classes around the metropolitan area to accommodate students. Some Minneapolis courses are held at the Courthouse. In St. Paul, students can take courses at the YMCA, the Mechanics Arts School, and the American Hoist and Derrick company plant. Duluth courses are held at Central High School and Washington High School.

—December 1927



Cover of the December 1933 issue, Vol. 14, No. 3

JUST PATENT IT



Bringing the Fruits of Academia to the Marketplace

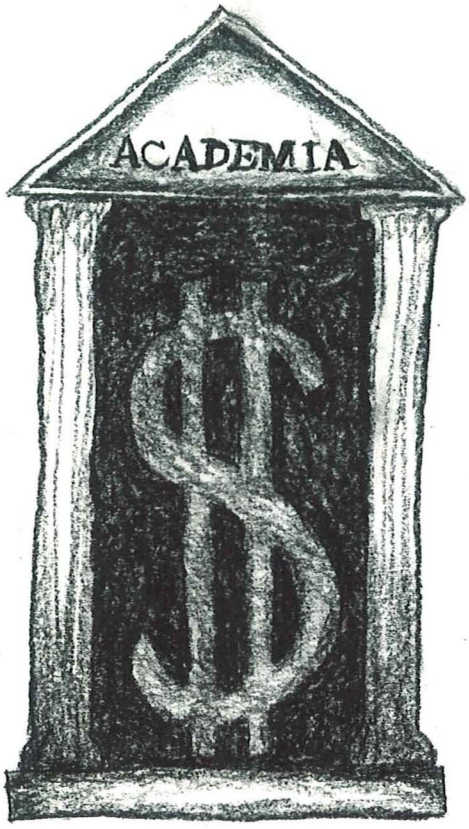
By Kari Siegle

Above photo: Dr. James Luby, a Professor of Horticultural Science who develops new varieties of plants, is part of a unique breed of academic researchers who are patenting for profit. ***Photo by Teddy Maki.***

In a routine walk through a section of apple orchard, James Luby, a professor of horticultural science, found something unusual in an apple he bit into. It gave a resounding crisp unlike any he had heard before.

Intrigued by his first impression of the apple, Luby and his associate David Bedford checked old orchard records to determine the apple's type and then began developing it in 1982. As it turned out, the apple, a hybrid of two parents, had been created in the 1960s but was later neglected.

Luby decided to patent the apple in an effort to bring money into the University's horticulture program. He knew that it would take years to see a return on the money used for the patent because of the growing season of apples. "Fruit breeding is a long-term venture," said Luby, adding that it generally takes three to four years after a tree is planted for it to produce apples. Today the apple is patented with the name Honeycrisp and is licensed to about 20 nurseries.



Through the University's Office of Research and Technology Transfer Administration (ORTTA), about 150 invention disclosures are received each year and about 40 patent applications are filed each year. Even in areas such as horticulture, where a decade ago many researchers did not bother to put a patent on their discoveries, many like Luby are doing so today.

In return for royalty payments on resulting products, the 'U' pays to patent inventions and license them to companies. Perhaps one of the most influential criteria for issuing a patent is that the invention or discovery be something new, useful, and not an obvious improvement on something already in existence. Another of the main criteria for issuing a patent, according to Anton Potami, director of patents and technology, is that there be a market to license the product to. "The question becomes, 'Is there a commercial interest in the technology?'" said Anthony Strauss, director of mechanical, chemical, electrical, biological, and technical aspects of ORTTA. Without a market, a patent essentially functions only as recognition of an achievement. Another criterion for patenting is the ability to protect the technology. If something cannot be protected through a patent, then there is no effective way of licensing it. It can take one to three years for a patent to be issued or denied by the US Patent and Trademark Office. Then it can take up to five years for commercial sales to start.

The cherry-red Honeycrisp apple was a new type developed through a cross between a yellow Honeygold apple and a Macoun apple. Forming the Honeycrisp apple tree involved crossing the two trees of these apple types.

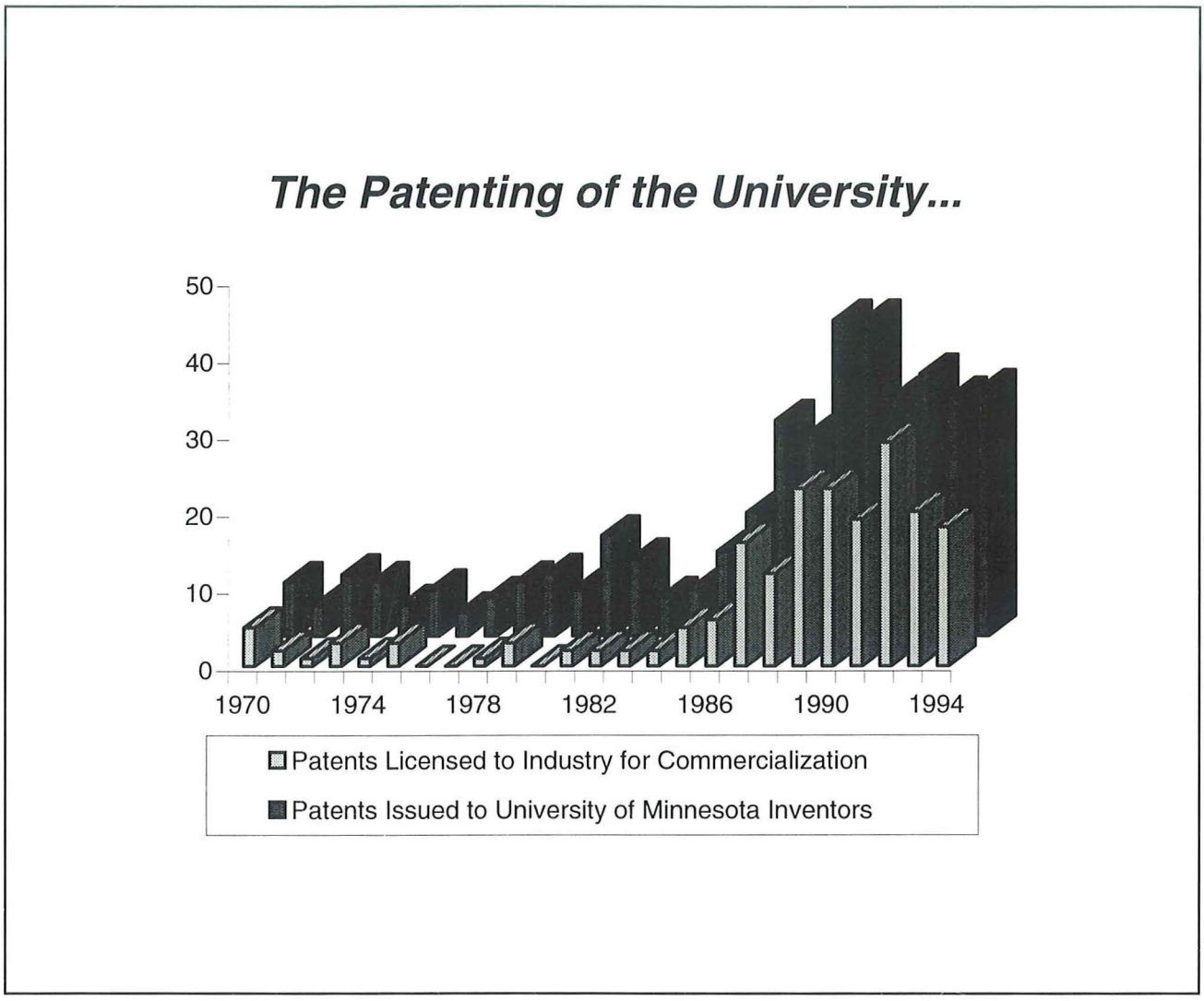
Starting with the pollination, a breathable net with small holes is put over the Honeygold's flowers to keep the bees from them. When the flowers open later, pollen from the Macoun is placed by hand on the flower's stigma. The pollen then germinates, enters the ovary of the flower and fertilizes it, enlarging the ovary and thus becoming the apple.

The apple's two parents were chosen for their complementary and contrasting features. Honeygold yields a compact tree and is highly resistant to a number of diseases. The Macoun has a nice flavor and is aromatic.

The Honeycrisp's most impressive feature is its crispness, which it retains for eight months under regular storage conditions. Using electron microscopy, Luby is currently trying to discover the Honeycrisp's secret. One link could be the apple's cell sizes, which are twice as big as the cells of most varieties of apples. Another possibility involves the way the flesh, or red outside skin, is broken. When the Honeycrisp's flesh is broken, the breaks extend through the cell walls. In other apples, the cell walls slide away from each other, releasing less juice than the Honeycrisp and turning the inside of the apple soft because they offer no resistance.

With the Honeycrisp, the pectin holds the cells together more tightly than in other apples. When a bite is taken, the walls break, releasing a sensation of great crispness. Two possible reasons why the cells hold together so well, Luby said, are that a substance in the cell walls does not break down as fast as in other apples or certain enzymes are not being made. If Luby can find the answers to these questions, the results could be used in the genetic engineering of other apple varieties.

Aside from money, patents are becoming increasingly important to secure active, practical use of technology, Strauss said. While some people argue that everyone could use the information if it were made public instead



Above: Since 1970, the number of patents issued to University of Minnesota inventors, and the number of patents licensed to industry for commercialization, has experienced explosive growth. Currently the University has 262 license agreements with industry, and 86 of those belong to Minnesota companies. ***Graph by Gregory Lauer.***

of patented, usually no group or company undertakes the cost of commercializing the product, he explained. "It's not the be-all and end-all of University activity or University research activity, but it is an important tool when selectively used to secure benefits of some technical device," Strauss said.

Under the University's patent policy, if a professor creates something under University time or using University resources, the University has a stake in the technology. "Essentially they need to give the University the first right to file a patent on it," Strauss said. He said if a researcher begins working on a project somewhere else but then continues to work on it at the University, the University is entitled to some share of the profits. If the University decides not to file a patent on an invention, then those rights are waived back to the researcher.

Luby plans to routinely patent what he is able to produce, mainly because of the potential to make money from the licensing and put that into further research. He is currently in the process of applying a patent to a strawberry he helped develop that blooms later in the season than other varieties. Luby plans to name the strawberry Winona, a Dakota word often given to the daughter when she is the first-born child in the family. But, Luby said, unlike in apples, strawberries' names are not often remembered by consumers. Apples are like cars in that the name needs to be something "sexy and that would sell," Luby said, adding that people generally buy apples according to their names.

Disagreements about patents between the University and personnel working on projects occasionally arise. A recent court case determined whether the University was entitled to a share of money generated by the 1992 sale of waste treatment technology developed by Jozef Tylko, a visiting University professor. Three years after the University sued Tylko and Kenneth Reid, head of the now-closed Mineral Resources Research Center, a jury ruled that they don't have to give the University millions of dollars generated by the sale. The University charged that its patents rules and Tylko's

contract entitled it to more than $3 million earned by the technology. In court documents, however, Tylko said he developed the technology before coming to the University and had patented it in England. A jury found that, in this case, Reid had the authority to decide when University patent policy applied to Tylko.

engineering a controversy

The University has over 260 license agreements with industry, 86 of which are with Minnesota companies. When no companies are interested in the technology, faculty members sometimes start companies to market it. Faculty members are free to start companies, provided conflict of interest and policy issues are dealt with.

Automated Transportation Systems, Inc., formed in 1984 with help from the University's Office of Patents and Licensing and now called Taxi 2000, has a worldwide license to commercialize personal rapid transit technology developed by former University mechanical engineering professor J. Edward Anderson. In return, the University receives equity in Taxi 2000 and royalties based on each vehicle built and each mile of guideway constructed by the company or sublicensees.

The University filed five patents for Anderson's transit system. Two were related to the guideway, two to the switch and one related to the network control system.

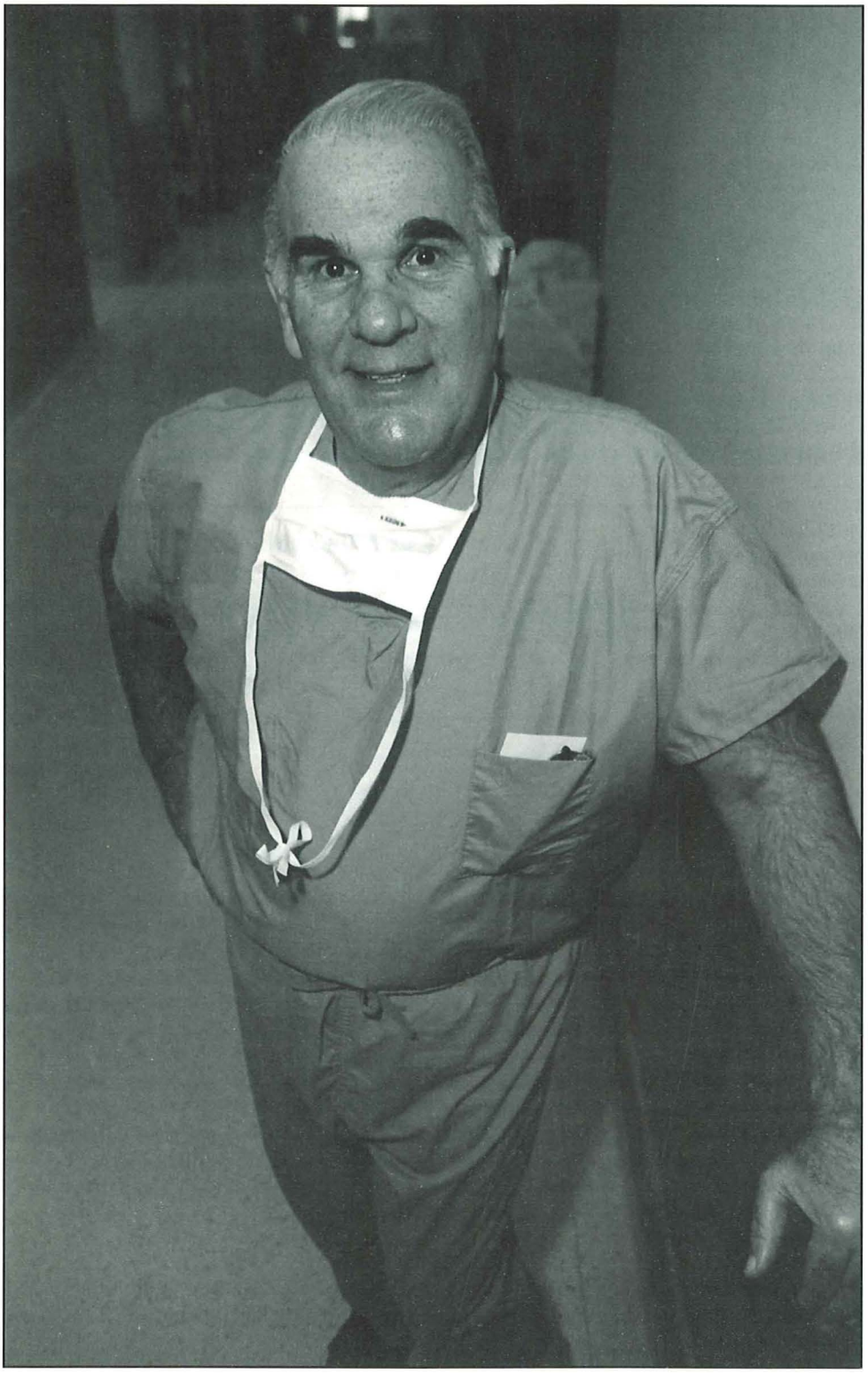
Personal rapid transit involves small, computer-controlled cars that ride on a network of elevated roadways supported by columns. Anderson designed the rapid transit system during the 23 years he worked at the University. In Anderson's rapid transit system, electric-powered vehicles carry up to four passengers, and the elevated roads power the cars as they ride onto charged rails. The vehicles can turn onto side ramps, which take them to station areas where people enter and exit the cars. While it may seem that small cars carrying from one to four people might not be able to move as many people as buses, the smooth traffic flow eliminates this problem. Controlled by an on-board switching mechanism and computers connected to the transit system, the vehicles can follow each other closely and travel a single route. The on-board switches would also allow the computer to anticipate bottlenecks and move the vehicles toward less crowded routes. Another job for the computers is to ensure that the vehicles only stop to let passengers off at their destinations, instead of stopping at many places like buses do.

"Once it was formed and we got the capital we could put meat on the bones of the idea," Anderson said. He said the NIH factor contributed to his wanting to form his own company with University help. NIH, or the "not-invented-here" syndrome, occurs when technology that is licensed before it is perfected can be harmed in the licensing process. Anderson said some people take certain technology ideas and change them without understanding the underlying principles.

While Taxi 2000 has undergone several changes over the years, especially in leadership, the personal rapid transit system that was developed has expanded. In August of 1995, a mock-up of a vehicle and station, based on Anderson's design, was unveiled in Rosemont, Ill., by the Illinois Regional Transportation Authority and Raytheon Electronic Systems. The Rosemont project is in a testing phase that will continue until 1997. Depending on reaction to the prototype, the Regional Transportation Authority will decide whether to build a 2.2-mile system in Rosemont.

Anderson said without the University's help he would have been unable to pay for the patents and start-up costs of the company. He also said he wouldn't have been able to develop the plethora of ideas he had if he were not working at a research university. "It's kind of a unique environment where a professor can follow his own leaning and have time to devote to research time that can lead to patentable ideas," Anderson said. ★

Surgeon General's



by Jodi Compton

Photos by Joshua Zuckerman

When Assistant U.S. Attorney Janet Newberg made her opening argument in the case against Dr. John Najarian, a celebrated transplant surgeon, on January 17, 1996, she moved quickly to divorce his medical reputation from the charges against him. The trial beginning that day in St. Paul's federal courthouse, Newberg told the jury, was not about Najarian's achievements as a doctor, but about "what went on after Dr. Najarian left the operating room." Neither, she said, would the trial make any judgment as to whether the anti-rejection serum Najarian developed was a good drug or a bad drug. But long before the jury acquitted Najarian five weeks later, it had become clear that much of the case was a courtroom battle to control how the jury viewed Najarian as a medical researcher and his drug, Minnesota Anti-Lymphocyte Globulin (ALG).

When Najarian arrived at the courthouse on January 16, 1995, the first day of his trial, he was facing a 21-count federal indictment. Ten counts were charges of embezzlement and related mail fraud. Five were tax evasion. Two alleged obstruction of justice — that Najarian had tampered with the case against him. Only four of the 21 alleged medical fraud.

But those four counts were disproportionately important to the case. The foundation of the case against

Warning:

PRACTICING MEDICINE MAY BE HAZARDOUS TO YOUR HEALTH

Najarian was the charge that for 21 years he and others conspired to sell the unlicensed drug ALG for profit, bringing millions of dollars into the University of Minnesota surgery department. Two other charges claimed he failed to report two serious reactions to ALG to the Food and Drug Administration as required by rules on clinical drug trials. A fourth count said that he lied to an FDA agent, saying that ALG-specific consent forms were used at Minnesota on every patient administered the drug (since the mid-80s, they had not been).

These charges were "the engine that has driven the case," as Najarian attorney John Lundquist put it. Had it not been for these suspicions of medical fraud, it seems unlikely federal investigators would ever have turned their attention to Najarian's use of University funds and his tax returns. But by January 1996, the investigation into Najarian's drug study had become a multifaceted criminal case that took three years to build, cost the surgeon his University position, and perhaps permanently removed from the market a drug that once had a marked effect on the field of transplantation.

For 25 years, Najarian was the chairman of the University of Minnesota's Department of Surgery. As a specialist in the field of organ transplantation, Najarian gained a reputation for handling the difficult cases other surgeons would have thought twice about taking. The first infant and the first diabetic to receive organ transplants were both Najarian's patients.

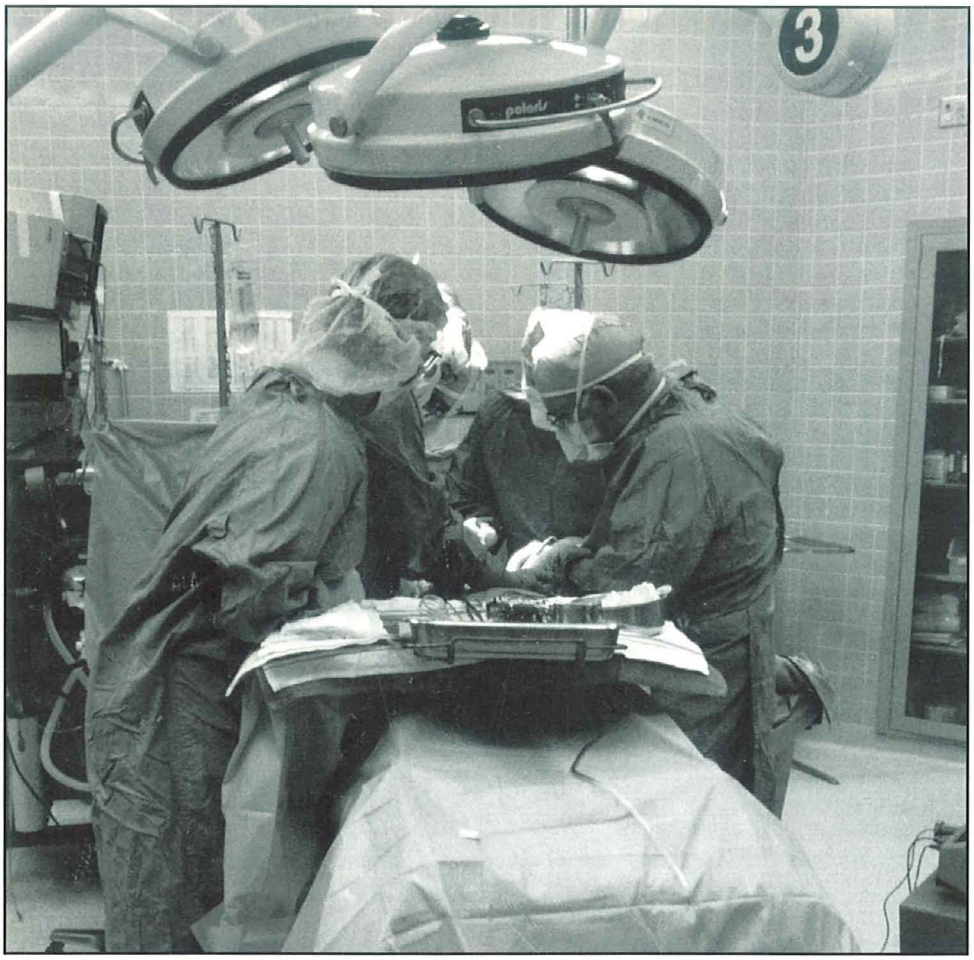
As a surgeon, a teacher and an administrator, Najarian's workload was immense. "He had more responsibilities than anyone I've ever seen," Pamela Johnson, his former secretary, said of him. He did transplants and general surgeries weekly. He made rounds with medical students and went to weekly conferences in which surgeons discussed complications and deaths in the cases they handled. He was the head of Department of Surgery Associates, the private-practice partnership of University surgeons. He was on the editorial boards of 15 medical publications. He also published journal articles, becoming the 14th most prolific scientific writer during the 1980s. And about 25 times a year, he traveled to speak as a visiting professor or guest lecturer at other universities or medical societies. In addition, Najarian was the principal investigator of the Minnesota ALG program.

engineering a controversy

The drug which would become known as Minnesota ALG had its roots in Northern California, where Najarian was born and schooled and began his medical career. After getting his M.D. at the University of California — San Francisco, Najarian joined the surgery faculty there. As a specialist in transplantation, the surgeon began working on the most serious problem facing the fledgling field — rejection.

Organ rejection is a natural, although counterproductive, reaction on the part of the body's adaptive immune system. The body identifies some cells as abnormal — cells infected with a virus, or tumor cells. Production of white blood cells called lymphocytes is stepped up in response. These cells attach to and destroy the infected cell or tumor. To the immune system, however, a much-needed transplanted organ is indistinguishable from other foreign cells and draws the same response. Tissue-typing, or matching donors and recipients as closely as possible, usually within families, helps to lower the risk of rejection. Nonetheless, what Najarian and other transplant specialists were working on in the late 1960s was a way to suppress the immune system's natural response to a foreign, transplanted organ.

Najarian began by injecting human



lymphocytes into rabbits. He bled the rabbits and treated dogs with the blood product. Since large amounts of blood were required to treat one dog, Najarian turned to bleeding larger animals — undesirable horses at Golden Gate Fields, a local racetrack. In 1967, Najarian came to the University of Minnesota, where he further developed equine and caprine (goat-derived) ALG.

In 1971, after some preliminary testing, a subordinate of Najarian's applied for and got an Investigational New Drug (IND) license for the serum. Under FDA rules for investigational drugs, the University could use ALG on their transplant patients and ship it to other hospitals chosen as participants in the ALG study. FDA rules also stated that the drug had to be used as part of a study. Data on its use was to be collected from all doctors involved. Furthermore, an investigational drug is not to be sold, even at production cost. Whether the FDA ever made it specifically clear to Najarian that ALG was not to be sold, even at cost, would become one of the linchpins of his defense strategy at trial.

That trial, however, was years down the road. In the interim years, the ALG program enjoyed great success. In the early 1970s, after the advent of Minnesota ALG, the University Hospital had 15 percent better results with organ transplants than other hospitals nationwide. In time, the drug made at the University came to be used at 175 transplant centers across the country. The credit, said Richard Simmons, now chairman of transplantation at the University of Pittsburgh, was all Najarian's. "He set the course," Simmons said. "He set the ship on course."

FDA officials would later testify that during the 21-year period that ALG was manufactured, shipped and sold out of the University, the agency had some concerns over how the program was run and about whether the drug was unlawfully being sold. Correspondence between the program and the agency bears this out. Nonetheless, aside from periodic letters and site visits, no regulatory action was taken until 1988.

That year the FDA specifically forbade charging for ALG until an explanation was made and permission for sale-at-cost was granted by the agency. In early 1989, Najarian and Richard Condie, the immunologist who ran the program's day-to-day operations, and several other ALG employees met with the FDA and got permission to charge at cost for the serum. The reason the FDA made the exception to their rules, their documents indicate, was that Najarian had told them the University was no pharmaceutical company, and without cost recovery would be unable to make the drug that was in such high demand nationwide. In addition, FDA agents believed that Najarian and Condie would soon apply for a license to sell the drug commercially. The manufacture and sale of ALG continued.

The demise of the Minnesota ALG program and the beginning of Najarian's legal troubles started at a Los Angeles children's hospital in 1991. The hospital's Institutional Review Board discovered that one of its clinicians had administered ALG to a child without first having the parents sign a consent form identifying the drug as investigational. When this came to the attention of the FDA, the agency began an inspection into the ALG program. It was not the first inspection, but it was probably the most thorough, and certainly the last.

What they found, testified FDA consumer safety officer Patricia Holobaugh later, was that the ALG study wasn't run like a study at all. Minnesota was not getting all case histories and study protocols from participating transplant centers. The ALG study, Holobaugh said, "had no statistical endpoint determined in advance. They just kept treating people and treating people," she said.

The FDA shut down the Minnesota program in August 1992. Afterward, events suggest, Najarian genuinely wanted to straighten out the ALG program — to get it run-

ning again with the FDA's blessing, and then license the drug for commercial sale. To this end, he hired a full-time "regulatory affairs specialist" to deal with the FDA, relegating Condie to strictly dealing with the scientific/research aspects of the program. But Najarian's problems were about to worsen, not improve. The chain of events which would eventually bring Najarian to the St. Paul courthouse was already in motion. Late in 1992, a federal grand jury began issuing subpoenas for records relating to ALG. In early 1993, under fire from the University, Najarian stepped down as head of the surgery department. In February 1995, when the University initiated tenure-removal proceedings against Najarian, he gave up his professorship as well. During this time, the grand jury continued to subpoena documents and call University and ALG-program witnesses as part of its ongoing investigation.

Two months after giving up his teaching position, Najarian was indicted on the counts of fraud, tax evasion, and embezzlement. Condie was indicted the same day on four related charges. Although Condie initially pleaded innocent, like Najarian, he changed his plea to guilty four months later. But Najarian called the federal case a witch hunt, maintained his innocence, and committed to a trial.

That trial was initially expected to last nearly three months. Instead, it lasted five weeks. And if it had comprised only the charges of financial illegalities, Najarian attorney Peter Thompson said, testimony would have lasted a mere four days.

Frequent witnesses in the prosecution's four-week case were medical professionals, doctors and nurses who came from different parts of the country to establish for the jury that nine transplant patients had ostensibly died after receiving ALG, that these deaths were reported to the ALG program, and that the Minnesota ALG program never in turn reported them to the FDA. The unreported deaths were said to be part of the conspiracy to defraud the government.

At regular intervals throughout the trial, the jury heard harrowing stories like that brought by Diane Bulman, a former University Hospital nurse who witnessed the 1983 death of Jay Brinkman. Brinkman, a diabetic, came to the University for a pancreas transplant. After the operation, Bulman testified, Brinkman was stable, alert, oriented. Then he began to receive his infusion of ALG, and within 15 minutes things changed.

Brinkman became short of breath, a condition which quickly worsened to serious difficulty in breathing. As Bulman ran to the door to call her charge nurse and the physicians on duty, Brinkman began foaming at the mouth, fighting for air. The doctors' resuscitation efforts were futile, and shortly thereafter later Brinkman was dead, Bulman testified. Thirteen years later, the nurse still sounded shaken by the incident.

Brinkman's death was the most directly linked to Najarian's drug — on his death certificate, anaphylactic shock due to ALG is listed as the cause of death. And the incident, it was correctly pointed out, was not reported to the FDA. But the story did more than reveal an unreported death. It made the violations of FDA rules not just an issue of paperwork getting done, but of patient safety. The inference jurors could draw from the patient-death stories was that patient safety was secondary to the ALG program staying open and making millions of dollars for the surgery department. While Najarian's subordinate Condie would later testify that reporting the deaths was his responsibility, not Najarian's, the prosecution pointed out repeatedly that Najarian was the principal investigator in the study — Condie's boss.

Najarian attorney Peter Thompson readily admitted that ALG had allergic properties and could cause serious reactions in patients. But he was quick to dispute that nine patient deaths were a significant number. He estimated that 40,000 patients were treated with the drug. Even had there been 90 or 900 deaths linked to ALG out of those 40,000 patients, Thompson said, the number still would have fallen into the

parameters of what the FDA calls safe.

It should be pointed out that when Condie took the stand, he estimated that about 20 deaths, not nine, went unreported. And an FDA spokesman says that the 40,000 cannot be verified — lax tracking of patient data makes it impossible to know exactly how many people were treated with ALG. Still, there is no doubt that ALG was trusted and valued by transplant surgeons across the nation. That fact was central to Najarian's defense. His attorneys argued that ALG was not treated as an experimental drug. If patient data was not kept track of, it was because ALG was so safe it was investigational in name only. It was a point Najarian's lawyers didn't have to wait to call their own witnesses to prove.

"We knew it was going to be tough going after the doctor in the white coat . . . John Najarian was the most well-liked defendant in the history of Minnesota."

—U.S. Attorney David Lillehaug

Under the cross-examination of John Lundquist, the defense attorney who handled the medical testimony, prosecution witnesses who had just told the jury that they believed ALG had caused the death of a patient would attest to the drug's efficacy. Asked whether he had known ALG was experimental when he administered it to a patient, one Michigan doctor said there was some "confusion" over whether ALG was investigational or not. The feeling at his hospital, he said, was that the FDA had given the unlicensed ALG a "special status — this was not to be treated like another investigational drug." Asked to clarify, he said, "It was word-of-mouth in the transplant community, that's the best way I can explain it."

Apparently, the confusion over ALG's unlicensed status began at home, the University of Minnesota Hospital. One University kidney specialist testified that she did not know that ALG was investigational until she read it in the Star Tribune (which did a series of articles on the ALG program in 1992).

In some cases, Lundquist was also able to weaken the assertion that an unreported death was in fact due to ALG. In some instances, death certificates or autopsy reports made no mention of ALG. Sometimes the link was as tenuous as "Suspect drug — Minnesota ALG" on a hospital adverse drug-reaction report. At times the witness would admit to Lundquist that while he or she suspected ALG to be the cause of death, a colleague or superior who had treated the same patient did not agree.

"Did your hospital continue to use ALG after the patient death?" was Lundquist's routine question to these witnesses. In every case the answer was yes, until 1992, when the FDA shut the program down. "Was it a good drug?" he'd ask each doctor. Again, the answer would be yes. "It was a wonderful drug," one University of Texas doctor responded, exceeding Lundquist's question. One regular courtroom spectator, after hearing a Lundquist cross-examination, observed, "What they [the prosecution] really need is someone to get up there and say 'Boy, we'll never use that stuff again!'" That never happened.

In light of such overwhelming evidence that ALG was safe and effective, FDA-mandated paperwork was a triviality, Najarian's defense implied. If Najarian was too busy practicing medicine to pay strict attention to the rules, his patients were the better and not the worse for it.

So certain were Najarian's lawyers that the jury would agree with this sentiment that Thompson, in his opening statement, brought up a violation of FDA policy that Najarian had committed that was not even related to a charge in his indictment. In doing a transplant on an 8-month-old girl, he said, Najarian broke the rules by administering ALG to her.

It was this same case— one of the unreported adverse reactions — that perhaps proved the most Pyrrhic victory for the prosecution. Dr. Mark Saxton, a University Hospital resident, took the stand to recount the case of the baby who received a kidney in 1990. Saxton testified that Najarian's signature appeared on a diagnostic summary that included the fact that the baby had respiratory distress after receiving equine ALG.

Saxton's testimony might have demonstrated to the jury that Najarian himself knew about an ALG reaction that was never reported to the FDA. But what they also heard was that Najarian saved the life of an 8-month-old, the

daughter of a 16-year-old mother whose grandmother had donated the kidney for the transplant, and who, after being switched to caprine ALG, recovered. Particularly attentive jurors might have remembered what Thompson said about the girl on the trial's first day. "She is fine. She is six years old. She is healthy. She lives out in Washington state. They say that is a crime Dr. Najarian committed."

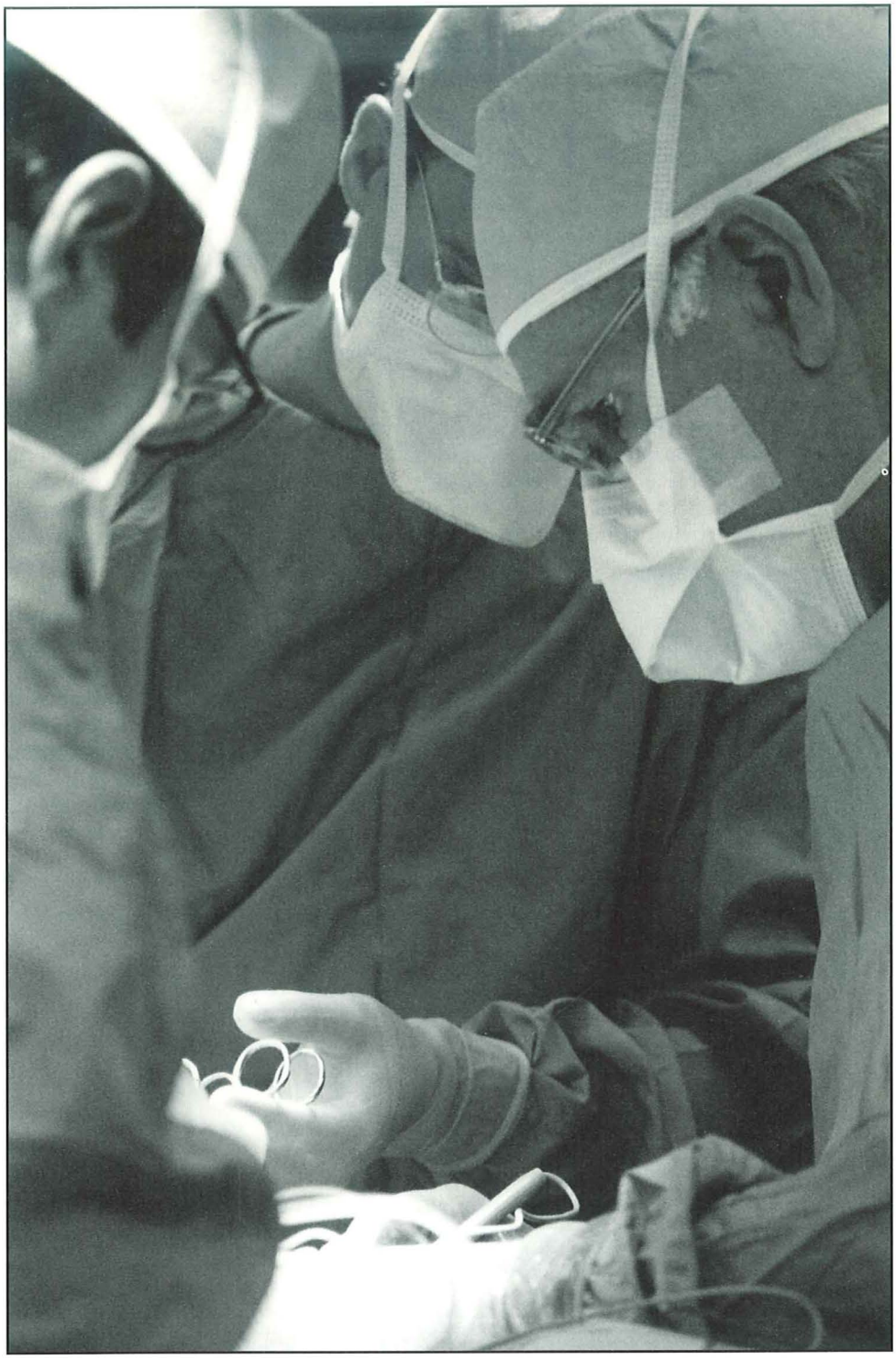
It is not hard to guess what the twelve Minnesotans on the jury would have done with such information, but it never got that far. On Monday, Feb. 12, Najarian's lawyers argued for the dismissal of seven counts against Najarian, including the four counts of medical misconduct. They claimed that the prosecution had not proved its case on those charges even enough to let the jury decide them.

For defense attorneys to file such motions is standard. The response of U.S. District Judge Richard Kyle was not. The following day he ruled that on six of the seven counts, including the four ALG-related counts, Najarian's attorneys were correct. In what is called a directed verdict, Kyle acquitted Najarian on those counts himself.

The trial was over a week later. Suddenly facing only charges of financial illegalities, Najarian was the defense's primary witness.

Largely through the testimony of an IRS investigator, the prosecution had laid out a clear pattern of double-billing on the surgeon's part, amounting to about $76,000, which stopped when the grand jury investigation began. They also made a strong case that Najarian had knowingly deposited $42,000 of other University funds into his private bank account and deliberately filed false tax returns.

On the stand, Najarian told the jury that while he did double-bill the University for travel, it was only to regain money he lost on those same business travels. Among the expenses the University's travel policy wouldn't reimburse, Najarian said, were business dinners and entertainment expenses he incurred recruiting students and doctors to the University. All the money he spent, the surgeon said, benefited the University. And if he double-billed to make up his losses, it always essentially came out even. "It was a wash," he told the jury.



The tax evasion and the misappropriation of other money meant for the University? Bad bookkeeping and carelessness, Najarian maintained: details that slipped into the cracks of an incredibly busy life. He pointed out that in the end he repaid all the money he owed, "when it was brought to my attention."

To the jury, the explanations sufficed. One juror said Najarian made "some errors in judgment and some errors of omission," but overall the jury was ready to let bygones be

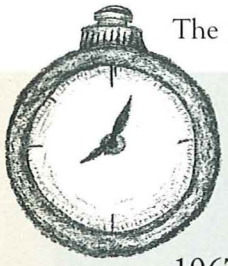
bygones. On the morning of Feb. 21, they re-entered the courtroom and acquitted Najarian on all remaining charges.

After the jury left for a celebratory lunch at O.J.'s in downtown St. Paul, U.S. Attorney David Lillehaug, who oversaw the case's prosecution, conducted a press conference/postmortem on the case in the law library of the U.S. Attorney's office. Lillehaug's comments that morning recalled Newberg's early statement that the case was about "what happened after Najarian left the operating room." He indicated that despite the prosecutors' best efforts to drive home their theme that "no one is above the law," jurors may not have been able to fully separate the operating room from the courtroom. "We knew it was going to be tough going after the doctor in the white coat," Lillehaug said. "John Najarian was the most well-liked defendant in the history of Minnesota."

The jurors were not the only ones who seemed to have great respect for Najarian's medical reputation. After the jury returned its verdict, Judge Kyle chided the prosecutors for raising violations of FDA rules — not laws in themselves — to federal crimes. In doing so, he made clear his admiration for the ALG program. "We had a program here in Minnesota which for all its problems ... saved a lot of lives," Kyle told the attorneys before dismissing them.

The verdict leaves a few unresolved questions. Minnesota ALG, painted during the trial as a drug in demand nationwide until the shutdown of the program, is still not on the market. The University, which owns the rights to the technology, has attempted without success to sell it to a pharmaceutical company. While two very similar products have replaced ALG in the nation's hospitals, both Najarian and Dr. David Sutherland, the current head of the University's transplantation program, have indicated that they are not superior products to ALG, having equal allergic properties. As the trial drew to a close in mid-February, head University attorney Mark Rotenberg confirmed that the University is currently in negotiations with a potential buyer for the ALG technologies.

As for Najarian, while he has been acquitted of all criminal charges, he has questioned whether his reputation will ever again be what it was before his indictment. Shortly after the verdict, he spoke bitterly of the University administration, which he said had "convicted me at every turn." And yet throughout his long legal battle he continued to practice through the University Hospital and has no plans to leave. In fact, it was to his University office that he returned the same day he was acquitted. Of all the things which have been questioned about Dr. John Najarian, his work ethic was never one of them. Only hours after the verdict, trailed by reporters and TV crews, Najarian put on his white coat and went back to work. ★



Chronology

1967
Dr. Najarian is recruited to the University of Minnesota surgery department from the University of California — San Francisco, where he began developing Anti-Lymphocyte Globulin (ALG).

1971
Najarian and subordinates get FDA permission to test the drug on human subjects and ship it to other hospitals. Under FDA rules, the drug is not to be sold, and patient data is to be collected from every investigator/hospital allowed to use the drug.

1988
The FDA, after an inspection, demands the ALG program stop charging for the drug until permission to regain production cost is granted by the agency. Several months later, Najarian and ALG-program employees meet with the FDA and get permission to charge at cost.

1992
The FDA shuts down the ALG program, citing violations of FDA rules on drug studies, like lax collection of patient data. Shortly thereafter a federal grand jury begins asking for ALG-program records.

1993
Najarian resigns as head of surgery department. Grand jury investigation widens in scope, delving into the surgery department's financial records.

February 1995
Najarian steps down from his teaching position after the University begins to take steps to remove his tenure.

April 1995
Najarian indicted by the grand jury on 18 counts of medical fraud, embezzlement and tax evasion. ALG program director Richard Condie indicted on four related counts.

July 1995
A revised indictment adds another embezzlement charge and two obstruction-of-justice charges, saying that Najarian tampered with the case against him.

Jan. 16, 1996
Najarian's trial begins in St. Paul.

Feb. 13, 1996
U.S. District Judge Richard Kyle throws out six charges against Najarian after the prosecution finishes presenting its case.

Feb. 21, 1996
The jury acquits Najarian on all remaining counts.

Inventing Tomorrow

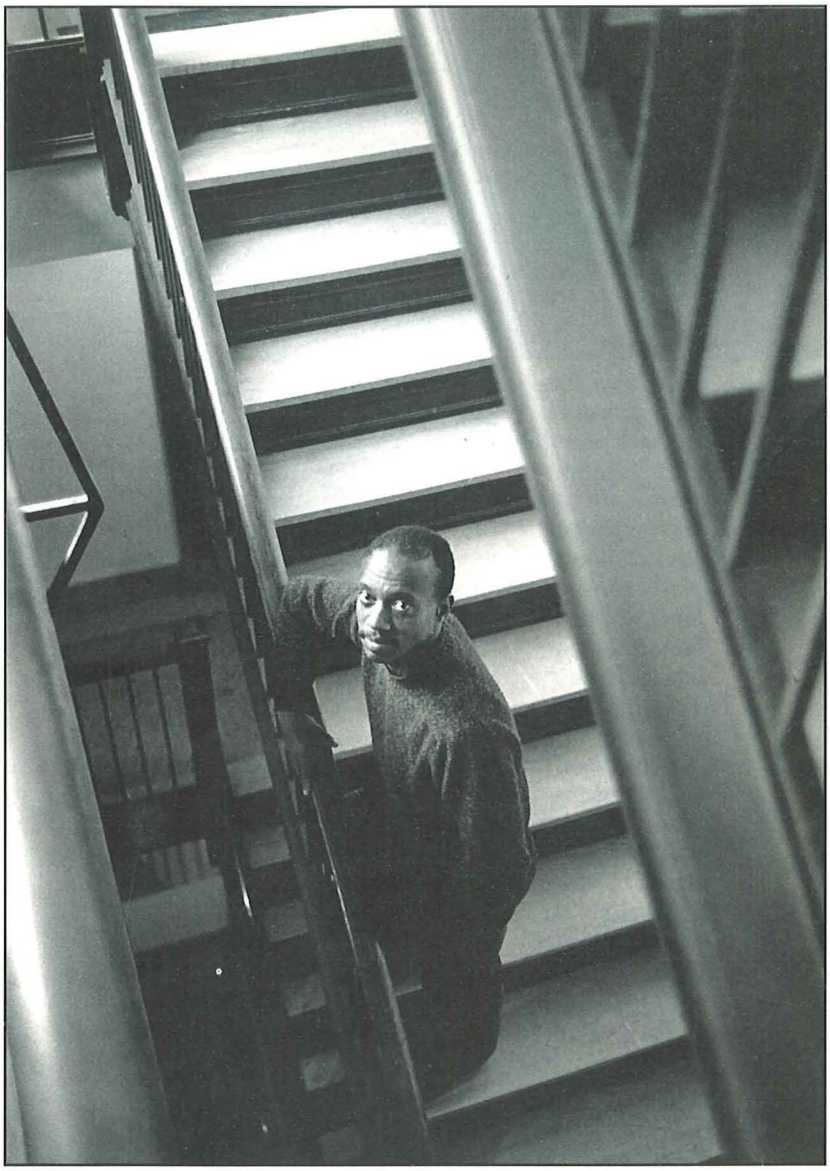
Reengineering the Institute of Technology

by Laura Walbrink

As it looks toward the next century, the Institute of Technology (IT) hopes to improve undergraduate education through several innovative programs. Despite its strong academic reputation, IT is plagued by low retention and graduation rates, particularly among students of color.

Forty percent of IT's freshman class of 1987 have graduated from IT; an additional 23% have graduated from other colleges within the University. The result is an attrition rate of 30%, a number that is high by comparison with other schools but consistent with the rest of the University. According to Dr. Peter Hudleston, Associate Dean of IT, better advising is necessary to "improve the undergraduate student experience and ensure that students can complete their program in a reasonable amount of time—four years."

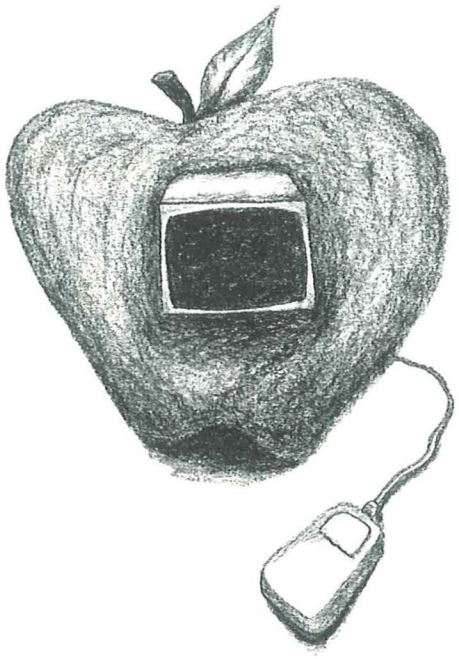
Although half of IT students graduate within five years, just 18% of students enrolled in IT's four-year programs actually graduate in four years. The numbers, while alarming at first glance, are somewhat misleading, Dr. Hudleston explained. "There are various reasons why students delay graduation," he said, "not all of which are necessarily bad." He noted that the Twin Cities campus attracts a large population of non-traditional students, many of whom work long hours and consequently take a smaller class load than is needed for timely graduation. Other students participate in co-op programs that defer graduation by a year or more. Because activities that postpone graduation may nonetheless be beneficial to students, IT should be wary of discouraging them, Dr. Hudleston said. With increased advising, however, "I think we should see an improvement in graduation and retention rates."



Samuel Moore, Director of the Program for Multiculturalism in Science and Engineering, is enhancing the University's commitment to diversity by attracting students from underrepresented populations to the Institute of Technology. **Photo by Chip Pearson.**

Another cause for concern within IT is its continued lack of success in attracting, retaining, and graduating students of color. While Asian-American students are well-represented and graduate at the same rate as the rest of IT students, African-American, Hispanic, and Native American students are significantly underrepresented. Dr. Hudleston called recruiting such students "a priority." A large part of the problem, he said, is that "there isn't the cultural support here that they might find in schools with larger numbers of students of color. We have a problem with critical mass, you might say, which is true of most schools in the Upper Midwest. Students of color feel isolated."

"We have to help make the University a friendly environment for students of color. One way is having people to talk to and advise them," Dr. Hudleston said. To achieve this goal, IT began Project Technology Power (PTP) several years ago. Its objective was to work with area high schools to recruit students and provide advice and services to University students of color. Although successful in advising its target students, "it has not been as effective as we would like in terms of recruitment and retention," Dr. Hudleston said.



Switch to Semesters

Dr. Hudleston is an active participant in the University's transition from quarters to semesters. The semester calendar, he said, will begin in fall of 1999. "The Legislature mandated the change to semesters for the unified state university system," he explained. "The University is autonomous, but the Legislature suggested to the 'U' that it might like to do the same. So, the basic reason for the switch to semesters is that the state has pushed us in that direction."

The University's decision to convert to a semester system has been met with mixed reactions, Dr. Hudleston said. "If you poll faculty and students here, you get a split. In terms of intrinsic merit of one or the other, I think it's a toss-up. The advantage of the semester system is that there's more time to develop the theme of the class and for the student to retain material. On the other hand, quarters are more flexible and can be tailored to individual preferences."

He confirmed that a calendar has been decided upon and will be voted on in the Senate next month. "It looks pretty certain that we will follow the Wisconsin system," he said, a logical move considering the number of students who transfer between the Minnesota and Wisconsin systems.

Moving to semesters will be challenging but "should not be a reason why students stay longer than four years," Dr. Hudleston stressed. Under the new system, "most courses will be three credits. A sequence such as the basic calculus, which currently has three four-credit courses, will probably be two four-credit courses. The total number of credits required for graduation will be two-thirds of the number now required." Liberal education classes, he said, are likely to be three credits. "The Senate committee on educational policy has been discussing the structure of the programs. It's still to be set."

Innovative Teaching Methods—Calc Class

Fall 1995 marked the inauguration of a new calculus sequence at the 'U': Math 1351-1352-1353, Calculus: Concepts, Explorations, and Applications. Strikingly different from the traditional basic calculus sequence, the course is taught by an instructional team and relies heavily on group work. The goal of the sequence is to better prepare IT students for later coursework by focusing on engineering and science-based applications.

The course is organized relatively traditionally. It meets for two one-hour lectures, one hour-long recitation, and one two-hour workshop per week. That's where the similarity ends, though, instructors say. The lectures, although large, encourage informal cooperative learning. "Because we're an instructional team, workshop material is connected to the lecture," explained Dr. Tracy Bibelnieks, Academic Director of the University of Minnesota Talented Youth Mathematics Project. "Instructors rotate through the workshops and get a feel for how students are handling the material. The lecture is not traditional. Only about ten to twelve minutes of lecture is the instructor talking. Then it's interactive; students work with their neighbor."

"In workshop, we try to do two things: expand upon what was said in the previous lecture and prepare for the next day's lecture," said Dr. Douglas Shaw, workshop coordinator and leader. "We give students practice with preparatory material." In contrast to most recitations, "workshops are very interactive, structured group work. They're not just for questions about homework," Dr. Bibelnieks added.

The textbook used in the course is unusual, approaching topics graphically, numerically, and symbolically. Workshops, said Dr. Shaw, "are really material-dependent. The chapter on integration was very computational, so there was a lot of practice involved. The center of mass topic was very theoretical. Students practiced stacking bricks, which involved

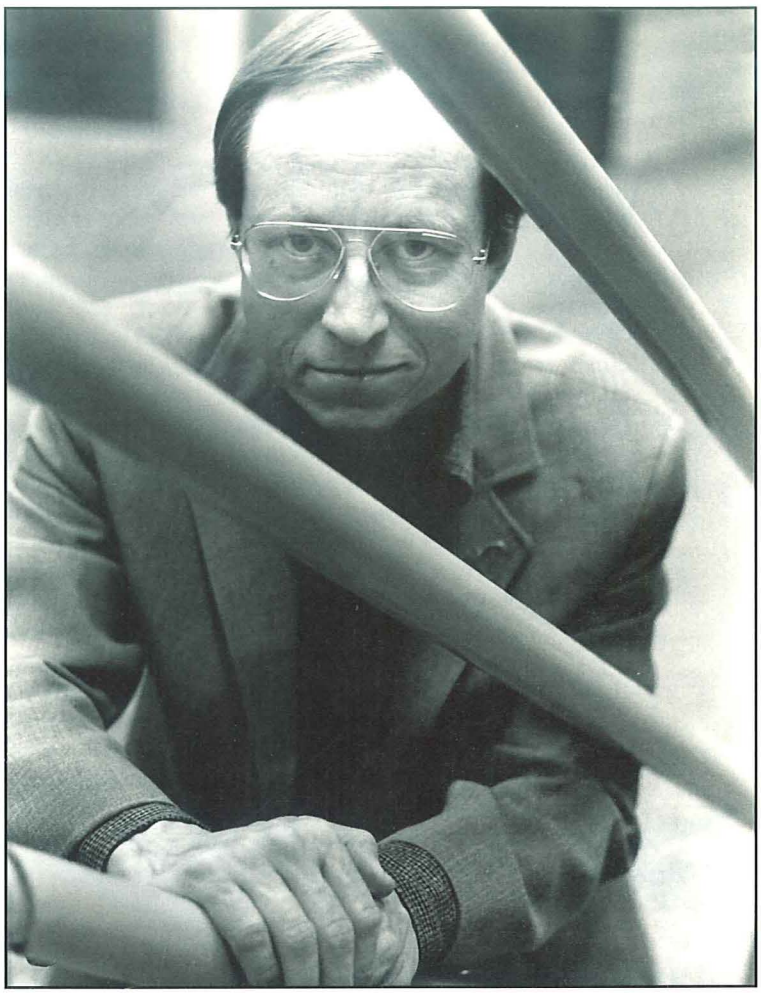
the concept of infinite series and the definition of center of mass."

The order in which topics are covered is also unorthodox, instructors note. "In the first quarter, we didn't get to symbolically calculating derivatives until the sixth week of the course. Students didn't get to limits until the fourth week," Dr. Bibelnieks said. Limits are typically among the first topics covered in an introductory calculus course. Instead, "we talked about what a limit is and how to estimate limits numerically, which is what engineers do," Dr. Shaw said. "Estimation in general is used throughout the course."

Using a hands-on, graphical approach allows students to understand more advanced material than that usually covered in beginning calculus courses. "We talk about antiderivatives early, in the first quarter," Dr. Shaw said. "We don't call them integrals, but once students understand what a derivative is, the concept of an antiderivative is intuitive." After students learn about derivatives, "they begin to guess solutions to differential equations. The connection between differential equations and modeling growth comes in very early in the course." As a comparison, differential equations are taught in the sixth quarter of the University's traditional calculus sequence.

Students work in teams to complete labs created by the Geometry Center. The labs are incorporated gradually into the sequence; one is completed during the first course, one during the second, two during the spring, and one every two weeks in the fourth quarter and beyond, Dr. Bibelnieks said. Students solve complex problems and submit professional reports. "The students have done an excellent job on the projects," she said. "They've been enthusiastic and put their hearts into it. We're amazed at the effort they put in and the quality we got out."

Surveys completed by students indicate a positive reception to the course. Rated particularly high are small group work, personal contact with instructors, and small class size. "Lecture attendance is unusually high," Dr. Shaw noted. Less highly ranked are technology and the textbook. "There have been misconceptions about the use of technology. World Wide Web use and graphing calculators are instructionally advanced," but they're not cutting edge to students. "They're not quite as convinced as we are that the applications are good ones," said Dr. Harvey Keynes, Director of Outreach Projects in the mathematics department. "Another issue that's been a little more difficult to deal with is the textbook. We believe in this textbook. It deemphasizes computation and routine skills, but it has to be read, not looked at. It's written at a different level, and students have a hard time adjusting. It was culture shock, but I think they're getting used to it." Said Dr. Shaw, "I think somewhere in the second quarter they started realizing they're learning a lot."



Venturing off the path of more traditional teaching methods, Dr. Karl Smith, a Professor of Civil Engineering, is developing new techniques in group learning. ***Photo by Teddy Maki.***

Having worked with each other frequently, "students in the class know each other well. They like the atmosphere," said Dr. Keynes. Instructors note a tendency for class members to "naturally make decisions together." Dr. Shaw recounted a situation in which students could individually volunteer to switch to another recitation section. Instead of deciding what was in their own best interest, however, "they immediately got together and discussed what to do. They ended up staying together."

"We're doing a big evaluation of the course, tracking students in the course and after the course. We're studying students this year and several years beyond using a comparative pool. Performance and attitudinal elements are being assessed. We're assessing the attitudes of faculty and students toward the course value," Dr. Keynes said.

"The math department is being very cooperative and supportive of this program," he added. "It's a high priority within IT. In the long run, we see this course dealing with half of the IT population."

Innovative Teaching Methods—Karl Smith

Dr. Karl Smith, professor of civil engineering, has studied cooperative learning for over 20 years. He has written several papers and books on the subject and conducted seminars and workshops to help other faculty incorporate the teaching method

into their courses. Dr. Smith advocates problem-based cooperative learning and technology-based learning. To solve the problems, students first decide what they must learn, then learn the material, and finally apply their knowledge.

Cooperative learning is extremely effective, Dr. Smith explained. "There are two things that most affect learning: the frequency and quality of student-to-student interaction, and the frequency and quality of student-to-faculty interaction." The method, he said, has existed for decades, but "there was a resistance among universities in the '70s to getting students involved, so it shifted to K-12. Now there's renewed interest."

In his early years of teaching, Dr. Smith's dissatisfaction with the effectiveness of his teaching methods led him to investigate other options. "The students didn't seem to learn what I was trying to teach them. I tried to rationalize it by saying to myself that this was high-level material that few people really understood the first time around. Students asked questions that showed their motivation but that I didn't really like: 'Will it be on the final?' and 'What do I have to do to get an A?' So I started exploring."

If used correctly, cooperative learning benefits all students, Dr. Smith said. He typically organizes students randomly, occasionally stratifying by common interest in a subject. "Having a common interest seems to make a difference in the group's performance," he said.

To encourage cooperation among students, he adheres to an absolute grading system. "Grading on a curve is fundamentally incompatible" with cooperative learning, he said, because it fosters competition among students and hinders their willingness to help each other. Nonetheless, "40% of engineering faculty are still using curve grading."

Dr. Smith uses a variety of groups in each course to "allow students to meet and work with as many peers as possible. Changing groups is a little disruptive, but it distributes challenging students." He gives students a lengthy and detailed syllabus at the beginning of a course, which he views as a contract between him and class members.

Extremely capable students benefit by cooperative learning in several ways, Dr. Smith said. "They gain a depth of understanding that they don't get working by themselves. They get appreciated by their peers. They're not viewed as threats, but rather resources. Their effect on the group is almost indescribable—the hard work, skills, and motivation they bring." In addition, "they gain skills for working with people and provide leadership." Struggling students benefit as well, he added. "They receive peer support and have models for motivation. The people you have to watch for are middle students. They can go either way. Success correlates with getting a group of people together to get things done."

Diversity—Samuel Moore

The Program for Multiculturalism in Science and Engineering (PROMISE) is addressing one of IT's largest challenges—a lack of diversity—by attracting students of color. Samuel Moore, a Ph.D. candidate in communication technology, is the new director of PROMISE. He plans to increase the pre-college recruiting pool of students, help current students succeed at the University, attract faculty of color, and attract students of color to the University's graduate programs.

Although the Twin Cities have a substantial number of students of color, attracting them to the 'U' is difficult, Moore said. "A lot of Twin Cities students want to go elsewhere. The best students get offers from Harvard, MIT, etc. We want to start competing." Because these students often make their decision based on scholarship offers, "our biggest obstacle is trying to identify enough financial resources. Every program across the country is competing for the same students. Hopefully, the student looks at more than the money, but it's an issue."

"Money," he added, "would start the students coming, but you've got to offer more than that to retain them. You've got to provide them support to get connected to the institution." PROMISE can help students become involved with the University, he said. Retaining students of color depends on "providing support to 17- or 18-year-olds who are facing misconceptions as well as a tough engineering curriculum. Programs like this are supposed to be a base for freshman and sophomore students. By junior and senior years, they should be assimilated into the department culture."

Another obstacle PROMISE faces in attracting students, unique to IT, is that many high school students lack the rigorous prerequisites necessary to enter the engineering curriculum. "Students often receive poor guidance in high school and lack preparation in science and engineering. They weren't encouraged in middle school."

One of the program's biggest challenges will be "showing people that this is not a program that pushes qualified people out for the sake of numbers. People don't want to admit it, but some feel that way." He wants to show that "diversity is an asset that's not taking resources away."

The implications of increasing enrollment of students of color, Moore said, are far-reaching. "Increasing diversity is about the economic security of everyone. They're depending on these students to work and eventually contribute to the US economy. To compete globally, it's in their best interest to increase diversity and produce an educated workforce.

"That's why I think corporations are sticking with diversity. It's good for the bottom line. Diverse backgrounds result in diverse solutions and make businesses more competitive for diverse populations. The smart people aren't looking at it as altruism anymore. It will determine the quality of life for the entire population," Moore said. ★

CARTOON

by Joe Scrimshaw

WRITERS WANTED

Minnesota Technolog is looking for writers (as well as illustrators) for the 1996-1997 school year. We're seeking IT undergraduate and graduate students who'd like some experience writing for publication! We have several beats in mind, including the environment, ethics, new technology, personal profiles and features, editorials, and personal reports on the specific projects you're working on for school.

Although our editorial board mainly consists of creatures from outer space, we've been known to work well with humans. If you'd like more information, or would like to come in for an informal interview with the editor, please leave a cover letter, a resume and any available writing samples in an envelope outside the *Technolog* office in Room 5, Lind Hall.

And, if you're not quite up to writing, but have interesting ideas for stories you'd like to see in upcoming issues of the *Technolog*, please jot them down on this form and drop it by the office.

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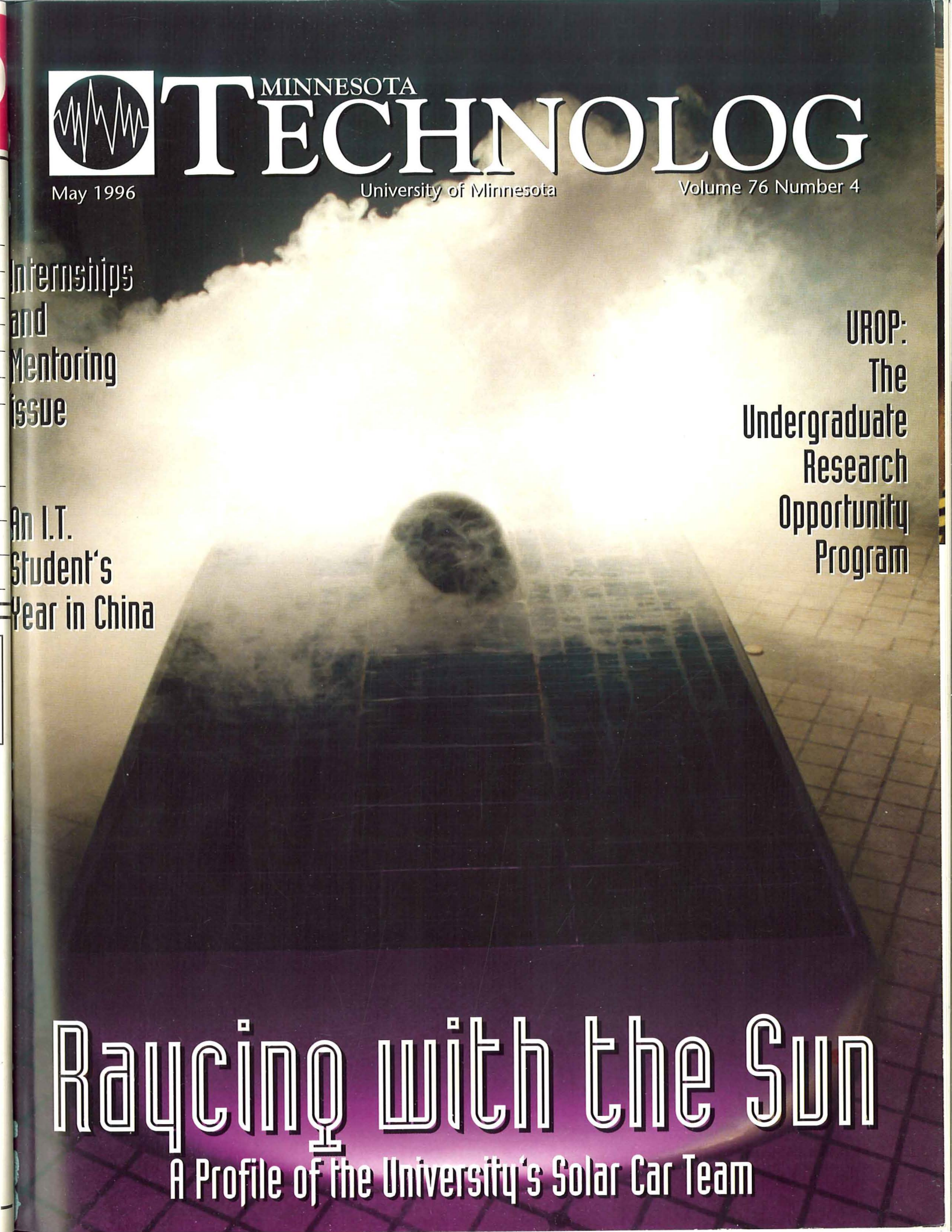


Internships and Mentoring Issue

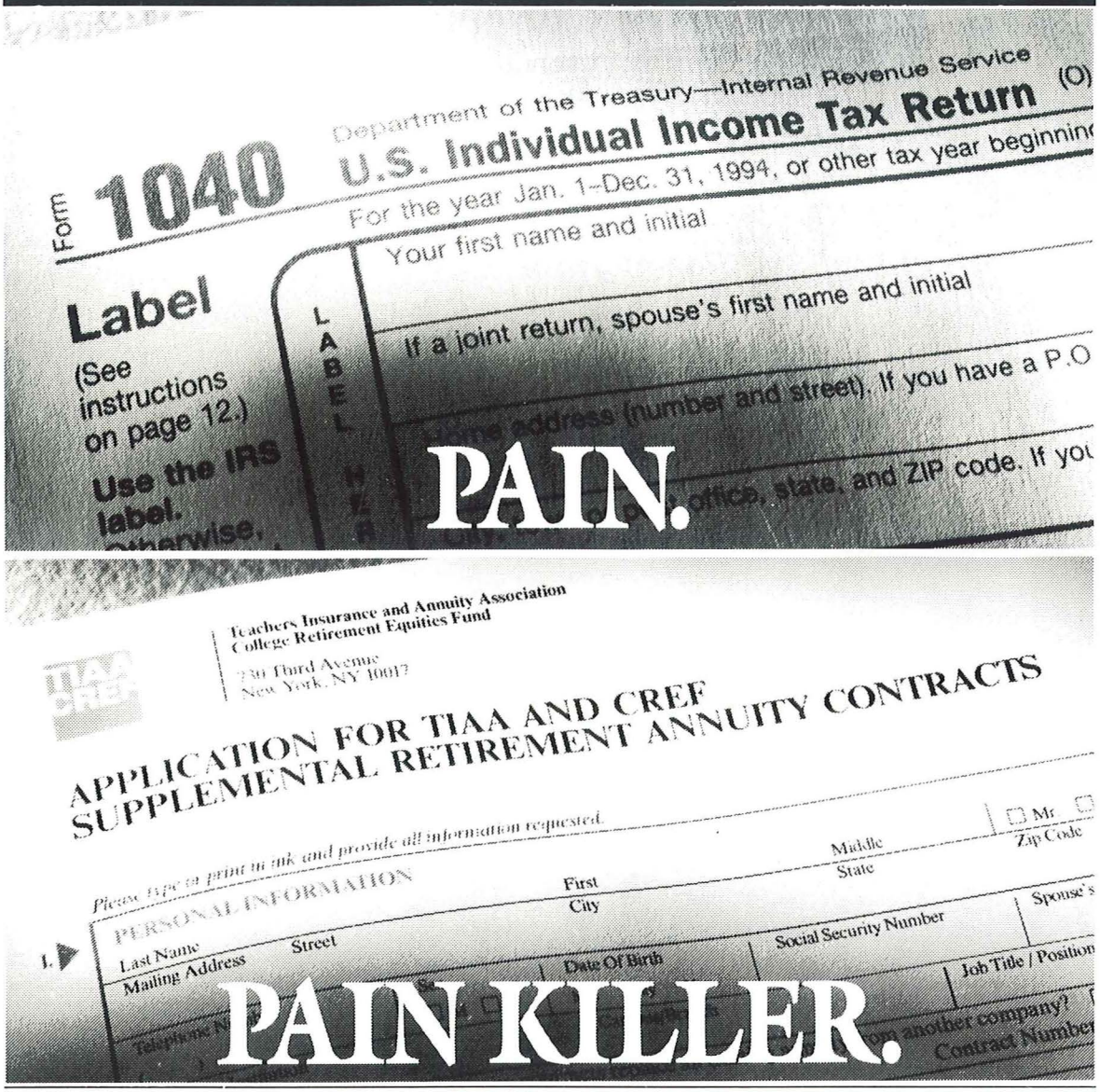
An I.T. Student's Year in China

UROP: The Undergraduate Research Opportunity Program

Raycing with the Sun

A Profile of the University's Solar Car Team

PRINCIPLES *of* SOUND RETIREMENT INVESTING



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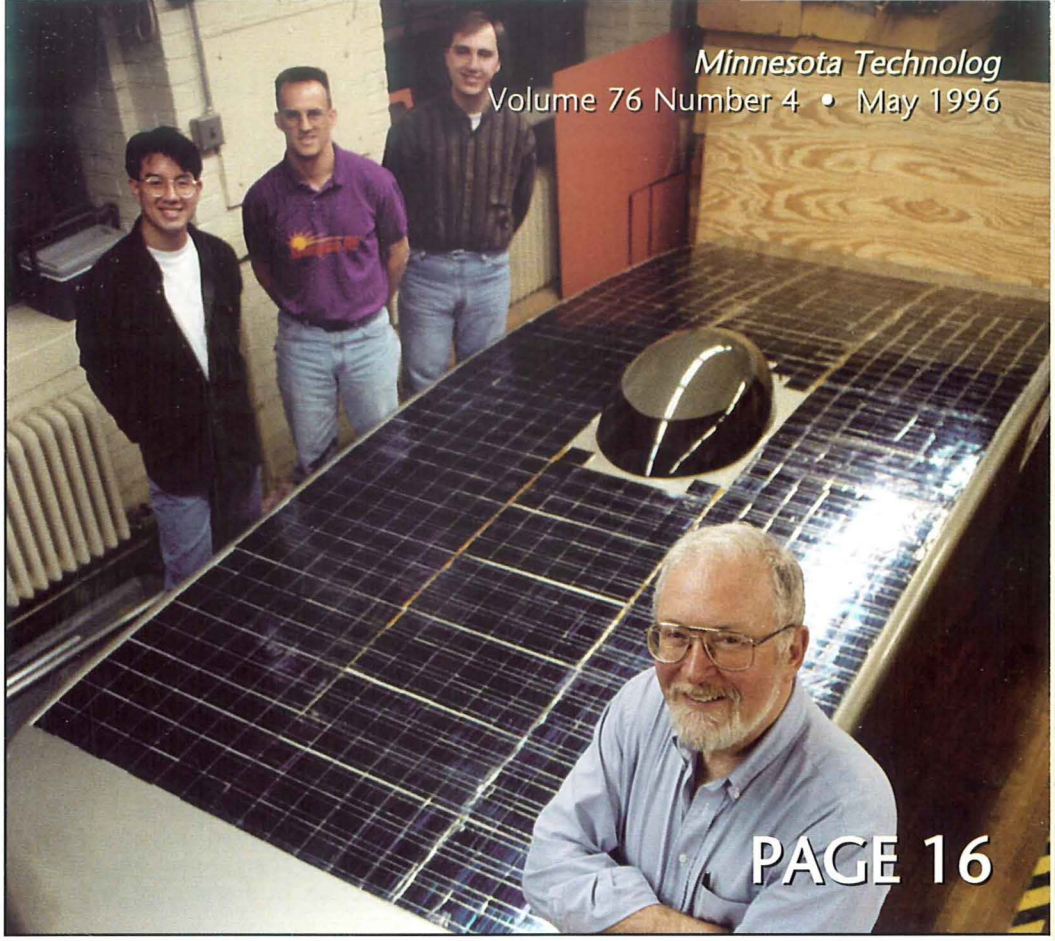

About the Cover

Straight out of a sci-fi flick, Aurora II, the University's entry into Sunrayce '95, possessed a surreal, futuristic look. Carrying the dreams of an entire team, the car coasted to a second-place finish in the country's premier college engineering challenge. The cover story begins on page 16.

Cover photograph by Joshua Zuckerman

EDITORIAL

by Gregory Lauer

High Tuition/High Aid Policy is Highway Robbery

In the political hubris of the last legislative season, Governor Arne Carlson banded together with a former legislator and representative and proposed the high tuition/high aid policy for higher education. Far from being a bold, forward-thinking funding paradigm for the future, Carlson's near-sighted tunnel vision threatens to make a University degree a distant dream for most middle-class, Minnesotan families.

The goal of Carlson's ghoulish nightmare is decent enough—increase educational opportunities for the poorest families on the economic landscape. The plan works something like this: by raising tuition at public institutions like the 'U' or St. Cloud State to stratospheric levels, more money is available for financial aid in the form of grants and loans. Unfortunately, backers of high tuition/high aid are mortgaging their initiative on the backs of the shrinking middle class.

To shamelessly steal from the in-your-face, get-off-your-butt motivational speaker, Susan Powter, I must protest, "STOP THE INSANITY!"

At Carlson's urging, former state legislator John Brandl and former U.S. Representative Vin Weber recently proposed sweeping changes to deal with anticipated budget deficits at the state level in the coming years. The dynamic duo is urging Carlson to slash spending by $1.2 billion by 2001, and education is slated to take a $500 million hit. Higher education's slice of the budget pie declined from an all-time high of 16 percent in 1987 to its present 12 percent, yet visionaries like Brandl and Weber are calling for another round of slash-and-burn policies.

Worse still, Brandl and Weber want to radically overhaul appropriations to the University. Currently, the 'U' receives approximately $1 billion every biennium, 90 percent of which is allocated directly and the remaining 10 percent of which is set aside for students in the form of grants and loans. Under the proposal, the University's share would plummet to 30 percent, while financial aid would skyrocket. If this draconian measure passes, tuition would rise sharply to cover the huge reduction in direct state appropriations.

This nefarious shell game must be exposed as the fraudulent funding scheme it is. The best method of insuring financial accessibility at public institutions like the University is to keep tuition low. Before sending the current system to the salvage yard of ideas from yesteryear, politicos should initiate small refinements like tightening eligibility standards for financial aid. Unfortunately, modern-day Robin Hoods lurking at the State Capitol are advocating a radical new system where we steal from the poor to help the poorer. Since 1990, the total of tuition loans has topped $100 billion, and the latest congressional cuts will exacerbate this trend.

Many students choose the 'U' because of its affordability, but sadly enough the muckrakers and social engineers in St. Paul ignore this fact. Simply put, the 'U' will price itself out of the educational market under the high tuition/high aid plan. While Harvard may be able to offer 70 percent of its students some form of financial aid, the annual price tag exceeds $27,000. This is not a model the 'U' should follow.

The former chancellor of Minnesota State Universities, Terrence MacTaggart, argued against a similar high tuition/high aid proposal that was circulating in the educational community in 1994. At Metropolitan State University, for example, increased financial aid packages would have been awarded to roughly 1,000 students at the cost of increasing tuition for 7,000 other students. That hardly seemed like an equitable solution.

Tuition increases at the University since the early '80s total a whopping 264 percent (and recent action by the Board of Regents will tack on another 7.5 percent). By comparison, the Consumer Price Index jumped 71 percent during this time. Another tuition hijacking is not in the students' best interest, although administrators and politicians like Carlson just don't get it. W. Phillips Shively, in his state of the Arts, Sciences, and Engineering address, highlighted this callous disregard for students by maintaining, "We could, in a sense, have our cake and eat it too."

A high tuition/high aid policy will not serve the best interests of Minnesota, and Carlson would do well to ignore the ramblings of his blue-ribbon advisors.

In the 1994 gubernatorial campaign, John Marty, the DFL-endorsed candidate, ran a series of political attack ads that ended with the familiar refrain, "That darn Arne!" It's a shame more of us weren't listening because he's still our darn governor, and he hopes to make the University darn more expensive. ★

ECMA NEWS

Reprinted from other members of ECMA, Engineering College Magazines Associated

Understanding Our Universe

Researchers at the James R. Macdonald Laboratory at Kansas State University are probing the inner workings of the atom. Built in 1967, the Macdonald Laboratory houses four primary particle accelerators. In many of the experiments, an atom is sped up and smashed into another target atom, and the outcomes of such high-speed collisions offer insights into the behavior of electrons. The Tandem Van de Graff Accelerator, built in the 1960s, generates medium velocity collisions. By "medium velocity," Tracy Tipping, a researcher at the center, explains, "Try approximately five percent the speed of light. At that speed, you could travel from New York City to Los Angeles in 1/35 of a second." Tipping goes on to explain the physics behind the accelerator. Negatively charged ion beams are sent towards a positive charge source, then stripped of their elections and given a positive charge, and finally sent speeding out due to the repulsive forces generated. The ions are then steered by powerful magnets toward a collision chamber. In the world-class caliber Macdonald Laboratory, researchers hope to gain a better understanding of high energy processes. Such knowledge is essential for members of the scientific community studying such areas as astrophysics and nuclear fusion. Tipping summarized the activities in the lab, saying, "We are building fundamental puzzle pieces (in atomic energy research). Hopefully others take our research and put the information we gather together."

—Prasanth Reddy
Kansas State Engineer
Spring 1995

River Deep, Mountain High

Behind a set of doors in the office wing of the chemical engineering department is a dimly lit room with Batman paraphernalia hanging from the walls. A table is covered with papers, experiments, and artificial body parts, and a rubber hand protrudes from a closed filing cabinet. Welcome to the Biological Altitude Testing Laboratory, the home of Dr. Igor Gamow and his colleagues. He created the Gamow bag, a portable chamber that relieves altitude sickness in mountain climbers, and he developed the High Altitude Bed. Gamow and others are working on a running shoe that conserves metabolic energy better than any product currently on the market. He is also improving the Magic Fluke, a human powered swimming machine invented in the early '70s that mimics the powerful movements of a dolphin's tail. Gamow chose an untraditional path to a professorship at the University of Colorado. After dropping out of high school, he danced with the National Ballet in Washington, D.C. and worked part time as a motorcycle courier for the Eisenhower administration. He then returned to Boulder and earned a degree in biology and later a doctorate in biophysics and microbiology at Denver. After hearing of Gamow's experiences before coming to the CU, it's not surprising that he considers himself a storyteller. He says, "Anthropologists have been trying to define what it means to be human for centuries. At one point they defined humans as tool makers, but clearly many animals make tools. Then they tried to define humans as users of language, but clearly many animals and some insects have language. But to date I challenge anyone to find an animal or insect that can spin a yarn about beautiful princesses, dark forests, once upon a time. The essence of being human is simply to be able to tell a story."

—Alicia Karspeck
Colorado Engineer
Spring 1994

MINNESOTA TECHNOLOG

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Play it again, *Technolog*

The Doctor is In

During the early 1960s, Jerry Weizenbaum of MIT teamed with Kenneth Colby, a Stanford psychiatrist, to create a computer program that would simulate the psychotherapy process. The program, called ELIZA, generated appropriate conversation in response to the user's statements. To many people, the program was so convincing that it seemed that they really were speaking to a responsive psychotherapist. An example:

HELLO. I AM THE DOCTOR. PLEASE TELL ME ABOUT YOUR PROBLEM. TYPE IN COMPLETE SENTENCES AND ALWAYS END YOUR SENTENCE WITH A PERIOD.

My mother makes me so mad sometimes.

CAN YOU GIVE ME AN EXAMPLE?

She phoned me and expected me to drop everything.

TELL ME ABOUT YOUR FAMILY.

I hate my parents.

WHY DO YOU HATE YOUR PARENTS?

They won't let me go.

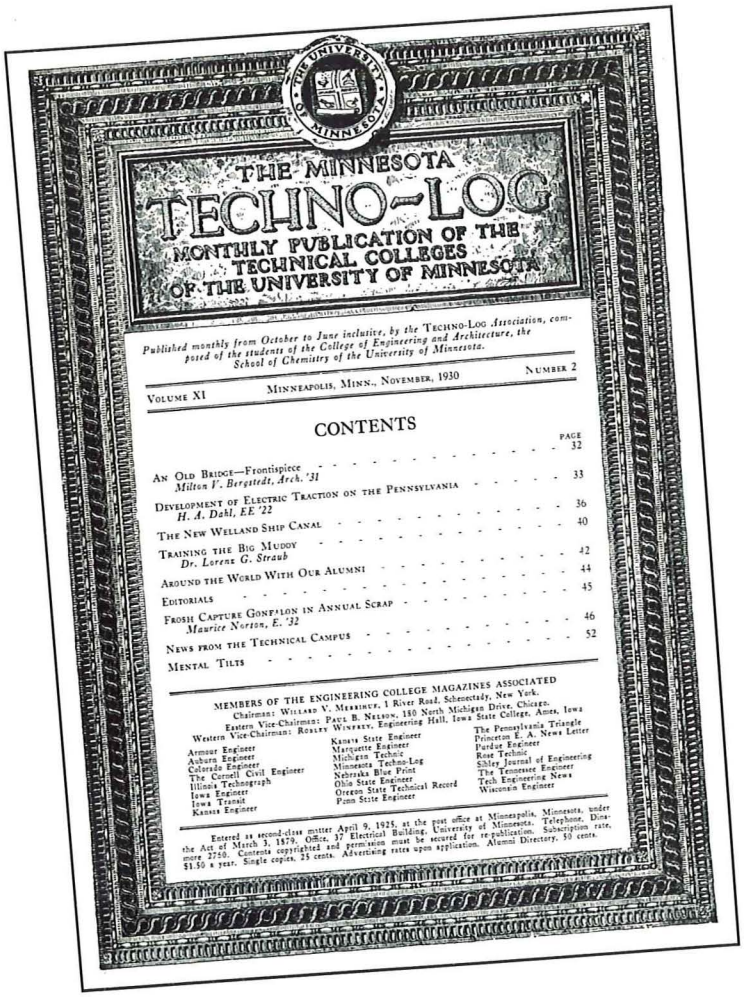
IS IT IMPORTANT THAT THEY WON'T LET YOU GO?

I'm suffocating.

Colby and Weizenbaum eventually disagreed on the ethics of computer psychotherapy. Weizenbaum felt that the human interaction involved in psychotherapy was essential. Weizenbaum was also displeased with the program because he knew that the computer was only responding to a sequence of words or key words and not actually understanding the user's statement. Users, however, did not know this. For example, if the user typed "mother," "father," or some other familial noun, the computer would respond with, "Tell me about your family." The computer could also invert certain sentence forms into questions. If the user wrote "I hate you," the computer would respond, "Why do you hate me?"

Part of ELIZA's success stemmed from the mysterious and fantastical aura surrounding computers in the 1960s. Very few people had ever used computers or knew what they were capable of and how they worked. As computers became more accessible, people realized that it would be very difficult for a computer to actually engage in meaningful conversation with a user without resorting to an extremely complex algorithm. As they began to understand that the computer could not really comprehend their words, the mystic powers of ELIZA were diminished.

—Winter 1986



THE MINNESOTA TECHNO-LOG

MONTHLY PUBLICATION OF THE TECHNICAL COLLEGES OF THE UNIVERSITY OF MINNESOTA

Published monthly from October to June inclusive, by the Techno-Log *Association, composed of the students of the College of Engineering and Architecture, the School of Chemistry of the University of Minnesota.*

VOLUME XI — MINNEAPOLIS, MINN., NOVEMBER, 1930 — NUMBER 2

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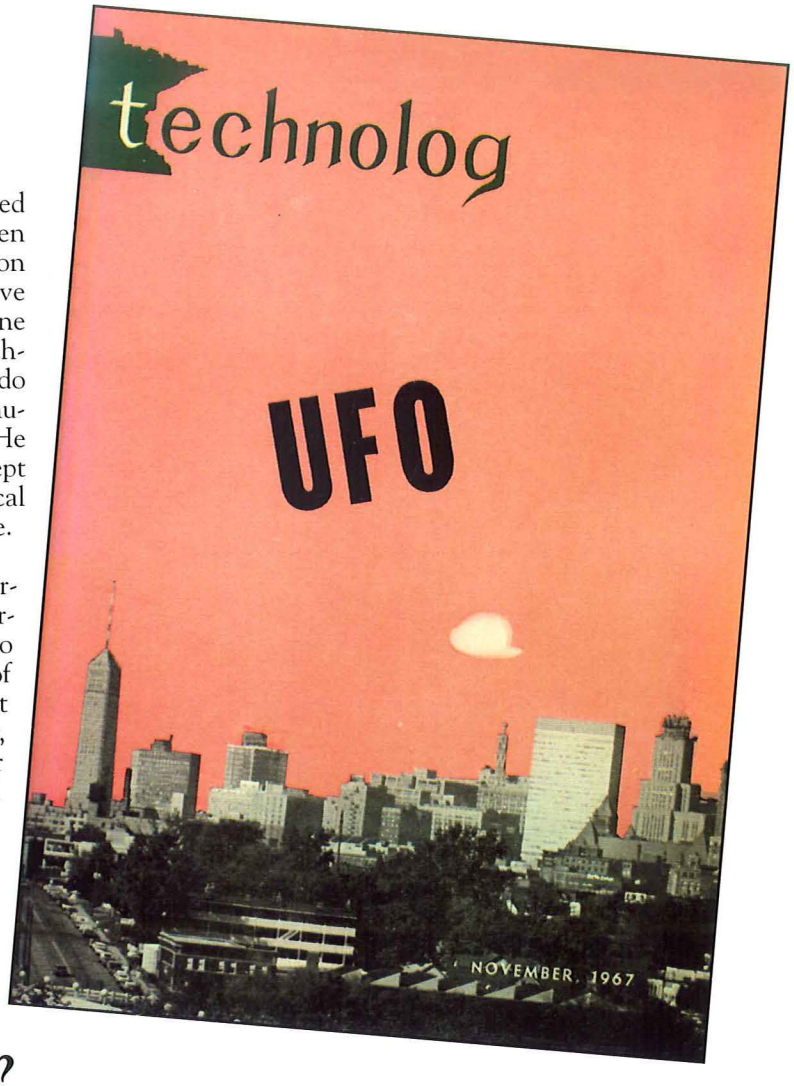
This page: *Cover of the November 1930 issue (Vol. 11, No. 2).* ***Opposite page:*** *Cover of the November 1967 issue (Vol. 48, No. 2).*

Before the Glass Ceiling

Since the war, employers have increasingly hired women with technical degrees. The demand for women is highest in chemistry, engineering, drafting, inspection engineering, metallurgy, and physics. Employers have found women to be highly qualified employees. As one employer stated, "In general, our experience with technically trained college women has shown them to do very well on manipulative work and repetitive accumulation of data on routine analytical assignments." He indicated that some women were hesitant to accept responsibility and criticism but noted that physical strength typically was not a factor in job performance.

Employers express concern over the "matrimonial mortality" factor: the high turnover of women due to marriage and childbirth. Some companies are reluctant to advance women into positions requiring a great deal of responsibility and experience because of the high cost of finding a replacement. Increasingly, however, women are choosing to continue their careers after marriage. They find that they enjoy their work and the lucrative salaries that accompany their jobs. Because the field of scientific research is growing rapidly, the number of technical positions open to intelligent, qualified, and imaginative women is likely to continue to exceed the supply.

—October 1946



In Need of Newer Editions?

The rapid and unnecessary changing of textbooks by faculty in the College of Engineering and College of Architecture is creating hardship for students who are not affluent. Students attempt to save money on textbooks by purchasing them used and selling them after use. If new textbooks are chosen and older ones discontinued, students must buy new books and are unable to sell previously used ones. Admittedly, changing textbooks frequently makes sense in fields and courses in which discoveries are constantly being made. However, many current textbooks are being replaced with new versions containing one new chapter or minor variations in material. For students, having to buy the new editions is only slightly advantageous academically and quite detrimental financially.

If departments are experimenting with texts, they should bear some of the financial burden.

—October 1934

Ever-Changing Curriculum

Several colleges have announced curriculum changes. In the Department of Electrical Engineering, Machine Design, previously required for all electrical engineering majors, has been replaced by a course in alternating current circuits. This course, mandatory at most schools, trains seniors in the theory of alternating current machinery and the complexities of communication engineering.

Public speaking and surveying courses have replaced two drafting courses required by the Department of Mechanical Engineering. An elementary course in industrial engineering has been added to the core curriculum. The change is in response to the evolving role of mechanical engineers. Because they are often promoted to executive and managerial positions, mechanical engineers need a broader background than was offered by the many drafting courses required for graduation.

The School of Chemistry has reduced its Chemical German requirements from eighteen to twelve credits. Students now take Unit Processes in the fall of junior year which allows them to apply classroom skills earlier in their collegiate careers. A course in chemical engineering economics has been added to the senior year curriculum, and Chemical Calculations has been made a three-credit course.

—October 1930

Far Beyond a High School Science Fair

the *U*ndergraduate *R*esearch *O*pportunity *P*rogram

by Kari Siegle

Since the beginning of his college career Ryan Godfrey has taken advantage of all the options available to him. He enrolled in the Institute of Technology his senior year of high school through a post-secondary program, took honors courses and is currently conducting research through the University's Undergraduate Research Opportunities Program (UROP).

Along with his studies, working on research projects for the UROP program helped him find his niche in the sciences. "Doing the research really confirmed and set me on the right path. This is what I want to do," said Godfrey, who will graduate this spring with a degree in physics. This past summer he measured how bits, which control a computer's memory capacity, lose their net magnetization over long periods of time. This phenomenon translates into lost data and information.

Above photo: *Ryan Godfrey, a physics undergraduate who participated in the UROP program, stands behind a test tube containing a ferritin solution. Godfrey is studying the exchange interaction, a quantum mechanical effect that occurs between neighboring dipole particles. His research is contributing to a better understanding of magnetism.*
Photo by Chip Pearson.

Internships & Mentoring

The program has given research opportunities to many undergraduates before Godfrey and continues to do so today, funding about 375 projects a year. It was one of the first programs in the country designed to support undergraduate research, and since its inception in 1985, a large number of similar projects have appeared in colleges across the country. The University began the program as an opportunity for undergraduates to connect with faculty and and conduct research. Participants often list UROP experience on a resume, and the program helps students make career choices. IT was one of the program's original sponsors, along with the College of Agriculture, College of Biological Sciences and the College of Liberal Arts. Today the program has expanded to include all the colleges on the University campus and students from Duluth, Morris and Crookston.

UROP coordinator Vicky Munro said the importance of research experience has filtered down the ranks over time. Although long a staple of faculty and graduate student life, today research experience is almost an expected part of an undergraduate education. The demand for students who have conducted scientific investigations and have written or published papers is greater than for those who haven't.

Full-time undergraduate students in good academic standing are eligible for the program. Students write a project proposal in which they outline an area of research and identify a faculty member to work with. Peter Hudleston, IT's associate dean for undergraduate studies and program coordinator, said the proposal must be scientifically worthwhile and the project must yield results during the 120 hours students are funded. At the end of the time period, students write a report on their findings and an evaluation of the program. Students receive a $950 financial stipend for the time they spend on their projects and can receive an allowance of $250 for supplies and expenses. Munro said by offering students monetary compensation for their research, the program allows many students an experience they might not otherwise get. "It's an opportunity for students to work on something that will help them more than being off-campus flipping burgers," she said.

Nearly 30 IT students applied for the program this past fall. Hudleston said the relatively small number of students is the result of students' full schedules, a lack of information about the program and a tendency for students to feel uncomfortable approaching faculty members. Current projects range from organic chemical synthesis to analyzing how the stock market works.

Looking at Godfrey's family, it's easy to see where he found his interest in the sciences. His father is a doctor, his mother a food scientist and his uncle is an electrical engineer. Another uncle worked on the University's particle accelerator project, and although he now lives in Texas, he often takes Godfrey to conferences on subjects like plasma physics. Through the UROP program, Godfrey was able to conduct undergraduate research of his own and continue a family tradition.

In a room where the ceiling pipes are painted in bright colors and five kinds of fish swim in a large tank near the door, Godfrey worked this past summer on hard disk drive decay. Understanding the decay is important because one of the trends in computer design is to squeeze more bits into smaller spaces, thereby increasing memory. The smaller the bit, however, the quicker decay can occur. By densely packing bits together, higher and more unstable energy states occur. By understanding this phenomenon, "safe" bit sizes may be determined, and computer memory can be optimized.

When computer bits in hard drives are "written to," their magnetized dipoles are aligned in a specific direction, creating a magnetic field. Godfrey used a c-magnet with wires wrapped around it and current pulsing though it. The apparatus was then held over the top of the bits. The c-magnet's current induced a magnetic field that aligned the bits' dipoles in a specific direction, creating another magnetic field and a high-energy state. But the bits are not all pointing in the same direction; in particular, a bit's neighbor will be in the opposite direction. Godfrey investigated this micro-universe by examining the peaks and valleys on an oscilloscope and measuring the strength of the magnetic fields.

Domain decay results when the bits return to their random orientations, low energy states, and a no-net-magnetism condition. But the decay is something few of us with computers need to be concerned about anytime in the near future. "You only have to worry about it if you're around for 100,000 years," Godfrey said.

The first method he used to study rapid domain decay involved two computer heads pointed towards each other over a rotating disk. He would write to the disk at one point and then examine the bits after the disk revolved to the second head. By doing this he hoped to measure the decay time. Unfortunately, the heads picked up magnetic fields from one another, and the oscilloscope's readout showed this extra noise. Another problem was that the bits decayed too slowly for

noticeable changes to be detected.

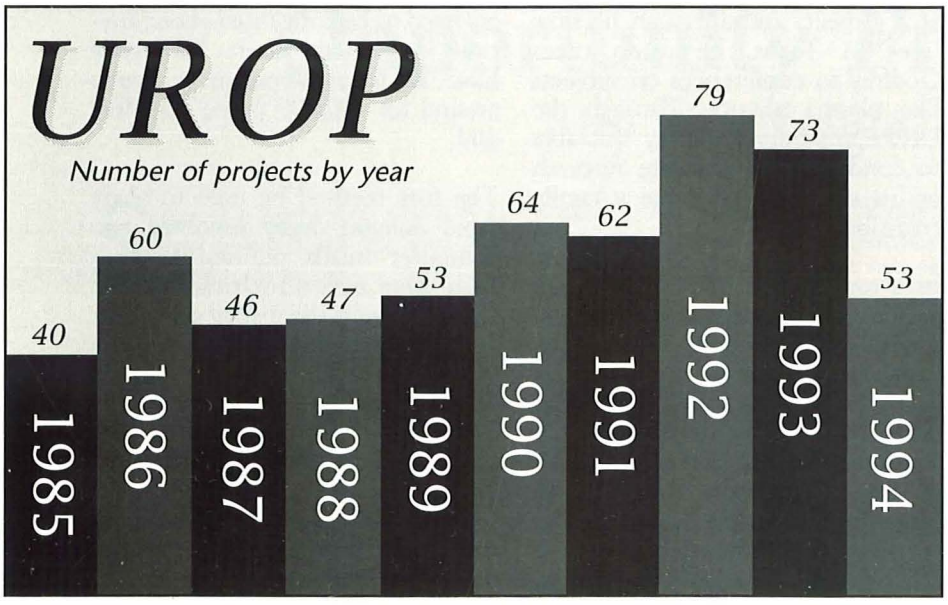
Godfrey developed another method to document decay by using only one head and allowing the disk to spin for a period of time. Instead of measuring in microseconds, as in the two head method, Godfrey measured the decay over a period of hours or even days. However, one problem this method presented was that the one head needed to remain in exactly the same position. Left for too long in one spot, outside forces acted on it and moved it.

Above: *Probing the secrets of rapid domain decay, Ryan Godfrey holds top computer hard disk drives.* ***Photo by Chip Pearson.***

He finally decided to heat things up a bit. By baking a disk drive in an oven at about 1,000 degrees he could speed up the decay. Then Godfrey extrapolated the data back to room temperature. "It was kind of a jump of intuition. I thought, 'Hey, it might work if I did it this way,'" said Godfrey, who added that it was his advisor, physics professor Dan Dahlberg, who gave him the idea. But he said he was unable to heat the disk drive at a number of different temperatures and collect the data because of a lack of time.

This was Godfrey's first research project, and he encountered a number of problems. He also had to deal with issues he hadn't encountered in the classroom before, such as building circuitry. Sometimes what he thought would work originally, didn't. "I had to learn it's not going to work the first time and it's almost guaranteed not to work the fifth time," he said.

Making mistakes, bumping into experimental problems and finding out where to go to answer questions are all discoveries students should make, Hudleston said. "It makes the scientific process much more real than if they get everything out of a book," he said.



Dahlberg's participation in the UROP program as a project advisor is a result of something he learned as an undergraduate. He said he might not have stayed in physics for as long as he had if he did not have the experience of working in a lab as an undergraduate. It's evident from looking around his lab how he tries to make the atmosphere more upbeat for his students. One year he contributed to the purchase of an espresso machine for them, and the bright powder blue door and paneling were his ideas. "Students can take classes but they really don't know what you do in the business," Dahlberg said. He likened a scientific career without real world experience to wanting to be a guide on wild river rapids and not going out and getting wet.

Another part of his research Godfrey likes is that he is largely left to discover new things on his own, with his advisor in the background to help. "It's nice from the standpoint that I'm working on my own on the project and I can go at my own pace," he said.

After analyzing the domain decay of hard disk drives, Godfrey decided to pursue another project. He's currently studying bio-magnetism and hopes to eventually develop it into a senior thesis. While his stipend hours have run out, he continues to work on the project under the direction of Dahlberg. Godfrey chose the topic because he wasn't interested in studying subjects where the results are predetermined and the conclusion is written before conducting the experiment.

Godfrey works with ferritin proteins, iron storage proteins extracted from horse spleens. These proteins have a polypeptide shell and an interior cavity that can be as wide as nine nanometers. Ions travel through tiny channels in the outside layer to the cavity where they couple together and cancel each other's magnetic properties. Normally these ions are frozen in particular magnetic directions. If alternating current is added and the temperature reaches 80 to 120 Kelvin, the ions can flip charge but still remain anti-parallel in relation to each other. This is called the blocking temperature, or the point where the thermal energy overcomes the magnetic order and energy. Godfrey plans to look at the AC susceptibility by varying the temperature, time and core sizes of his samples.

Godfrey was especially intrigued because two previous studies offered conflicting conclusions. "It's attractive to me because it's something new," he said. One study used reduction, meaning an empty core was used and ions were added to make it larger, resulting in graphed conclusions that were non-linear. These proteins also had rough textures in their outer coatings. The other study considered full cores, so ions were removed to make it smaller.

While Godfrey said this project doesn't have any direct applications, it can contribute to the basic knowledge of magnetism. "It's useful from the standpoint that when you understand something you can better utilize the properties of it," he said.

Also, much of the research conducted today is done without an immediate application, said Dahlberg. No one would have guessed, he said, that when scientists like Marie Curie began researching radioactivity their results would eventually lead to x-rays, nuclear power, and radiation therapy for cancer.

"You never know when something you do in fundamental research is going to have a big impact in technology or just in how we view ourselves in the universe," Dahlberg said. ★

Above: *The trend in computer design today is to squeeze more bits into smaller spaces, thereby increasing memory. Smaller bits, however, decay faster. By studying domain decay, "safe" bit sizes may be determined and computer memory may be optimized.* **Photo by Chip Pearson.**

GOTTA GET A JOB!

INTERNSHIP PROGRAMS IN THE INSTITUTE OF TECHNOLOGY

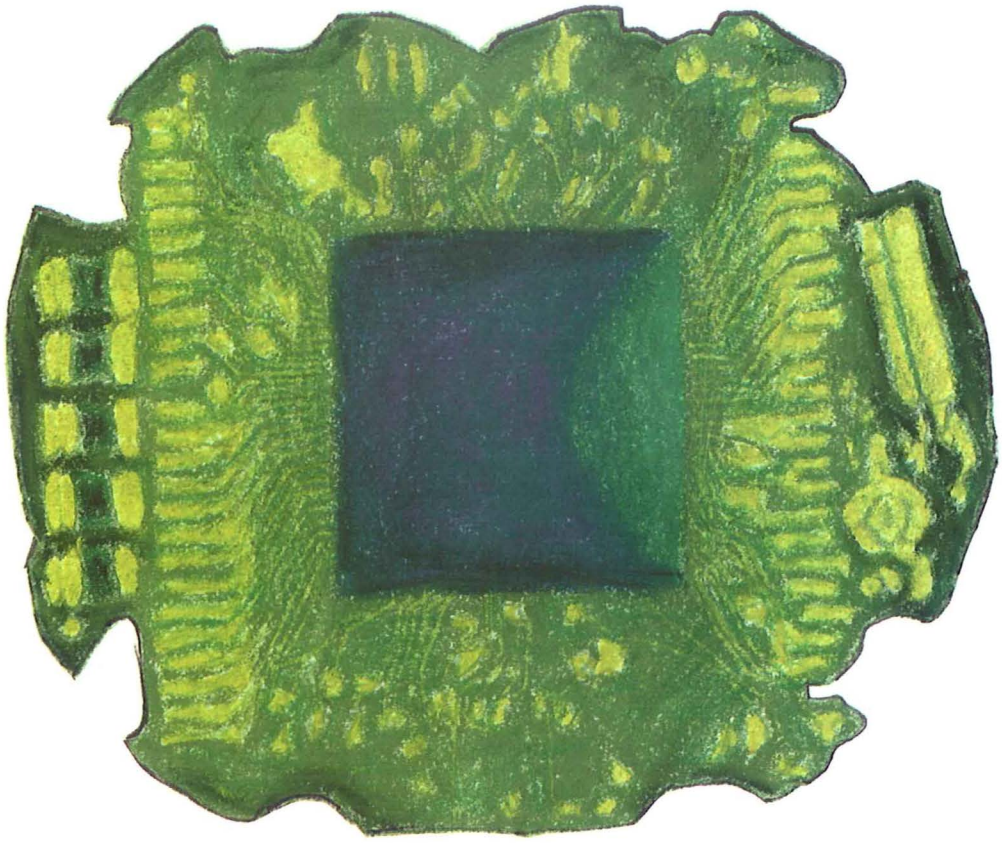
BY STEVE GIGL

IT is a well-known paradox: To get a job, you need experience, but to get experience, you need a job. There is always a healthy demand for engineers in this country, but companies tend to look for applicants with experience in the field, those who can make a contribution right away. Participating in a cooperative internship program within their academic department may help students qualify for such positions.

Internships and co-ops give students experience in industry, an environment totally different from that of the University. The time they spend on industrial assignment looks enticing to employers on a resume, and students learn about the requirements of at least one job in their chosen field before they graduate. Companies benefit as well: they hire short-term employees at a relatively low salary and have the opportunity to evaluate them for possible full-time positions.

Three of the major engineering internship programs at the University of Minnesota belong to the Mechanical, Electrical, and Civil Engineering departments. Companies in (and sometimes out of) the area contact

each department and inform them of their needs for the next work period. In some cases, they are responding to invitations from the department to offer internships. Students accepted into the programs are given the chance to interview with one or more of the companies and are told soon after whether they have been offered a position. After that, students alternate working with going to classes, the exact schedule of which depends on the department.

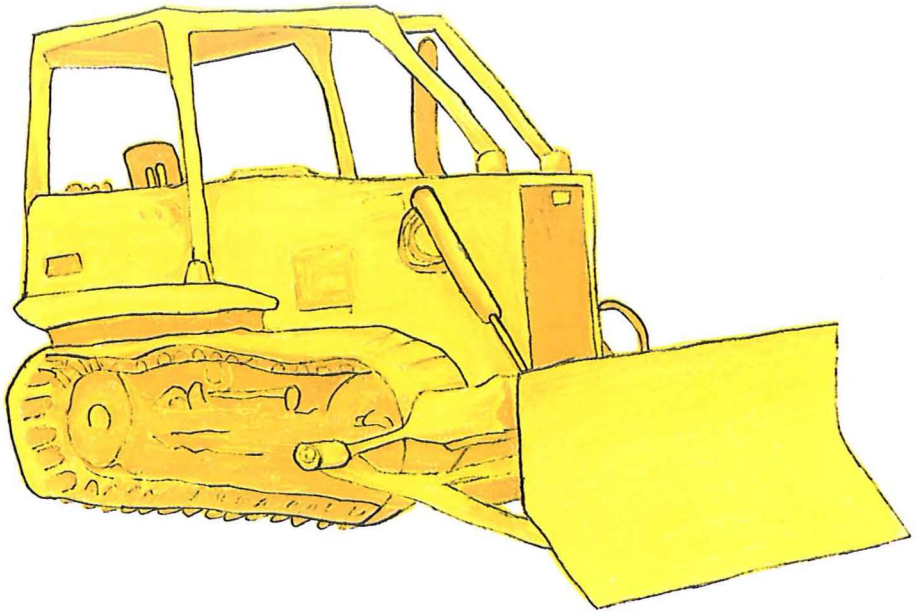


ELECTRICAL

The E.E. Co-Op Program is set up for students to alternate working quarters with study quarters, for a total of three working quarters (the fourth is optional). Candidates can apply any time during the year, but mass interviews are only held during fall and spring quarters. "Nearly everyone who applies will get a job. The only problem in placing a student occurs when that student only wishes to work in a certain area of electrical engineering," said Kathleen Propp, the E.E. Co-Op Program Coordinator. E.E. co-op students must be admitted into the upper division and have completed certain courses before their co-op experience begins. Companies like Honeywell, NSP, and Cypress Semiconductor want to be sure that the students they hire will be able to perform the tasks they are assigned.

Co-op students often get involved in design work, research, and other technical jobs performed by a regular engineer. "The first quarter primarily consisted of getting used to the company by doing smaller projects," said Robert Vinje, a senior E.E. co-op student. "Most of the small projects required asking multiple groups or people for information, which only helped in getting to know the company and everyone in it." Holly Prato, another E.E. co-op senior, worked on mainly technical projects for her host company, Fisher-Rosemount. She designed hardware and software for test fixtures on products and conducted tests on competitors' products, the results of which she presented to a conference of marketing executives and engineers. Now in her third quarter of work, she is responsible for the design of a more efficient sensor board that combines both the digital and analog boards of a meter. "During the quarter, I will work on creating a working, tested prototype and hopefully start it into production," she said. During their work periods, E.E. co-op students take the 2-credit industrial assignment and are encouraged to take nontechnical classes, for a total of about six credits. To get credit for the industrial assignment, students must write a technical report on their work, excluding any sensitive details their employers would rather not have released. These reports are generally 15-25 pages and follow guidelines given in the co-op handbook. As students progress through work assignments, the reports begin to have themes: working in a team and participating in a design project, for example.

Internships & Mentoring



One drawback of the co-op program is that graduation is usually delayed by a few quarters. Co-op students feel that the money and experience are worth the extra time. "The two or three quarters that it slows you down from graduating are made up for by the ability to get a job easily and the additional money that is offered because of the relative experience," said Vinje.

Civil

The Department of Civil Engineering runs two programs to help students get experience in their field. The Career Development Program helps undergraduates in civil and geological engineering find temporary and part-time jobs. No credit for this work is offered, but students get experience that looks good on a resume. The C.E. department keeps a file of employers that have responded favorably to their search for openings, and students consult the file for companies to contact. Interviews and terms of employment are worked out between the student and the employer. "Over the last five or six years, my guess is that we've had about one hundred students a year find jobs through the program," said Dr. Steven Crouch, head of the Civil and Mineral Engineering Department and Director of the C.E. Internship Program.

Civil Engineering also runs a more formal internship program open to both civil and geological engineering majors. Since the work of civil engineering interns is usually at least partly done outdoors, Minnesota winters can limit the usefulness of students who intern over winter quarter. To maintain the system of alternating periods of work and classes, C.E. internships are run as six-month work assignments (running either from March to September or June to December) followed by two or three quarters of classroom study. To get into the program, a civil or geological engineering major must have a GPA of at least 2.5 and have taken classes in surveying, soil mechanics, and construction materials.

The department loosely matches students and companies or agencies, then gives the students some information on each potential employer. The student is encouraged to find out as much as possible about each in order to help the interviews proceed smoothly. The interviews are then arranged by the student, unless prearranged by the employer and the department.

C.E. interns work in a variety of fields including soils and materials testing, surveying, construction, municipal engineering, and consulting. They are employed mainly by local businesses and government agencies. "One of the challenges that we have is identifying students who are prepared to work in some of the locations where the job opportunities are," said Dr. Crouch.

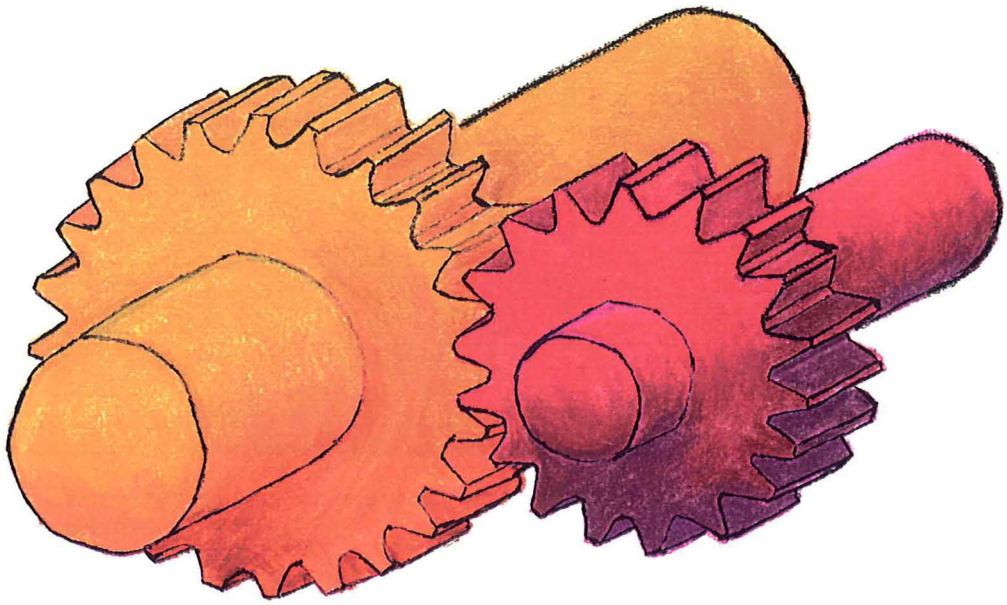
C.E. interns are also required to write a report about their work to get credit for the internship. Writing skills, from the technical report due at the end of the internship to cover letters on resumes, are an important part of being a professional engineer, so students are encouraged to get as much writing practice as possible. "You might think that being able to design a good steel structure is going to be what it's all about, but the person who designs that good steel structure and can't tell anybody about it, either orally or in writing, will soon fall by the wayside in favor of someone who can write better and speak better," said Dr. Crouch.

Mechanical

The Mechanical Engineering Co-Op Program (MECP) is another large co-op program at the University. Like the E.E. co-op, the MECP is a four quarter per year program in which the student alternates work and school. The MECP, however, requires that students take four industrial assignments to get credit for them as technical electives.

To apply, students with a GPA of at least 2.8 must enter their application onto a computer in Room 121 Mechanical Engineering. If accepted, a student must create a resume and sign up with individual companies for interviews, which are conducted through IT Career Services. MECP has changed its interviewing methods

this year from holding mass interviews in a single week to scheduling interviews throughout the year. "Now we are going to allow the students to interview all year long and companies to come in all year long," said Professor Virgil Marple, Director of the MECP. This and other changes in the co-op program are a result of budget cuts in the Mechanical Engineering Department and the elimination of the position of the assistant who arranged interviews in the past. This change, however, may help students in the long run. "I think there are going to be more companies from outside of Minneapolis [that are willing to interview for co-op positions]," said Dr. Marple. With interviews occurring throughout the year, companies that couldn't come for the interview week between winter and spring quarters would be more likely to interview here, especially out-of-town companies that only pass through once a year. Also, with much of the responsibility for setting up interviews and finding a position left up to the students, they get more experience with the interview process than they would have before. "It's going to give them a running start when they graduate, because they've already been through the process once," said Dr. Marple.



Mechanical engineering co-op students work at a variety of companies and government agencies. Daniel Butterfield, a fifth-year senior in MECP, interned with NASA at the Johnson Space Center. His work there over four quarters covered everything from developing computer programs to designing components for use in space. "[My] first assignment consisted of independently verifying a test matrix used to program SPIFEX, a detailed flight experiment [that flew] last year." He went on to design an augmented orbital debris shield mockup for international space station Alpha and perform an analysis on the Russian docking system. A prototype of another of his designs will be flying on the shuttle in March. After he graduates this spring, Butterfield will be working for Andersen Consulting here in Minneapolis. He is a strong supporter of the co-op program and was sorry to see its budget cut. "It's really too bad that the M.E. co-op program had to be cut when it was one of the best in the U.S. It reflects heavily on the University as a whole."

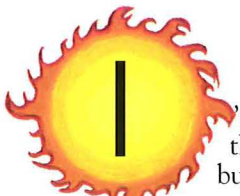
Despite the advantages of co-oping and the proliferation of such programs throughout the University, most students choose not to pursue the programs in their departments. One of the reasons students avoid co-oping is that it can delay graduation. That is not always the case, however. "We did a study some years ago and found out that the students in the [M.E.] co-op program actually graduated sooner than students that weren't in the program," said Dr. Marple. "It probably is an indication that most of our students are working part-time anyway," he added. This would likely cause non-co-op students to take fewer credits each quarter and even the field a bit between the two, since co-op students get credit for their work assignment and are encouraged to attend class during their working quarters. "I think they might possibly be a little more motivated [to graduate sooner] if they are working for a company where they think that they might be able to get on with that company as an engineer when they graduate," said Dr. Marple.

Co-op/internship programs are generally considered one of the best ways to improve a student's chances at starting a career after graduation. "A lot of people seem to shy away from it, but experience only leads to better things," said Prato. Butterfield concurred, saying, "I have friends now that are suffering due to lack of experience." In a decade of cutbacks in business and government, finding a job in any given field is only going to become more competitive, and the experience that co-op programs and internships provide can only help students find work after graduation. ★

Racing with the Sun

A Profile of the University's Solar Car Team

by Alyson-Kathleen Riley



I'm sitting in a dark and dusty classroom on the third floor of the Mechanical Engineering (ME) building, my notebook in front of me on one of several long wooden tables that look like they've been here since the founding of the University. The lights are low, there are slides up on a projection screen, and the other students around me are intently scribbling down notes on the "calculation of roll-over conditions using distributed inertial loads." These students, under the guidance of Dr. Pat Starr, meet twice a week to discuss electric vehicles, solar power, composites, aerodynamics, chassis and suspension design, and telemetry. I'm an obvious outsider here, and I know it. I'm getting paid by *Technolog* to learn and write about this stuff, but these people are here during their free time, dedicated to continuing a University tradition started several years ago.

The University of Minnesota's Solar Vehicle Project teams have achieved unprecedented success. But how does one make the leap from slides and sketches in a dimly lit classroom on a sub-zero Monday afternoon to a second place vic-

Racing in Akita, Japan, in the World Solar Rallye.
Photo courtesy of Pat Starr.

tory in North America's largest solar vehicle race? For Alex Detrick, the Electrical Team leader for Aurora-II, the University's second solar car, the thrill of jumping from the engineering classroom into real-world competition was the experience of a lifetime. "Now that I've gone through this whole thing, I look back, and it's fulfilling. I went through all this and it's *unbelievable*." Aurora-II was the product of history and the hard work of a dedicated team of students and faculty, where the catalyst for success was a mix of hard science, creativity, and ambition.

Aurora History: The Sunrayces and Beyond

The development and success of the Aurora-II project in Sunrayce '95 can be traced to early competitions and the involvement of the University of Minnesota in previous Sunrayces.

Sunrayce 1993: Two years after the first Sunrayce, GM and the U.S. Department of Energy (DOE) sponsored Sunrayce '93, where the University of Minnesota solar vehicle team made its debut in solar car racing. Aurora-I competed with 34 other cars in a collegiate race that extended from Arlington, Texas, to the Minnesota Zoo. Once again, the University of Michigan captured top honors, followed by California Polytechnic Institute at Pomona and California State University at Los Angeles. Aurora-I finished in 21st place and was later displayed by the Minnesota High Technology Council at the Minnesota State Fair.

Sunrayce '95 saw 38 university teams compete over nine days in a staged, cross-country race that covered a 1,000-mile course from Indianapolis to Golden, Colorado. To make the most of daylight hours, the race began at 10:00 a.m. and ended at 7:10 p.m. each day. Aurora-II broke the Sunrayce record for average daily speed, setting a new standard of 50.4 mph. In addition, the U team won the Electronic Data Systems (EDS) award for "Best Use of Aerodynamics in Design." The University of Minnesota finished in second place.

The 1995 World Solar Car Rally: Just three weeks after Sunrayce '95, the U team flew to Akita, Japan to compete with top international teams in the 1995 World Solar Car Rally. In this race, laps were completed on a closed track of 19.3 miles without public road intersections. The competition, which included 24 hours of racing, tested the cars' endurance.

Alex Detrick and Lance Molby confer with the driver, Dan Evanson, during the Sunrayce '95 Qualifiers at Indianapolis Raceway Park. ***Photo courtesy of Pat Starr.***

On the first day, Aurora-II's fastest lap was 32 mph and its position just three laps down from Honda's Dream, the overall and Free class leader. Aurora-II took second place in the Junior class and ninth overall at the 1995 World Solar Rally.

The Rayce Itself: During Sunrayce '95, the University of Minnesota's Solar Vehicle Project achieved its highest level of success to date. Aurora-II entered the competition in January of 1994, when the U of M team answered an invitation to submit a proposal detailing its solar car project. Every college in North America was invited, and 65 schools, including all Big 10 universities, responded. A team of experts from the list of Sunrayce sponsors evaluated the proposals, choosing the best thirty and ranking them as seeded teams. Each seeded team received $2,000 from the DOE in addition to $1,000 from the Environmental Protection Agency (EPA).

On June 14 and 15, all solar vehicle entries raced in a qualifying event that reduced the number of teams from 65 to 38. After undergoing a rigorous inspection process called "scrutineering," teams were required to drive a minimum of 50 miles within two hours around a closed course in order to qualify. Seeded teams automatically qualified by meeting this standard, but unseeded teams competed for the remaining ten places in the race.

Aurora-II and the University of Minnesota Team: The University of Minnesota Solar Vehicle Project team entered Aurora-II in Sunrayce '95 after many hours of marketing, design, and fabrication. The Aurora-II project, whose teams included both engineering and liberal arts undergraduates, consisted of co-project managers Jessica Gallagher (Business) and Paul Kelsey (Technical) and the following people: the Aero/Shell Team, led by Lance Molby (one of the drivers); the Solar Array Team, led by Steve White; the Electrical Team, led by Alex Detrick; the Mechanical Team, led by Dan Evanson (one of the drivers); the Logistics Team, led by Charles Habermann; the fundraising and marketing team; the Executive Advisory Board of eleven mentors; the graduate advisor, Scott Grabow; and the faculty advisors, Dr. Pat

Starr and Dr. Virgil Marple.

The Mechanical Team, led by Dan Evanson, designed and built the car chassis, suspension, steering and braking systems, and the frame. Initially, team members considered using an aluminum frame but, given the project's limited time span, opted to simplify construction by using fiberglass composite panels. Very stiff and light, composites solved another problem—the "jolt" factor. The electrically conductive carbon frame of Aurora-I had occasionally shocked team members.

To estimate the construction time for the real Aurora-II, the Mechanical Team built a full-scale model from plywood in just two days. They used the model as a guide when cutting the final chassis, a composite monocoque much like an Indy racing car. The final design included the three-wheel concept adopted in 1994, A-arm suspension, and a hydraulic disc braking system. The rear wheel, mountain bike style brakes, and the motor were held in a four-bar swing arm located directly behind the driver. In anticipation of possible flat tires during the race, wheels were designed to be changed quickly. The team shaved every available ounce from the chassis, which eventually weighed in at only 105 pounds.

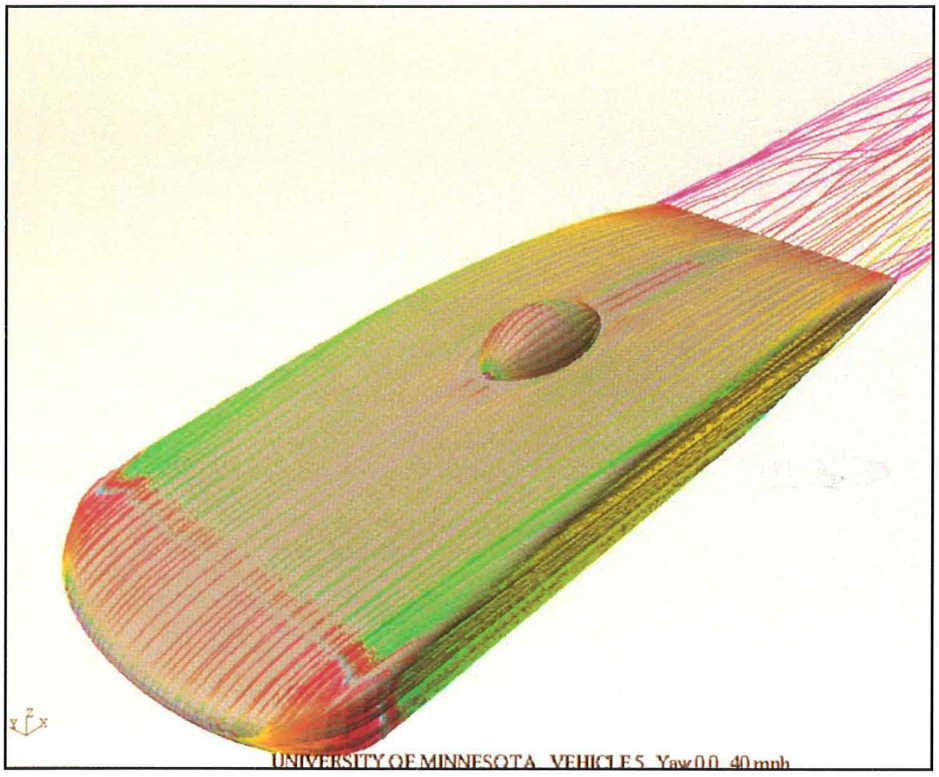
The Electrical Team's duties included choosing batteries, developing a data acquisition (telemetry) system, and determining motor type and specifications. Aurora-II used a battery pack to store energy collected from the sun during non-driving parts of the day, a crucial component of its success. Energy stored in the batteries was used during cloudy weather or in hilly areas, serving to supplement the solar array. According to Sunrayce rules, teams could only use 309 pounds of commercially available lead-acid batteries. Aurora-II used seven Delco Remy batteries.

To determine the amount of available energy from the batteries, the team needed to create a powerful and accurate telemetry system. The Electrical Team looked at data acquisition systems that monitored the amount of battery power used by the motor, sending that information real-time via a wireless system to a computer located in the support vehicle. The system would be equally effective in monitoring the solar array and track speed, distance, acceleration and g-force. In choosing the best-suited motor and controller system, the team tested Aurora-I's to answer questions about the car's energy consumption, the size of the motor needed to propel the car, and what type of forces were acting upon the car while it was moving. By meticulously testing Aurora-I's motor, the Electrical Team reviewed the repeatable data to determine which motor and telemetry system would best fit their application. In the end, the team adopted a Fluke Hydra Datalogger telemetry system to test electrical and array components for performance.

Since it was a difficult task to find a charger capable of charging 7 batteries with a constant voltage and current profile, the Electrical Team also decided to build its own battery chargers. The charger created by the team was composed of two ferroresonant transformers and materials obtained from the Electrical Engineering department.

The Solar Array Team: The responsibilities of the Array Team included determining solar array size, selecting the kind of solar cells to use, and then laying those cells out on the array itself. After considering several major U.S. manufacturers of solar cells, the team decided to use cells from Photon Technologies that were cheaper and 1% more efficient than the next-best brand (Siemens Solar Industries). These cells were also available presorted, which eliminated the need to presort over 1,500 cells. Once the cell manufacturer was known, the team could make the final decisions about the design and layout of the cells on the array. The trick was to find the maximum number of cells to fit into the allowable array area.

Once the design was completed, the team could focus on the actual solar cells. According to Steve White, the Array Team leader, "a solar panel is only as good as its worst



The first computer-aided designs of Aurora II's shell were completed more than a year before the race. Students refined their initial designs using Computational Fluid Dynamics (pictured above), and they won the Electronic Data Systems award for "Best Use of Aerodynamics in Design." ***Courtesy of Pat Starr.***

cell." With this in mind, the team decided to gather like cells into panels to prevent the bad cells from limiting the output of good cells, to keep them clean and insulated from the environment and the internal vibrations of the vehicle. With materials donated by 3M, designed and could be constructed simultaneously. If changes needed to be made to one component, the other would remain unaffected, and

Hurrying to beat the morning dawn, the Aurora II team diligently inspects their car at the Rose Hulman Institute, Terre Haute, Indiana. ***Photo courtesy of Pat Starr.***

and to increase the overall solar array power. The team connected string of cells (or modules) together by using a flat copper ribbon and special solder paste compatible with silver pickup traces on the cell. The students then grouped three strings together into larger, stronger modules which were then mounted to a thin Tedlar® film. The modules had to be placed one by one on the shell, with holes drilled into the shell at each end of the string to create interconnections between the strings of solar cells. The modules were then fastened to the shell with 3M Very High Bond™ joining tape.

Once the modules were connected to the shell, they were encapsulated DuPont, and E. Jordan Brookes, the team vacuum-wrapped the car using a large sheet of clear, lightweight optical plastic whose light properties would not interfere with solar transmissions and the efficiency of the cells. The film was glued to the surface of the vehicle with a silicone-based, two-part adhesive mixture that White characterized as having "the consistency of Karo syrup."

The Aero Team was responsible for designing, manufacturing, and testing the outer shell of the solar car, including the car's shape and the canopy. The team decided to use a modular chassis and shell layout, both of which were independently the shell design could change without greatly affecting the rest of the vehicle.

This year, the biggest factor to be considered was the direction of the race. In the Sunrayces of the past, the direction of the race was north to south, but in Sunrayce '95, the route was east to west, and the shell design made allowances for this environmental condition. The final shape decision was based on a light weight requirement (790 pounds total in the end), small size, and aerodynamic efficiency given the particulars of the race.

To manufacture the final product, the team used a large gantry robot

donated by PaR Systems to mill the molds for Aurora-II, thus reducing the mold-making time by about two months. These molds greatly increased the accuracy and surface quality, reducing the time necessary to make shell pieces. Once completed, the two shell halves were permanently glued together into a final product strong enough to withstand the driving environment of the race, yet light enough for several people to lift without difficulty.

The University of Minnesota solar vehicle was without doubt a high-tech project. In April 1994, the first Computer-Aided Design (CAD) of the car was created, and the model was simulated in a wind tunnel using Computational Fluid Dynamics. The CAD model was also used for chassis development, solar cell layout, and additional shape changes to improve performance. From these CAD drawings, the team was able to create two different solid models using Stereo Lithography. This process uses lasers to harden resins into the shape of the car. Stereo Lithography was a key element used when the team incorporated safety features into the design of the vehicle and the final nose shape, resulting in improved aerodynamics.

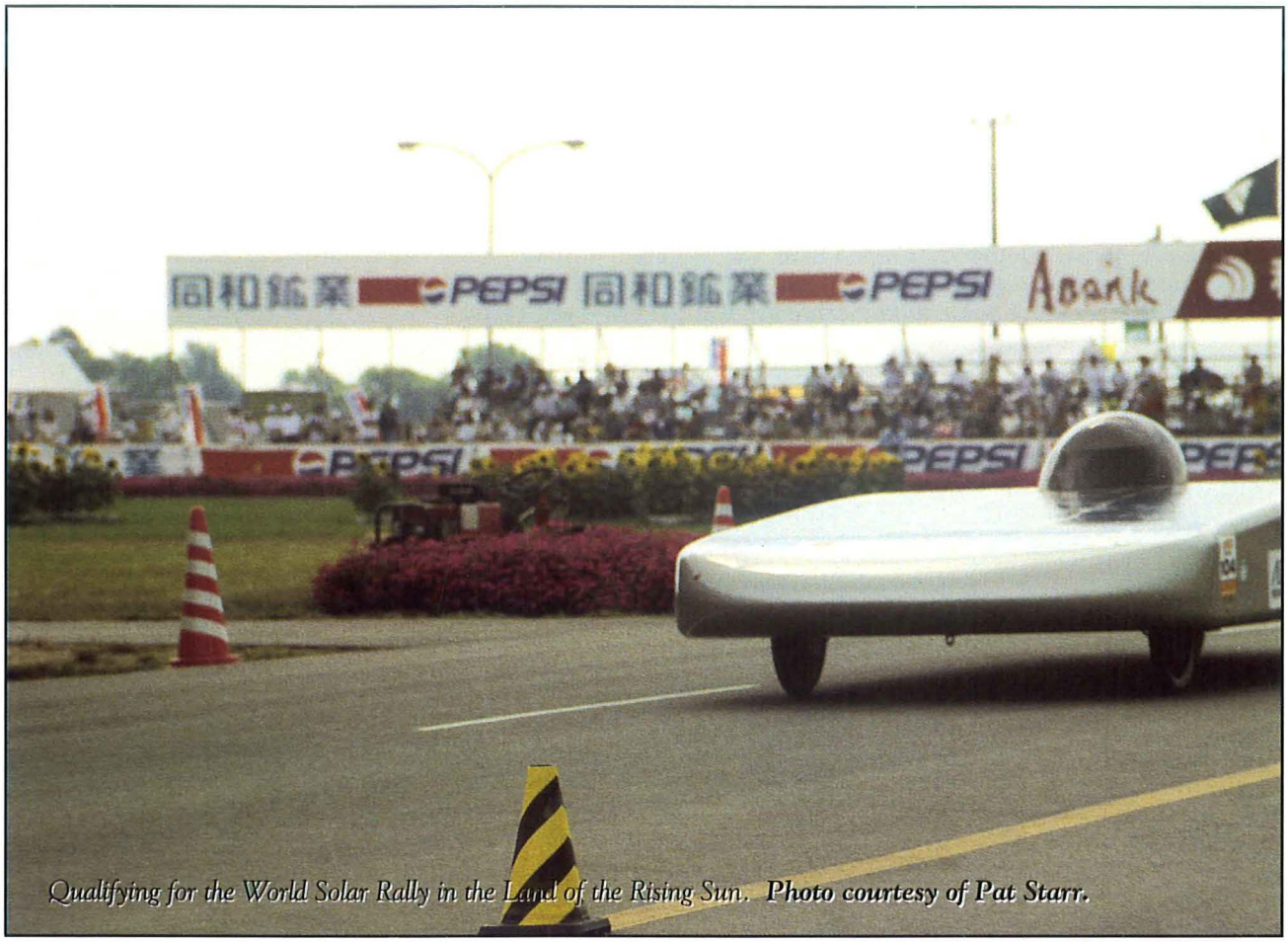
Conversations with the Team

Aurora-II was the result of the combined efforts of many talented individuals. The way in which the various teams worked together to create their technical masterpiece could only have been accomplished with a great deal of personal motivation, commitment, and creativity.

As may be expected, there were many issues both personal and professional facing the team members. "As a team," Detrick observed, "most of [our problems] were scheduling conflicts, classes, keeping our grades up, and trying to work as a community. It's always kind of hard for college students to do that. Eventually, you're just with each other long enough and you become good at working as a team." Paul Kelsey, Technical Manager, agreed. "[Aurora-II] was built between 6 p.m. and 6 a.m., and often in 24-hour shifts with very little sleep. There was a drive to push each other, to get the job done. And someone was always there to pick things up when you fell down in a corner from lack of sleep." Kelsey also found this teamwork to be an important component of his education. "In any classroom the normal academic environment pits you against the rest of the world–tests are curved and all that nonsense. [Working with the Solar Vehicle Project] takes you out of that environment and puts you in contact with a good group of people and a good team. A place where my part affected your part affected their part. I hadn't had that in the normal classroom environment. Any engineer needs exposure to that, because that's what they will encounter in the real world: team-based productivity."

Both men agreed that working with the Solar Vehicle Project was worth the long hours of hard work and continues to be beneficial. "While I was job-hunting," Detrick commented, "people were looking to see the qualities I had gained from my experience with the project. What's the point of going to college? Getting a job. The Solar Vehicle

Dr. Pat Starr, a professor of mechanical engineering, is pictured with Aurora II and student team members in the workshop. ***Photo by Joshua Zuckerman.***



Qualifying for the World Solar Rally in the Land of the Rising Sun. ***Photo courtesy of Pat Starr.***

Project made it a piece of cake. Granted I had to work really hard ... but it paid off in the end." Once again, Kelsey agreed. "The project positioned us well when we hit the industry. " The real-world experience added a dimension to these students' educations that could never be simulated in a classroom. "In engineering, you have magic equations and calculators and computers, but it isn't necessarily the real world. There's always an answer in the back of the book when you're doing homework problems. We knew if we had the wrong answer if a part fell off the car when we were going down the road at 65 or 70 miles an hour," Kelsey commented.

The most obvious characteristic of the team members past and present seems to be the level of loyalty, energy and excitement they hold for the project. "You almost live on the adrenaline," Kelsey laughed. Laurie Miller, an Electrical Engineering junior and novice team member, is just getting started with the project, but spoke with the enthusiasm of a veteran. "Part of what's so exciting about this," she notes, "is that we are talking about dealing with cutting-edge technology." She goes on to explain that the reason she's "willing to commit so strongly to this project, allotting time in [her] schedule for the next year and a half, is that [she's] going to the U to get the best engineering education [she] can, and this is an excellent opportunity to round out that education." Miller is already thinking about new Sunrayce speed limits and new technology. "It keeps it exciting," she comments. "There's no prize for taking your car home in a bucket."

Just Around the Corner: Sunrayce '97

Back to the classroom and the sketches. In this dark old room in the ME building, a new team of students is ready to commit to the project and the creation of the next solar vehicle. Rules for Sunrayce '97 are different from those for previous races, and it's time for a new car. As of Monday, Jan. 29, 29 students had turned in Solar Vehicle Project interest sheets to Professor Starr. Miller noted that they are "expecting a slow trickle of new people all the way through," and that there will always be places for "self-motivated and hard-working" students to become involved in the project and assume leadership roles. The next race is not far off, and the team's excitement is contagious. When they talk to me about their plans, it is impossible not the feel the effects of their adrenaline.

But before the next win comes the months of hard work. "Stick with it," Detrick advises. "It's all an experience and if you go through with [it] it will pay off in the end. You just have to be patient." ★

WorldWideWeb

For more information:
http://www.umn.edu/umnsvp/

by Kari Siegle

Are you being served?

An interview with the Dean of IT

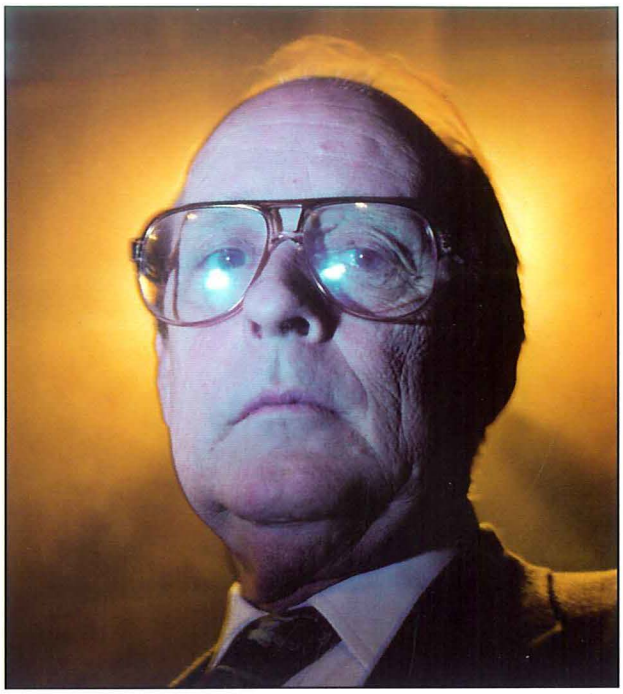


Photo: Joshua Zuckerman

When Francis Kulacki stepped down as dean of the Institute of Technology last summer, he made way for a man who really cooks. Literally.

When he's not spending time at his new job or conducting research, H. Ted Davis prepares gourmet meals and makes a hobby out of finding the best baguettes in town. Besides trying a new recipe here and there, his latest challenge is leading IT.

After serving as head of the University's top-ranked chemical engineering and materials science program for 15 years, Davis was elected dean of IT winter quarter.

He decided to become a professor his sophomore year at Furman University in South Carolina. He pursued a Ph.D. in chemical physics at the University of Chicago and then came to the University in 1963. In 1969 he became a full professor of chemical engineering.

State contributions to IT have remained fairly flat in the past two years, so in order to maintain quality programs, alternative sources of funding must be found. Much of this responsibility falls on Davis' shoulders.

"The traditional partnership that we had was that tuition and state tax paid the salary for teaching the undergraduate programs," Davis said. Now IT must bear this burden *and* raise one-third of the money needed to construct new buildings or renovate old ones.

The cuts will affect students in several ways. When supply budgets and possibly the number of teaching assistants are reduced, Davis said undergraduates may find that they have fewer homework problems graded and fewer laboratory exercises. Also, more course materials might be placed at copying services so that their prices fall more squarely on the undergraduates.

And then there are the inevitable tuition increases. When state contributions diminish there is always a chance more of the fiscal pressure will be passed on to students, Davis said. But in spite of this dim picture, there are still some spots of color in IT.

Davis said Residential College has taken an active role in creating a community of learners within the University. "There are possibilities we can increase that concept to provide programs and special courses within IT that improve the quality of the undergraduate experience and increase revenues," Davis said.

But, he added, "We can't do new things if we don't find new sources of revenue because we are losing funds we already needed for carrying out all of our old things."

In an effort to increase the funding IT desperately needs, Davis plans to establish betters relationships with companies and IT alumni. He hopes to explain the serious financial crunch confronting the college. He wants them to know what to expect from IT, and Davis is emphasizing that the school does its best with the resources available.

One strength is IT's faculty and their research. The tuition and state contribution to IT's operating budget is $55 million and the faculty raised $77 million this year.

While budget worries and departmental concerns might seem like a handful for a new dean to handle, Davis said he hasn't had any surprises in his job so far. There was some troubling news, however. Last year IT suffered a large budget cut and was led to believe that this year would be cut-free.

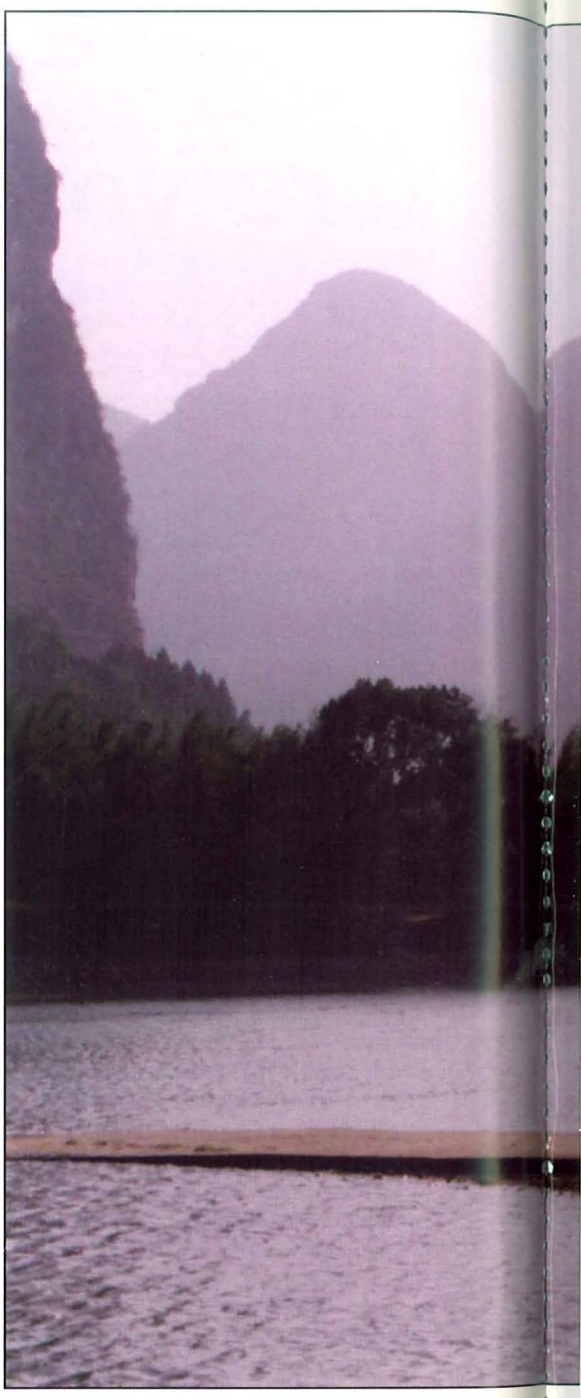
"I suppose you could call that a surprise but, on the other hand, it's not really a surprise in the sense that anyone can read the budget and see that, if we're going to have any cost of living relief in terms of raises at all, the money has to come from somewhere," Davis said, adding that this translates into internal cuts.

While this might be a tough time for IT to get through, the college will make it, Davis said. He pointed out that every program in IT is essential to the University. Math, physics, chemistry and geology all contribute to the general University education, and the engineering graduates drive the state and national economy.

"We'll get through. We won't get through easily, but this is a strong college," Davis said. ★

East meets West

An I.T. student spends a year in China



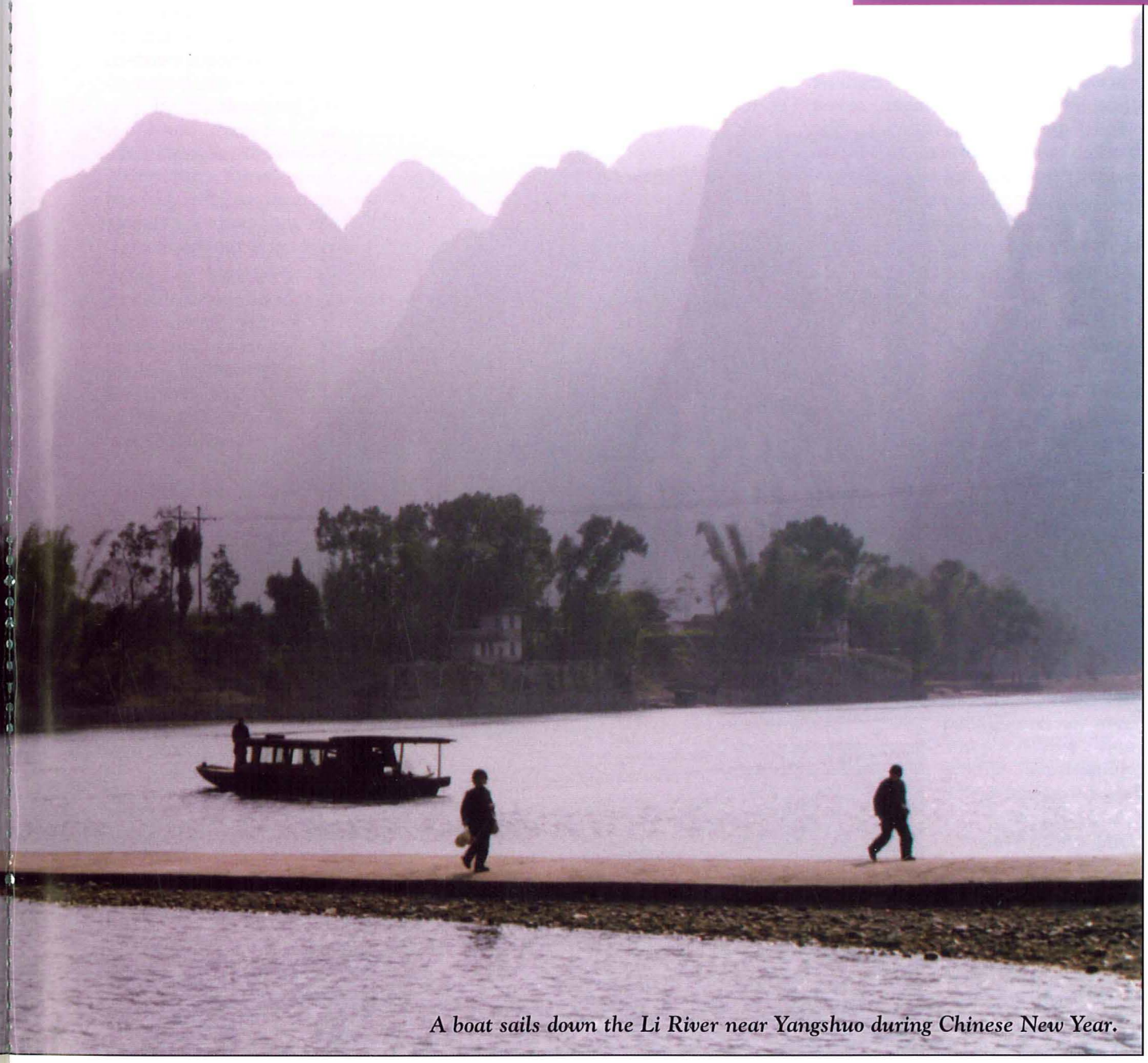
by Laura Walbrink

photographs courtesy of Michele Zoromski

China seemed like the best fit for me," says Michele Zoromski of her decision to study abroad last year. "One Chinese class turned into a minor and then into a major. I figured that the quickest way to get an overseas position with a company would be to have already gone to China."

Michele, a senior majoring in chemical engineering and Chinese, spent 14 months in China. Beginning at Nankai University in Tianjin, she completed one year's worth of credits in Chinese language and literature. She enrolled at Beijing University through the Chinese Universities Exchange Program. Michele's studies at Nankai University were "very structured. I went to a Tai Chi class before school. I took literature in the afternoon and Chinese language in the morning." She attended four hours of language classes each day and notes that "the basis for grading of tests and papers was very similar to U.S. academics." The relatively rigid schedule proved to be "a good transition. The first three months were concentrated on my language skills," which, she says, needed improvement.

Because the Nankai program is developed in conjunction with the University of Minnesota, grades and credits appear on a student's transcript. For this reason, a program coordinator is assigned to ensure that the grading is fair and comparable to that of the University of Minnesota. During Michele's stay, Theresa Wang, an American gradu-

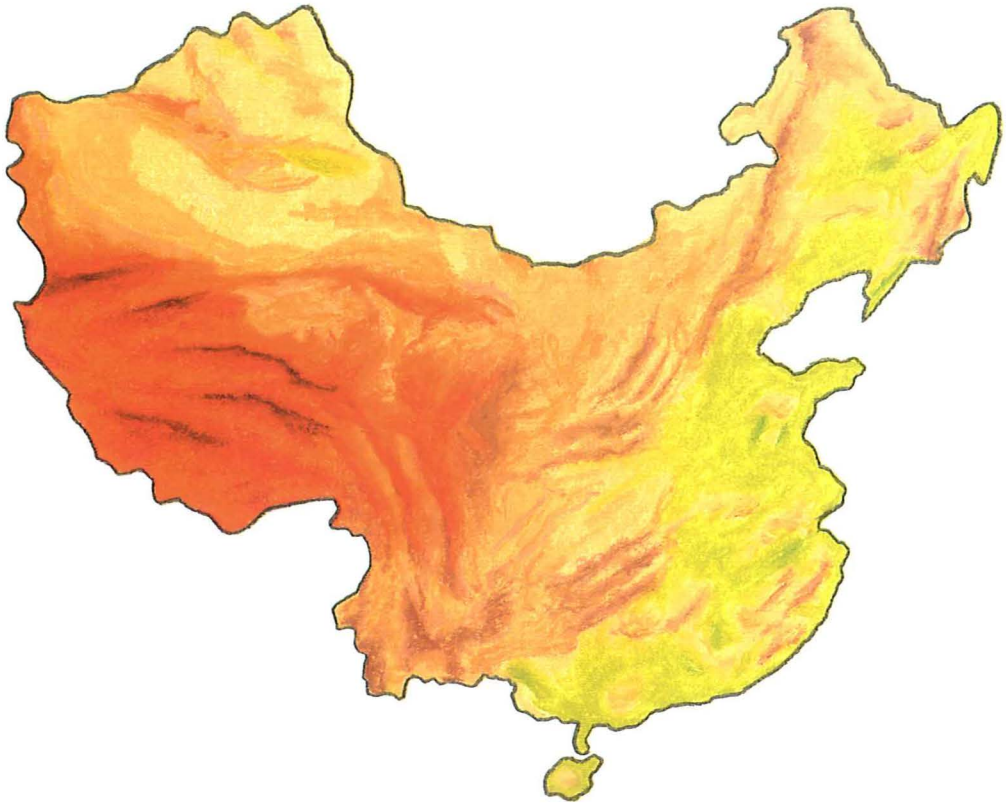


A boat sails down the Li River near Yangshuo during Chinese New Year.

ate student at the University of Minnesota, filled this position, but her duties extended beyond academic administration. She coordinated extracurricular activities, including a trip to inner Mongolia. As a fluent speaker of Chinese, she was able to help students with visa problems and other bureaucratic difficulties. "She knew the faculty and the president of the university," Michele says. "She had the 'guanxi,' or 'connections'. If you don't have the 'guanxi' in China, you'll never get anything done." For students who were living abroad for the first time, "she was always there. She was your friend, your mother, your everything."

At Beijing University, Michele, who had taken two years of Chinese courses at the University, pursued an intensive course of study. She earned an additional thirty-six credits in classical Chinese, Chinese literature, and Chinese grammar courses. Her advisor spoke only Chinese and, while helpful, offered less guidance than the coordinator at Nankai. In Tianjin, she was among other University of Minnesota students and many Americans; at Beijing, she was the only student from Minnesota, and the majority of international students came from Korea, Japan, and Europe. During the first five months, Michele studied Chinese in classes comprised exclusively of international students. When she enrolled in language courses with Chinese students for the second half of the program, she found the material more rigorous.

Particularly demanding, she says, was classical Chinese. Even native speakers find this subject challenging because the characters are more complicated than the simplified ones used in China today. Because "one character can mean seven words," translation is difficult. She worked with a private tutor six hours per week to enhance her skills. "It gives you respect for students who are coming here and studying engineering," Michele says. "They have to take the tests and do the homework. The technology terms are entirely different from standard English vocabulary, and they're doing their whole degree here."



Before participating in the study abroad programs, Michele had decided that she wanted to use both her chemical engineering and Chinese degrees by working for a U.S. company in China after graduation. She knew little of the culture, however, and was concerned about taking a job there before seeing the country. "Just because you like the language doesn't mean you're going to like the country," she says. "But I loved it there and definitely plan, if the opportunity arises, to work in China."

Although learning English is now mandatory for Chinese students, they usually read and write it far better than they speak it, simply because "they don't have anyone to practice with." Since "it's very rare to find a Chinese person who can speak English in your everyday travel, you're completely immersed. You're always speaking Chinese." Michele remarks that the Chinese were very supportive of her. "They're very impressed when you just try to speak Chinese. It's shocking to them."

As an exchange student, Michele was housed in an international student dormitory. "Foreigners are always housed separately from the Chinese," she explains. "They don't want foreigners influencing the Chinese. Before I went, I was a little upset because I wanted to be fully immersed, but it was really great living in the international dorms." The 400 international students at Nankai University and 800 at Beijing University are housed two per room. By comparison, six Chinese students share a room. Space is at a premium in China, Michele says, and the government is subsidizing Chinese students' housing. International students, on the other hand, must pay their expenses. Michele participated in a University of Minnesota program in which she paid tuition for an exchange student to come here; in return, she received a scholarship to attend school in China.

Universities in China are arranged quite differently from those in the United States. Each university specializes in either liberal arts, technical studies, or medicine. All, however, are generally located in one area. "Every school is like its own city," Michele says. "It has a wall and guards. You have to show your ID to get in and out. The teachers live there, and most of the students live there. There are stores and restaurants inside the university. All campuses have lily ponds and landscaping. They're meant to be very beautiful."

At Nankai University, "there are guards, but you don't usually have to show your ID. They're not armed at either university," but security is much tighter at Beijing University. The school is considered to have been "the nerve center for the uprising at Tiananmen Square. As the top liberal arts university in China,

it's got a lot of people with opinions." She compares its political climate to that of the University of California at Berkeley. As the nation's capital, Beijing itself is heavily guarded. "If anything were to start, that's where it would happen," Michele says.

As a foreigner, Michele struggled daily with China's pervasive bureaucracy. Even the seemingly simple act of purchasing train tickets can be frustrating for those who don't understand how the system works.

"It's like when you first come to the University of Minnesota," she says. "Offices don't know anything about other offices, and the rules are really rigid. There's no book where it's written down, but every culture has its own way of getting things done." In Beijing, though, new legislation left Michele wondering whether she would be forced to leave China. "I came with a three-month visa because Beijing hadn't given me the papers for my year-long visa. They said not to worry and that it wouldn't be a problem. In the meantime, they changed the laws so that now you have to leave the country to get a visa extended. I would have had to go to Hong Kong, which would have been very expensive." Believing that "that wasn't my responsibility," she refused to travel to Hong Kong. After a month and a half, she finally received special permission from Beijing University to renew her visa every three months.

Foreigners who move to the country go through three stages, Michele says. "When you first get there, everything is exciting and new. You have problems with the bureaucracy, but you block them out. Then three months later, as you begin to recognize the system, you realize that you've got these problems and you're arguing every day." For Michele, the stress associated with the constant battles resulted in anger and fatigue. "But one day," she discovered, "you're fighting just as hard and it doesn't affect your day at all. You're not angry or sad or moody; you realize that that's what you have to do to get things done. All of a sudden, the irritation stops. That's when you become integrated into the society."

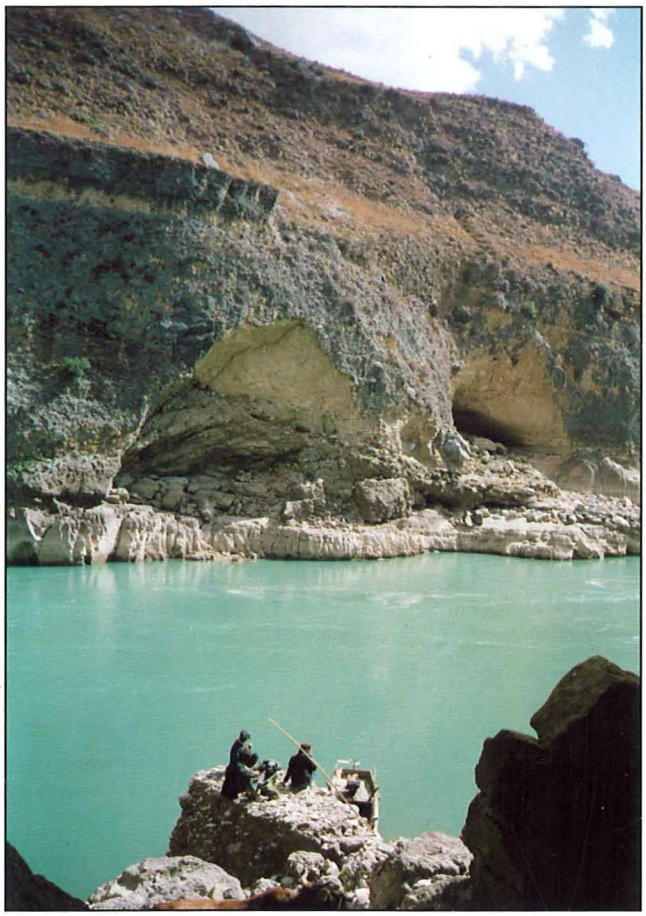
Above: *Michele Zoromski visits the Mandarin Gardens Bazaar.*

Below: *The presence of Western architecture is unique to downtown Shanghai. The buildings were occupied by foreign nations after World War I.*

Of the Communist Chinese government, she says, "Of course it's a trade-off. But when I left this country, I wasn't very happy with the U.S. either. It's very materialistic here—so much excess and waste." After living in China, she finds that "there are still bad things in the U.S., but you realize how much you have here." For Michele, China's attractive qualities compensate for its governmental deficiencies. "It's amazing to live in another culture. The people are so nice. They're very hospitable and friendly. Their culture is based on three thousand years of history. They all know their history and are very proud of it. You won't find that in the U.S."

While in Beijing, Michele developed appendicitis and needed surgery. The symptoms, which she initially mistook for food poisoning, began late at night. She took a cab to the foreigners' clinic, where she was referred to the Chinese-Japanese Friendship Hospital. The hospital, a joint venture between the Chinese and Japanese governments, is generally considered to be Beijing's best because all of its doctors have studied in Japan, a first-world nation. Before her surgery,

though, she was unsure of the quality of China's medical resources. "The worst thing I had to do," she says, "was call my parents. My mom, who has worked in health care for years, asked, 'How's the medical care?' I had to say, 'I don't know, but I don't have a choice.'" As it turned out, she was pleased by the high quality of treatment she received at the hospital. Although she endured hours of testing before the operation, "I was very fortunate because the medical care was excellent—doctors, nurses, everyone was great." Because her Chinese health care coverage did not extend to the hospital's geographic district, she had to pay up front for her surgery. "I charged it with my Visa card," she says. Her private insurance policy eventually reimbursed her for the one-week hospital stay, which cost just one third of the price of comparable medical care in America.



Crossing the river to enter the Tiger Leaping Gorge along the Jinsha River, located in Yunnan, a province in the south of China.

One benefit of residing in China as a foreigner is the low cost of living. The favorable currency exchange ratio allowed Michele to buy breakfast for as little as fifteen cents. Even dinner at a restaurant usually cost only slightly more than a dollar. Transportation was also inexpensive. Taking the bus across town cost twenty cents, and Michele traveled around the country by train for less than fifty dollars round-trip. The low cost of public transportation combined with the high price of cars provides an incentive not to purchase automobiles. "The only cars allowed are Audis, BMWs, Mercedes—expensive cars that few people can afford. The government doesn't allow cheap cars to be imported because the highway system can't support the traffic."

Although crime in Beijing is said to be on the rise, Michele never witnessed one. The most common crime in China is theft, she says. A typical setting for pickpocketing is the bus, which is usually extremely crowded. "Criminals see where you take your money out to pay the attendant. Then they take the money from that area, sometimes using a knife to cut open fabric." Friends told Michele how to carry her money safely. She suggests that another reason why she was never a victim of crime is that "if you were a Chinese person caught committing a crime against a foreigner, the sentence would be pretty severe. It might be stricter just because of the potential publicity. The American embassy is located nearby, and if something happens to a foreigner, CNN is right there. Foreigners are very visible," she adds.

Shortly after arriving in Beijing, Michele attended a University of Minnesota Chinese alumni meeting. The 'U' has the highest Chinese population of any American university. At the meeting, she listened to people, some in their seventies, describe their experiences and what they're doing today. "They made me food and explained traditions and history," she says, adding that she visited their homes once or twice a month. Michele befriended Chinese as well as international students, but most of her friends were older adults. Many of the Chinese students wanted to go to America and had questions about life in the U.S., but they were also seeking an English tutor. "That wasn't what I was looking for," she says. Instead, she spent time with the families of her older friends, many of whom had children her age.

One of the more difficult cultural lessons Michele learned was how to bargain for the best prices in the Chinese open market. Vendors prey on foreigners, particularly Westerners, whom they correctly perceive as having a lot of money, at least by comparison to the Chinese. They were surprised when Michele refused to accept their initial marked-up price. Bargaining is "kind of addicting," she admits. Usually, though, she didn't mind paying what she considered to be a fair price. "They figure that you've got money to spare, so they'll make money off you if they can. They know that you definitely have more money than the Chinese," she explains.

Unlike Americans, who typically do not consider it polite to discuss salaries and ask the cost of others' purchases, the Chinese consider it a compliment to ask someone where an item was purchased and how much it cost. Asking about the price of something serves a practical purpose: it helps the inquirer determine the proper value of the item, which is valuable information when bargaining for it.

The stereotype among Chinese of

the wealthy American followed Michele throughout her stay. "They think we all live like in 'Dynasty,'" she says. "When you tell them you're a student and you borrowed your money to get here, they don't really believe you. Sometimes it's hard to get around that. People ask questions; they want their ideas verified. They want to hear that you have a lot of money. It can be frustrating."

During the Chinese New Year holiday, which lasts one month for students, Michele hiked through the mountains of Yunnan, a province in the southwest near Vietnam. She spent three days on Hainan Island, a tropical locale in the south of China. Fireworks exploded throughout her visit. "You could never have imagined anything that loud in your life," she says. Last year, she adds, was the Year of the Pig. "There were all these little inflatable pigs everywhere," she describes. "People would put up signs, poems, and sayings on their doors. It's like a carnival. There are games and music. There was a basketball contest." She spent New Year's Day mountain biking through the countryside in Guilin, a southern city known for its mountains. "It's beautiful," she says.

Michele went to China with very little knowledge of the country. "Everything I knew was based on the accounts of people who went there five years ago," she says. When she arrived, "it was the modernization that shocked me, just because it's progressing so rapidly." She believes that Americans should become proficient in Chinese language and culture. "If you can speak Chinese and English," she says, "you can converse with half of the people in the world. If we expect everyone to learn English, we're going to be at a disadvantage. Right now, we're bringing our products to China. Someday, they're going to bring their products to us—cheaper and more efficiently. We're going to have to be able to communicate and negotiate with them." The U.S., she says, expects everyone to conduct business in the Western model. "If we don't understand the Eastern way of doing business, we're going to lose out," she warns.

Studying abroad "gives you a different outlook on life. It gives you a sincere sense of accomplishment. You've learned a new language and become integrated into the society. That's what draws me to China," Michele explains. "It's a challenging place. You come back and you really appreciate how convenient everything is in the U.S., how easy it is. Everything's so comfortable here. Every place has air conditioning and heating. You have a car. You can go wherever you want and do whatever you want."

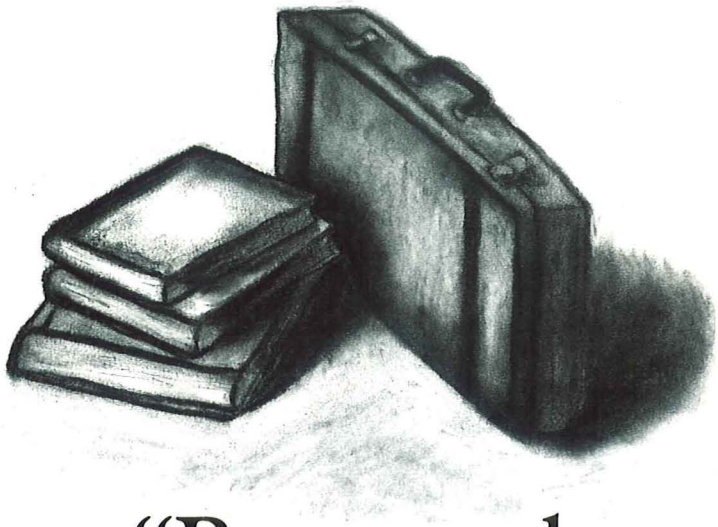
Despite the advantages of American living, Michele hopes to return to China after graduating. "The job, in general, will offer me a technical challenge as well as a cultural challenge, which is what I'm looking for," she says. "I live for that challenge." ★

Above: *Michele has dinner with an alumnus of the University of Minnesota, and family, in Beijing.* ***Below:*** *Worshippers light incense before praying at a Buddhist Wengshu monastery in Chengdu.*

by Slava Thaler

Mentoring Makes A Match

Each year, thousands of students choose a major, a decision that will affect them for the rest of their lives. Unfortunately, many do not assess the likelihood of getting a job in their selected major. Upon graduation, they find that employment opportunities in their field are scarce. By then, though, it's too late. The Institute of Technology has attempted to solve this problem by offering a mentor program to assist students in making career decisions.



Begun in 1991 by the University of Minnesota Alumni Association, the IT mentor program matches undergraduates with alumni who work in fields of interest to the students. The program is beneficial to both parties, said Frank Robertson, Director of Alumni Relations in the Institute of Technology. "It provides a mentor for as many students as would like to have one. That's the primary goal. It also helps to keep our alumni involved in the affairs of the University."

Students work with mentors to make career choices and find contacts. In contrast to looking through a course catalog or IT bulletin, the mentor program "is a way of making a one-on-one contact with someone. The important thing is that students have someone who is currently or has been in careers that they want to pursue," Robertson said. Christine Siebenshuh, a mentor, added, "It's good to have someone that's working out in the field to talk with students, prepare them, or let them know how it is to be in the workplace in a particular field."

Because the transition from college to work can be very difficult, knowing someone who has gone through the process is comforting. "I'm still communicating with my student from last year. I think it's helpful for her that we can get together," Siebenshuh said.

"Because the transition from college to work can be very difficult, knowing someone who has gone through the process is comforting."

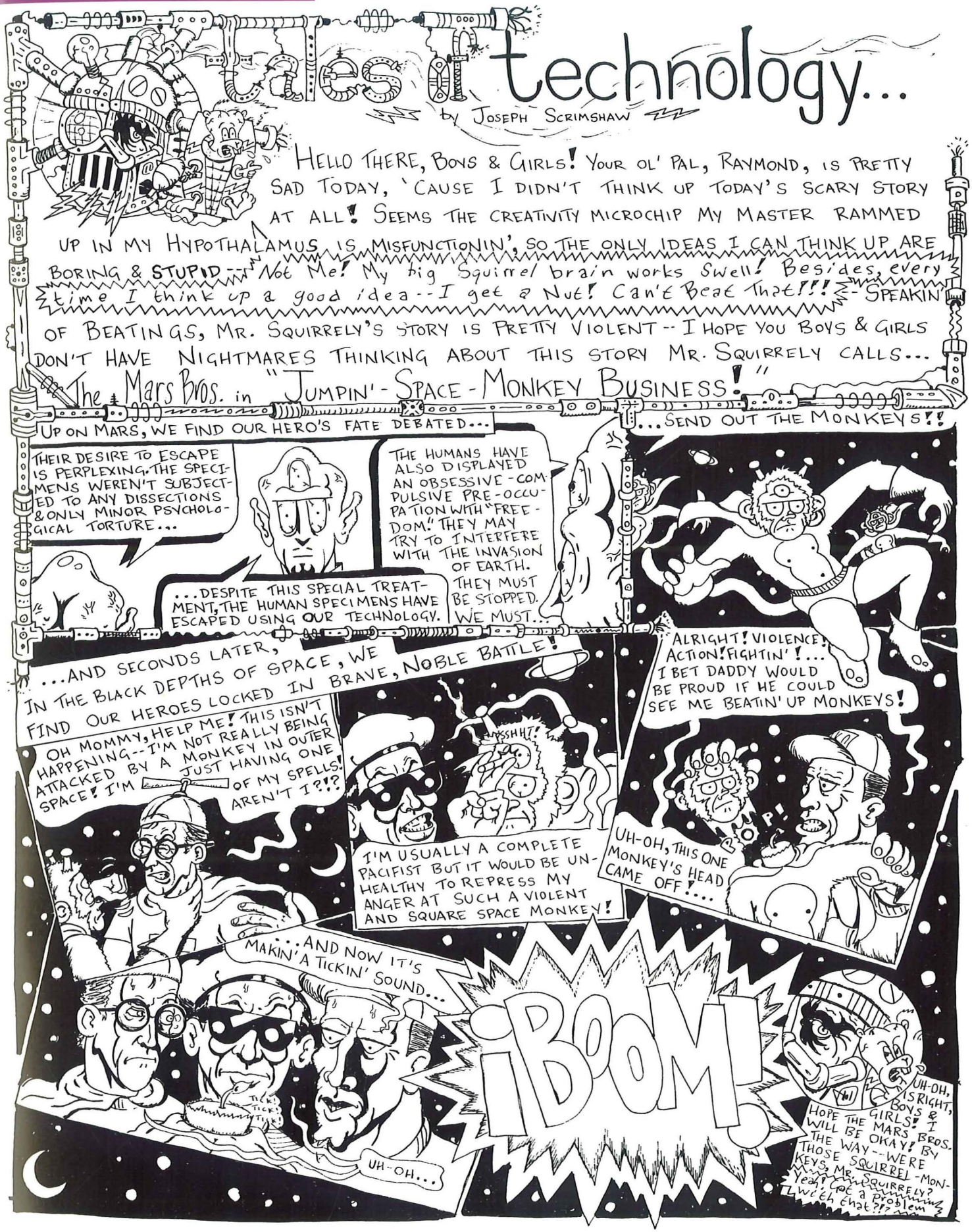
The IT mentor program benefits mentors as well. "It was an opportunity for me to get back to campus, which I don't normally do," mentor Mike Cepek said. "It's a way I can stay connected with the U." The program also allows mentors to give something back to the University community. "All of us like it when we can help someone, and this is a very real, meaningful way that people can help other people," Robertson said.

The growth of the program has been steady. "We had about 34 mentors and 45 students in 1992-1993," Robertson said. "During the following year, we had 94 students and 156 mentors." To strengthen mentor/student relationships, IT sponsors "a kickoff event in January where we have different speakers. In the past, we've had a tour of the Geometry Center for mentors and students. For two years, we've had a networking seminar," Robertson said. Mentors and students are encouraged to meet at least three times, one of which usually occurs at the mentor's workplace. For many students, seeing what working in the industry is really like is the most valuable experience of the program.

If you are interested in participating in the IT mentor program next fall, contact Cindy Kilmore in 128 Lind Hall. ★

CARTOON

by Joe Scrimshaw



WRITERS WANTED

Minnesota Technolog is looking for writers (as well as illustrators) for the 1996-1997 school year. We're seeking IT undergraduate and graduate students who'd like some experience writing for publication! We have several beats in mind, including the environment, ethics, new technology, personal profiles and features, editorials, and personal reports on the specific projects you're working on for school.

Although our editorial board mainly consists of creatures from outer space, we've been known to work well with humans. If you'd like more information, or would like to come in for an informal interview with the editor, please leave a cover letter, a resume and any available writing samples in an envelope outside the *Technolog* office in Room 5, Lind Hall.

And, if you're not quite up to writing, but have interesting ideas for stories you'd like to see in upcoming issues of the *Technolog*, please jot them down on this form and drop it by the office.

MINNESOTA TECHNOLOG

Description of story idea(s):

_____

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Would you like to write the story? _____

Name (optional)_____

Address_____

City/State/Zip_____

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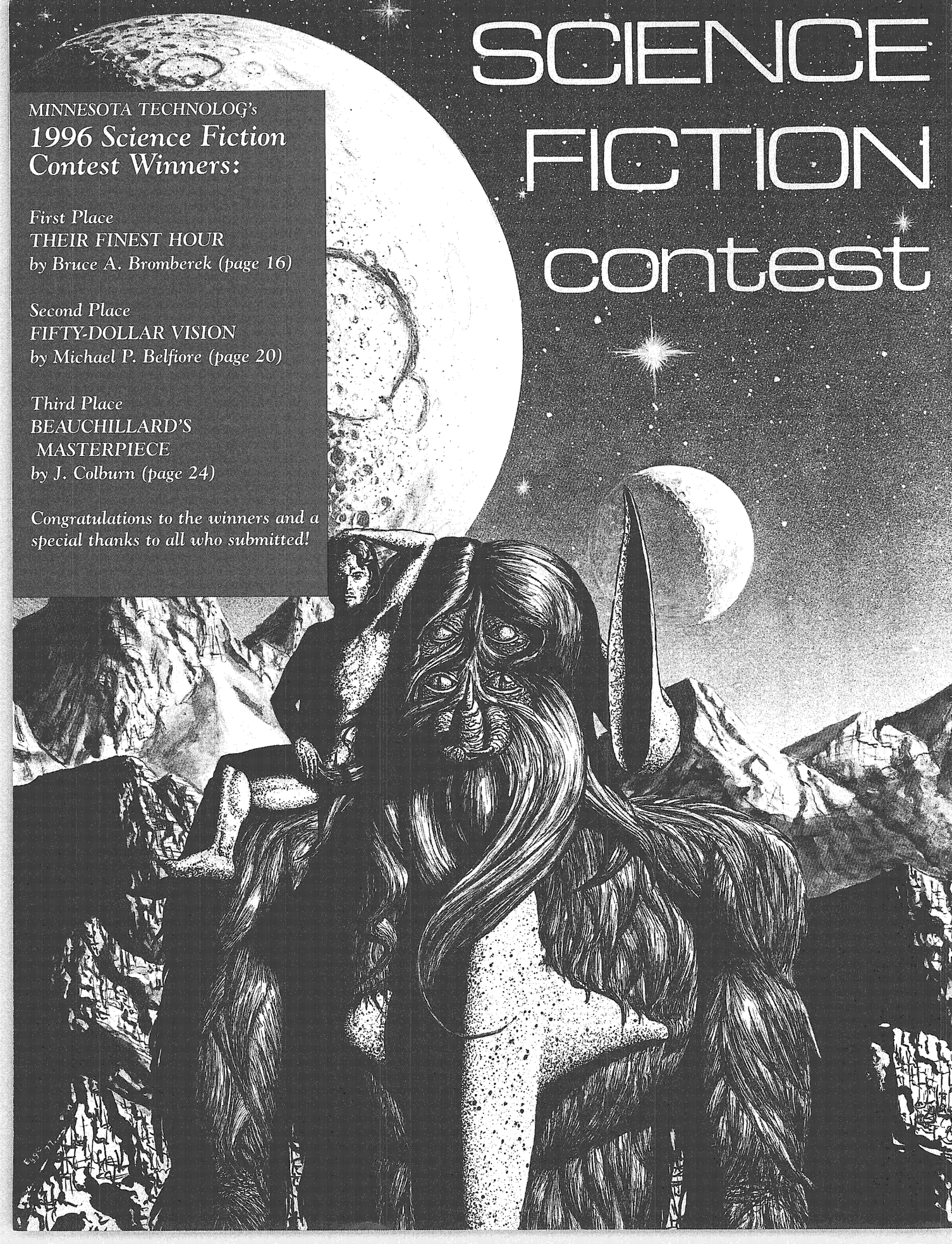
July 1996 University of Minnesota Volume 76 Number 5

SCI-FI CONTEST WINNERS

THE MUSEUM OF QUESTIONABLE MEDICAL DEVICES

+ FAVORITE SCI-FI MOVIES AND BOOKS

SCIENCE FICTION contest



MINNESOTA TECHNOLOG's

1996 Science Fiction Contest Winners:

First Place
THEIR FINEST HOUR
by Bruce A. Bromberek (page 16)

Second Place
FIFTY-DOLLAR VISION
by Michael P. Belfiore (page 20)

Third Place
BEAUCHILLARD'S MASTERPIECE
by J. Colburn (page 24)

Congratulations to the winners and a special thanks to all who submitted!

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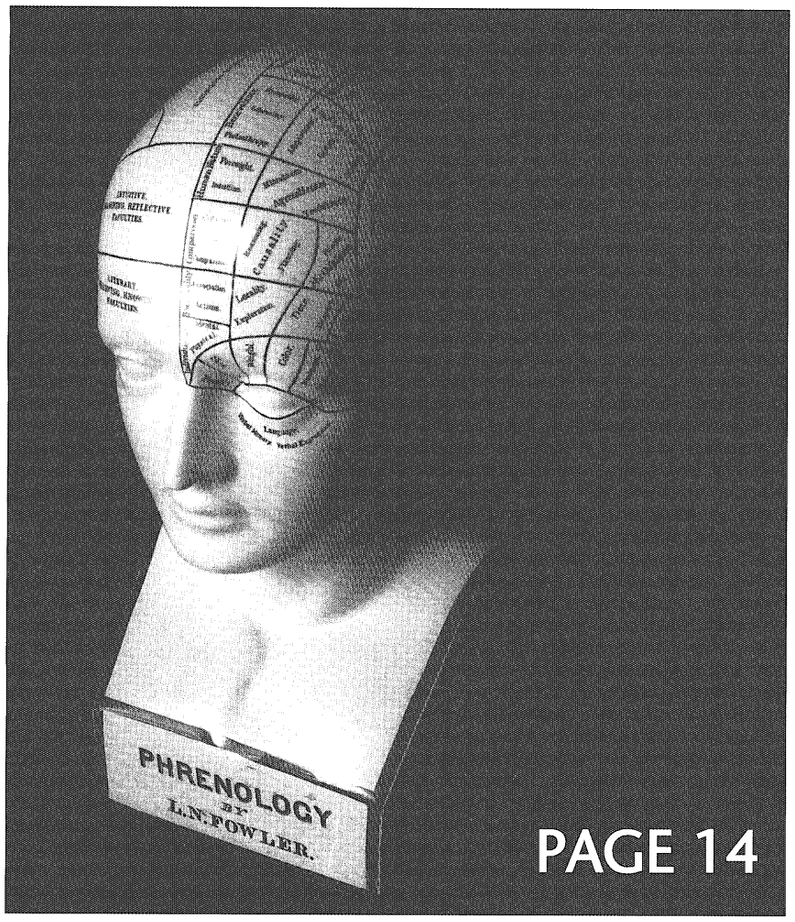

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SCI-FI '96

Their Finest Hour

In the first place winner of our Science Fiction contest, a group of soldiers defends the Queen and her empire from imminent destruction.

—by Bruce A. Bromberek

PAGE 16

Fifty-Dollar Vision

Down on his luck, a young man travels a supernatural route in search of guidance. Second place winner.

—by Michael P. Belfiore

PAGE 20

Beauchillard's Masterpiece

A professor's last and greatest invention has dark implications for humanity in our third place winner.

—by J. Colburn

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EDITORIAL

Is the Communications Decency Act a gross abridgment of First Amendment rights? Or is it a legitimate piece of legislation intended to protect children from Internet trash?

—by Gregory Lauer

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PHOTO ESSAY

Harboring the history of medical quackery, the Museum of Questionable Medical Devices contains everything from a prostate gland warmer to a foot-operated breast enlarger pump.

—by Kenei Sato

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MOVIES

Wookies, Trekkies, Mashed Potatoes, and Nerds: The *Technolog* 100?

—by Chris Lee

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Cover illustration by Joe Scrimshaw.
Contents page photograph by Kenei Sato.

EDITORIAL by Gregory Lauer

The Indecency of the Communications Decency Act:

The Congressional Thought Police Attempt to Dismantle the First Amendment

I suspect Senator James Exon (D-Nebraska) is a devoted follower of the late psychedelic guru Timothy Leary, because his attempts to regulate the Internet show an almost unwavering dedication to the '60s generational mantra, "Tune in, turn on, drop out." The delirious thinking in Exon's Senate Resolution 314, which later metamorphosed into the Communications Decency Act (CDA), is so constitutionally contrarian that the only logical explanation is LSD inspiration.

The CDA is a draconian measure intended to restrict the access of minors to indecent or obscene material on the Net. Ostensibly, Sen. Exon is "making the Internet safe for families," but the vague language and far-reaching provisions of this technophobic piece of legislation promise to put the brakes on the free-wheeling Internet.

Inserted into the Telecommunications Deregulation Act under Title V, the CDA rests on the "indecent" and "patently offensive" standards. The "indecent" provision states that any person in interstate or foreign communications who "by means of a telecommunications device knowingly makes, creates, or solicits and initiates the transmission of any comment, request, suggestion, proposal, image, or other communication which is obscene or indecent, know that the recipient of the communication is under 18 years of age shall be criminally fined or imprisoned." The "patently offensive" provision is equally disturbing and distasteful.

Signed into law on February 1, the CDA was promptly challenged by the American Civil Liberties Union (ACLU) on constitutional grounds. The suit was joined with another put forth by the American Library Association; all together 47 organizations (including a petition sponsored by Citizens Internet Empowerment Coalition containing more than 47,000 signatures) banded together to battle the U.S. Department of Justice (DOJ) and the purveyors of prudish thought.

"The net effect of the Communictions Decency Act would be a dumb and dumber Internet."

The ACLU, in conjunction with the Electronic Freedom Foundation, the Society of Professional Journalists, Microsoft, and many others, argued that the CDA arbitrarily expands the powers of the federal government, violates the "least restrictive means" test used to control indecent material (*Sable Communications* v. *FCC*), and suffers from vagueness and overbreadth in using the terms "indecent" and "patently offensive." Additionally, the CDA infringes upon a parent's right to determine what material is appropriate for a child to hear or see.

The net effect of this legislation would be a dumb and dumber Net, and content would be reduced to that of a children's reading room at a public library.

Thankfully the CDA was struck down by a three judge panel on the Court of Appeals in Philadelphia in early June. For the time being, netizens have triumphed over the Luddites. The victory may be short-lived, however, as Janet Reno and the Department of Justice are considering an appeal to the Supreme Court.

President Clinton, in what can only be attributed to election year politics and his inexorable slide to the right, remarked, "I remain convinced, as I was when I signed the bill, that our Constitution allows us to help parents by enforcing this Act."

What rubbish. The CDA is a terrible infringement of Constitutional rights, and the Court of Appeals agreed.

In a sweeping 219-page decision, the Court rightfully gave three thumbs down to the CDA and argued, "Any content-based regulation of the Internet, no matter how benign the purpose, could burn the global village to roast the pig."

As a practical matter, the task of regulating the Internet is an almost

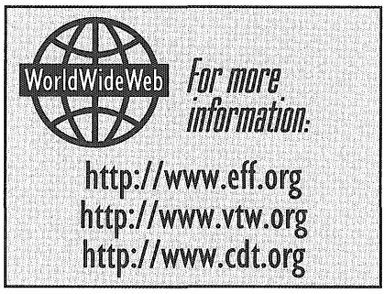
Herculean job that no service provider like America Online or CompuServe is equipped to handle. It would require legions of snoops poring over every email message, web site, newsgroup, chat room, and network server; the sheer volume of information to be screened precludes the possibility of any such effort. The DOJ argued that the Act requires only monitoring that is technically achievable, but that, too, is a murky concept that was poorly defined in the proceedings and was likely to become a "moving target" had the CDA withstood judicial review.

Furthermore, the programmers in Silicon Valley and others in the industry are making good-faith efforts to keep their electronic house in order. The Platform for Internet Content Selection, more commonly called PICS, is being developed as a voluntary compliance tool similar to the Motion Picture Association's movie rating system. And software like Net Nanny or Surf Watch, already on the market, allows parents to monitor their children's daily uptake of trash, filth, and smut.

In addition to questioning our ability to control the content of the Internet, the Court issued a stinging critique of the indecency standards contained in the CDA. George Carlin's infamous "Seven Dirty Words" monologue resulted in a lawsuit, FCC v. *Pacifica Foundation*, that eventually established the FCC's right to filter indecent material from broadcast media (television and radio). Congress later stepped in and granted the FCC regulatory powers to reign in dial-a-porn lines using similar indecency standards in the late '70s. The CDA wrongly attempted to broaden the police powers of the FCC and throw the Internet in the same category as TV, radio, and 1-900 chat lines. Our electronic ether world, however, has more in common with print media and should be governed according to the rules of the publishing world which offer stronger First Amendment protection for free speech.

Contrary to popular belief, the Internet is not the Wild West or a bastion of lawlessness. The Supreme Court's definition of obscenity, a three-part test that stemmed from the case *Miller* v. *California*, does not specify the media that a work be viewed, created, transmitted, or stored in. Thus the Internet is currently a regulated entity, and subsequently obscene material is a hazardous substance to be handled with extreme care (or rather, not at all).

The Court of Appeals correctly concluded by writing, "Cutting through the acronyms and argot that littered the hearing testimony, the Internet may fairly be regarded as a never-ending worldwide conversation. The Government may not, through the CDA, interrupt that conversation. As the most participatory form of mass speech yet developed, the Internet deserves the highest protection from governmental intrusion." ★



TECH INDEX

Inspired by *Harper's* magazine

Number of movies shot on location at the U since 1972: 9
Average SAT score of freshmen entering IT in 1995: 1161
Number of bikes thrown off the Washington Avenue bridge by angry pedestrians this year: 1
Average cost of tuition, fees, books, housing, & misc expenses for an upper division IT student: $10,966.85
Percent increase in tuition at the University of Minnesota since 1980: 264
Percent increase in the Consumer Price Index in that same period: 71
Number of times President Hasselmo said the word "change" in his last State of the University address: 29
Number of 12-ounce cans of beverages sold last year on campus: 3,200,000
Number of cars that parked at the U on a typical day in January of this year: 23,858
Number of coffee shops within three blocks of the Minneapolis campus: 10
Harvard Market markup (percent) of Super Chunky Skippy relative to suburban supermarket price: 46
Average value of a bicycle stolen on campus last year: $431
Number of ophthalmic/contact lens technicians employed by Boynton Health Service: 2.75
Number of bars in Dinkytown, Stadium Village and on the West Bank: 15
Number of times the *Daily* was voted Best Daily Student Newspaper in the last 10 years: 6
Number of copies of the *Daily* printed every day: 26,800
Number of people who read a copy of the *Daily* every day: 45,560
Total budget of the University last year: $1,738,101,000
Gross Domestic Product of Belize last year: $550,000,000
Total number of University employees in 1995: 34,452
Number of employees of the median *Fortune* 500 firm: 21,552
Estimated amount to be paid by Coca-Cola to the University over the next ten years: $28 million
Number of IT doctoral programs ranked in the top 20 nationally: 8
Percentage of parking spaces used during the lunch-hour rush in Dinkytown: 110
Number of landlord-tenant cases handled by the University Student Legal Service last year: 267
Percentage of IT freshmen who graduate within five years: 57
Estimated cost of upgrading computer systems to recognize the coming millennium: $4 million
Number of journal subscriptions in the Science and Engineering Reserve section of Walter Library: 3,126
Number of visits to the *Penthouse* Web site by U students in a one-month period earlier this year: 8,751
Number of registered student organizations on campus: 528
Average daily number of visits to the Department of Recreational Sports: 1,660
Number of MSA resolutions discussing ROTC, grapes, dorm lofts, and monopoly-fundraisers this year: 5
Change in the proposed stipend of Helen Phin, the student body president: -$800
Number of votes cast for Homer Simpson in last year's election for student body president: 462
Number of years the *Technolog* included a centerfold pinup in the magazine: 18
Amount charged IT students quarterly to finance the *Technolog*: $4.32
Estimated number of e-mail accounts administered by the U: 100,000
Number of courses offered in Spring '96: 5,330
Amount spent on a prisoner by the state of Minnesota in 1993: $34,499
Amount spent on a student at a public post-secondary institution in the same year: $4,581

Sources: **(1)** M, **(2) (4) (26)** IT Office of Student Affairs, **(3) (12)** Department of Health and Safety, **(5) (6)** *Star Tribune*, **(7) (10) (11) (14) (35)** *Minnesota Technolog*, **(8)** Vending Services, **(9)** Parking Services, **(13)** Boynton Health Service, **(15)** Society of Professional Journalists, **(16) (17) (37)** *Minnesota Daily*, **(18) (20) (22)** University Relations, **(19)** World Almanac, **(21)** *Fortune*, **(23)** National Research Council, **(24)** Hennepin County, **(25)** University Student Legal Service, **(27)** University Student/Office System Support, **(28)** Walter Library, **(29)** *Penthouse*, **(30)** Office of Student Activities, **(31)** Department of Recreational Sports, **(32) (33)** Minnesota Student Association, **(34)** All-Campus Elections Commission, **(36) (38)** Office of the Registrar, **(39) (40)** University of Minnesota Coalition for Higher Education

ECMA NEWS

Reprinted from other members of ECMA, Engineering College Magazines Associated

Egg Exposé: L'eggo My Eggo (Patent)

Food processing conglomerates, the North Carolina State University, and an army of highly-paid lawyers are arguing over an invention that traces its origins to the labs of the Food Science Department here at Virginia Tech: the ultra-high-temperature pasteurization/aseptic packaging process. At stake is a multi-million dollar segment of the egg industry and untold thousands in royalty payments. The saga began in 1973 when Dr. Warren Stone and Dr. Peter Rony developed a novel method of processing liquid foods. Whereas traditional approaches of pasteurization used stainless-steel, plate-and-frame heat exchangers, Rony covered surfaces of the device with Teflon, DuPont's non-stick super-coating. Additionally, the duo sealed the entire system in a Plexiglas glove box, preventing the processed liquid food from ever coming into contact with the atmosphere. Stone retired from the department several years later, and Dr. Eskel Essary climbed on board, bringing with him the financial support of the American Egg Board. The experiments then ended with Essary's retirement in 1983, and a pitch was made to N.C. State to continue the program. They rejected the offer but continued research in the field and later filed a patent in 1989 on the UHT-pasteurization/aseptic packaging process, but not on the actual fluid eggs product. For the most part, the egg-processing industry ignored the claim because many of the ideas were contained in published works by Essary, Stone, and Rony, and N.C. State promptly responded by suing companies in New Jersey, Florida, California, and Minnesota. In legal discovery proceedings leading to the Florida case, N.C. State had access to the confidential documents of the Virginia Tech research team, and in a shocking move they refiled their original claim (which was a process) as a process-and-product patent. Trials in Minnesota and California are pending until a decision is reached by the U.S. Patent Office. All of this legal maneuvering leaves many consumers wondering which came first, the UHT-pasteurization/aseptic packaging process or the fluid eggs product?

—Scott Walters
Engineer's Forum, February 1996

Building a Brave New World

A computer application developed here at the University of Colorado by Eddy Rojas, a Ph.D. candidate in the Department of Civil Engineering, promises to radically overhaul many of the paper-based systems currently used for building inspections. The program, Field Inspection Reporting System (FIRS), is capable of inspecting both existing structures and buildings under construction. The emphasis for existing buildings is preventive and emergency maintenance, while quality assurance and code compliance are higher priorities at construction sites. FIRS is a web-based program designed in conjunction with powerful databases and pen-based computers. Presently a long paper trail exists once a corrective action is requested until it is actually performed, and FIRS eliminates this excessive bureaucratic burden. The system may be expanded to accomodate insurance claims processing. A version of FIRS will be implemented by the Department of Facilities Management this coming summer, and a commercial version will also be made available.

—Kurt Duerksen
The Colorado Engineer, Spring 1996

MINNESOTA TECHNOLOG

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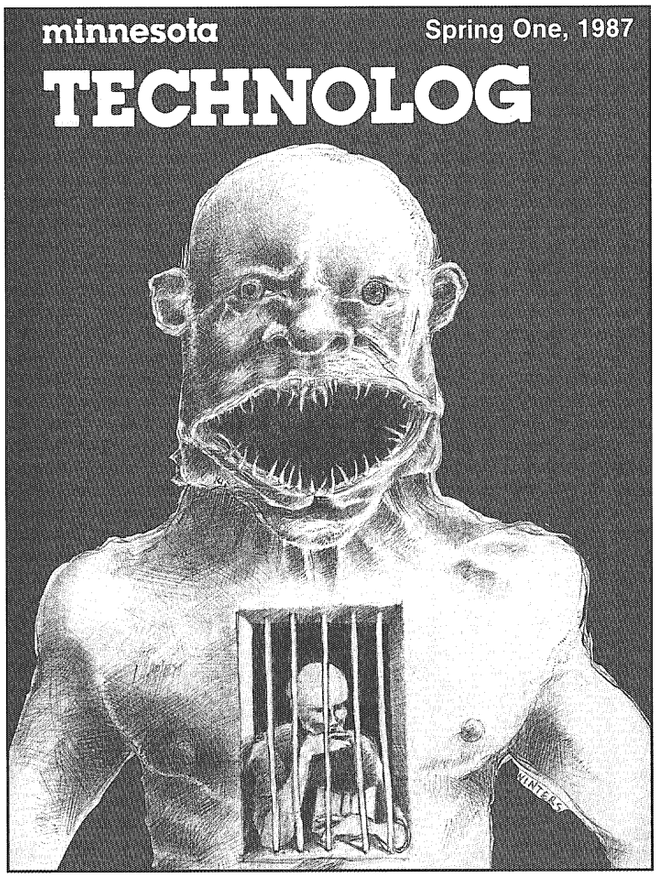
Boldly going where we've gone before



Above: *Cover of the Spring 1987 issue (Vol. 67, No. 5)*

The Cultural Abyss: Educating an Engineer

In America, universities and engineering schools were created during a period of great industrial expansion when engineers were needed quickly. The academic tradition in the sciences has, unfortunately, never evolved. Schools continue to churn out graduates who have memorized formulas but do not understand the cultural implications surrounding scientific advancement.

The U.S. has excelled at technological innovation and production, but it lacks the rich base of intellectual thought that accompanies scientific theory in Europe. There, science emerged from the liberal arts and has been built upon a classical educational foundation. The U.S., on the other hand, produces engineers who perpetuate the cycle of science without meaning.

Educators are well aware of this alarming cultural deficit but have not responded adequately. The assembly line approach to scientific education has been modified only minimally. At the University, adding a senior English program in technical communication and emphasizing liberal arts courses have helped, but these efforts should be redoubled on behalf of students and American civilization. *(December 1960—taken from an editorial)*

A Dreary Day for Diversity

Unlike many other industries, science and engineering fields remain overwhelmingly white and male. Women hold just 1.6% of American engineering jobs; African-Americans hold just 1.2% of these positions. Employers, meanwhile, are attempting to change this situation to meet affirmative action requirements. Their searches are largely futile, though. Lack of preparation in science and mathematics, social pressure, and stringent entrance requirements have combined to discourage women and minorities from enrolling in technical colleges.

IT's record in attracting such students is particularly dismal when compared to other colleges. Only 15 minority students were enrolled in IT last year, or approximately 0.5% of the student body. The 239 women enrolled represented 7% of all students. To increase enrollment and retention of women and students from

Above: *Where are they now? A former* **Technolog** *staff of days yesteryear poses for a groovy photo.*

minority groups, IT has begun a series of initiatives designed to recruit and retain them.

Among these is the Peer Teaching Program, directed by Dr. Jack Moran, which attempts to encourage students in inner-city schools to take math and science courses. Students in the program work with their regular teacher and receive special training at the University to provide assistance to other students in the course. After four years, 15 schools and 100 students in the Minneapolis and St. Paul schools participate.

IT has also established scholarships for female and minority students only. These awards, distributed exclusively on the basis of merit, are sponsored by companies such as 3M and attempt to counter lucrative offers by private universities to high-caliber students. Although these scholarships have been criticized for espousing reverse discrimination, the University feels that they are justified because of their success in attracting, retaining, and increasing the comfort level of minority students. *(November 1974)*

Grades Are a Private Matter

Although the Techno-Log has complained repeatedly about IT's policy of posting student grades in public places, it has received no response from the administration. Once again, students are seeing their grades both through the mail and on bulletins posted outside Main Engineering.

Students' grades should be treated privately, much as the amount of their salaries would be, and disclosed only by their volition. No other college at the University engages in this childish game. If the idea is to motivate students to boost their grades through implied peer pressure and humiliation, administrators should consider that students may instead feel discouraged by seeing others' higher marks. *(January 1930—taken from an editorial)*

URAS Call Home . . .

The University Radio Amateur Society (URAS) began several years ago when a few amateur radio operators got together for lunch. As interest expanded, the club established a newspaper, the *Weakly Emission*, and offered code practice and theory sessions for prospective members. Most members of URAS are engineering students.

URAS members have attended ham radio festivals in Wisconsin and Minnesota. As the club has grown, members have sought a permanent meeting room in the Union. The club currently has an account number but no provision in its constitution for collecting dues. Trips are organized on an individual basis to avoid the need for club funds. *(March 1956)*

by Chris Lee

Wookies, Trekkies, mashed potatoes, and nerds: The *Technolog* 100?

It sounded easy, like something that bungling droid C-3PO could handle even after being ripped apart and temporarily shut down in *The Empire Strikes Back*.

My assignment was to ask nearly everyone—friends, family, co-workers, strangers—to name their all-time best-loved science fiction films, then narrow the list down to the 100 titles most-often mentioned for something of a sci-fi equivalent to the "*Fortune* 500." But as I interjected the apparently startling question of "What's your favorite sci-fi movie?" into conversations, e-mails, phone calls, and letters, I soon discovered that compiling a list of hundreds of flicks to work down from was about as pleasurable as shopping for pants to fit Jabba the Hut, since the average pollee couldn't even think of anything outside of the George Lucas/Steven Spielberg *oeuvre* of blockbusters . . . or if they could, remembering the title was always another matter.

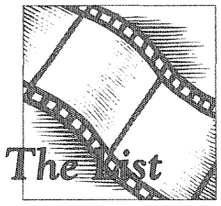
"The one where Richard Dreyfuss or whoever makes a big thing out of mashed potatoes" turned out to be *Close Encounters of the Third Kind*. Another person couldn't recall the name, but referred to *Explorers* as "that movie where River Phoenix and Ethan Hawke are little nerds."

Riff-Raff and Magenta model their futuristic wardrobe in The Rocky Horror Picture Show.

Some couldn't even remember that much—one woman mentioned the robot comedy "where they tried to make what's-his-name seem like some kind of G.Q. hunk." (The robot comedy: *Making Mr. Right*. What's-his-name: John Malkovich.)

Of course, my informal survey found three of the most popular films to be the *Star Wars* trilogy, countlessly referred to as "classic," though the original was favored over the sequels. *2001: A Space Odyssey*, *Aliens*, *Terminator 2: Judgment Day*, *Blade Runner*, and recently-crowned all-time box office champ *Jurassic Park* were among the obvious favorites.

Campy and/or humorous sci-fi also fared well, with *Barbarella*, *Flash*



A quick perusal of this list of 100 titles shows that different people have different ideas about what qualifies as "science fiction" in 1996.

Interesting quotes from various pollees about their favorite films follow some of the titles, and the 20 most popular movies are listed in bold-faced type.

The Adventures of Baron Munchausen
The Adventures of Buckaroo Banzai
Alien Nation
Alien 3
Aliens
Altered States
Attack of the 50 Foot Woman
Bad Taste ("There's this houseful of humanoid cult members who turn into aliens, *and* you get to see brains! It's really funny!")
Barbarella
Battlestar Galactica
The Black Hole
Blade Runner
A Boy and His Dog
Brazil
Buck Rogers in the 25th Century
C.H.U.D.
The Cat From Outer Space
Cherry 2000
Chopping Mall ("Robots go crazy and kill everybody.")
A Clockwork Orange
Close Encounters of the Third Kind
Communion
Cool World
Critters
Day of the Triffids
The Day the Earth Stood Still
Doctor Who (TV)
Dune
E.T.
Edward Scissorhands
The Empire Strikes Back
Enemy Mine ("Well, I liked it when I was 15.")
Explorers
Flash Gordon
Forbidden Planet
Frankenhooker
From Beyond
Future Kill
Gremlins
Hal 2000
The Handmaid's Tale
Highlander

Gordon, and even *The Rocky Horror Picture Show* receiving several votes each. Even critically-panned epics like David Lynch's *Dune* were well-appreciated, suggesting that the likes of Siskel & Ebert don't always influence fans of this particular genre.

But the most intriguing discovery of this survey had to be the very wide definition that people seem to have for the words "science fiction." *Webster's New World Dictionary* defines it as "highly imaginative fiction involving some actual or projected scientific phenomenon." Within these parameters, *A Clockwork Orange*—with its futuristic, ultra-violent story and setting—can arguably be considered sci-fi. But when one joker cited Disney's *The Lion King*, I started to wonder if science fiction had been lost in the process of integration and appropriation by other genres, and if its own popularity (seven of the 20 top-grossing films of all time can be considered sci-fi) has left it an impure, watered-down version of itself. Judging from some responses to my question, I was surprised that no one asked for elaboration on just what science fiction is; everyone seems to know, but has everyone come up with their own answer?

Some respondents felt that a plot even briefly touching upon the mysterious and unexplained, ghosts, the walking dead, monsters, hackers, fantastic or technological topics, computers, or electricity qualifies as science fiction. For example, *Raiders of the Lost Ark* made the list because, as one pollee defended her choice, "It's sci-fi, it's got celestial things and the Ark of the Covenant!" Another person mentioned Mel Brooks's *Young Frankenstein* because "it had electricity in it." The belief that lightning and comedy mix to combine science fiction was also furthered by a man who brought up the cult B-movie *Frankenhooker*—about a female monster assembled from the body parts of murdered prostitutes—adding, "Well, *Frankenstein* was essentially science fiction." Apparently so are the rest of his cinematic descendants.

The mere presence of certain archetypes and even specific actors also set off the sci-fi alarm in some minds. A movie about hideous, murderous creatures that live in the sewer, *C.H.U.D.* (an acronym for Cannibalistic Humanoid Underground Dweller) was cited because "It's got mutants!" Another person excitedly replied, "Anything with Christopher Walken in it, especially *Communion* because it's so bad, it's so hideous!" At least that one featured extra-terrestrials, a basic component of the genre.

Since much of this survey was conducted on a college campus, it's not surprising that most of the favorites were from the past 20 years. Some classic, influential sci-fi was mentioned, however, including *War of the Worlds*, *The Day the Earth Stood Still*, and the original *Invaders of the Body Snatchers*, which was praised as satisfyingly "creepy" by more than one fan.

Another thing that's interesting about the films that made the list is the absence of certain others. Box office success and sci-fi comedy *Back to the Future* and its two hit sequels never came up once. *Aliens* and *Alien 3* were both cited several times ("*Alien 3* is the moodiest one, it's very dark and very biblical," said one man) but there was no mention of Ridley Scott's original *Alien*—who could ever forget the much-imitated scene where the creature explodes from one character's stomach? And with all those Trekkies out there, the only *Star Trek* film even mentioned was the recent *Generations*, which was spun-off from the spin-off of the original television series.

Speaking of TV, many people were apparently confused about what they saw in a theater and what was viewed on the small screen. No matter; *The X-Files*, *Doctor Who*, *Max Headroom*, *The Outer Limits*, even *The Jetsons*, were all chosen as favorites. (Thankfully, *ALF* was overlooked by all.)

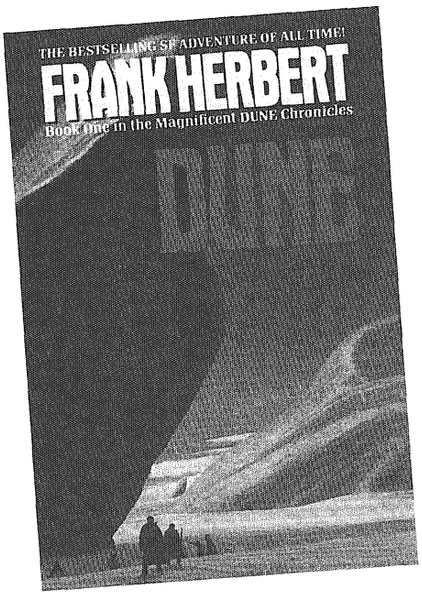
It was tough to actually cap the list off at 100, but it finally happened. For every person that claimed to absolutely hate sci-fi (and that was approximately half of them) someone would remember a forgotten hit or miss (like *Westworld*, *Tron*, *Logan's Run*, or *Howard the Duck*), covering the gamut of good, bad, and ugly. And considering that this is an under-appreciated genre that people say they don't like, science fiction movies and their subsequent merchandising (think *Star Wars* action figures) have made a lot of money—unless all those movie tickets are being snapped up by C.H.U.D.s, bored with the subterranean world and hungry for nights of big-screen light and magic. ★

Hitchhiker's Guide to the Galaxy (TV)
Howard the Duck
I Was A Zombie For The FBI
The Incredible Shrinking Man
Invaders From Mars
Invasion of the Body Snatchers
It Came From Outer Space
The Jetsons (TV)
Jurassic Park
The Lion King
Liquid Sky
Logan's Run
Making Mr. Right
The Man Who Fell to Earth
The Martian Chronicles (TV)
Max Headroom (TV)
Meteor
Metropolis
Naked Lunch ("You know, it's kinda sciencey.")
Night of the Comet
The Outer Limits (TV)
Plan 9 from Outer Space
Planet of the Apes
Raiders of the Lost Ark
The Re-Animator
Return of the Jedi
Robocop
The Rocky Horror Picture Show
The Running Man
Short Circuit
Something Wicked This Way Comes
Spaceballs
***Star Trek** (TV)*
Star Trek: Generations
Star Wars
Stargate
Starman
Star Crash: The Intergalactic Adventures of Stella Star
The Stuff ("We saw it at a drive-in! It's great!")
Tank Girl ("She's hot!")
The Terminator
Terminator 2: Judgment Day
Tetsuo the Iron Man
The Thing
Time After Time
Time Bandits
Total Recall
Troll
Tron
20,000 Leagues Under the Sea ("It's cheesy, but I liked it.")
2001: A Space Odyssey
2010
Until the End of the World
V (TV) ("The actor who played Willie, the good alien, ended up becoming Freddie Krueger.")
War of the Worlds
Westworld
***The X-Files** (TV)*
Young Frankenstein

by Steve Gigl

From Douglas Adams to Roger Zachary: The *Technolog* Top Ten

Here, in no particular order, are some of the best science fiction books ever written. Since science fiction stories are often too large to fit into a single novel, most of these books are the first of a series of books.



1.) *Dune* by Frank Herbert

Dune is the first in a series of six books centered around the planet Arrakis, nicknamed Dune because its surface is entirely desert. *Dune* was the basis for the David Lynch movie of the same title.

Herbert could craft a plot and its background of such scope that the reader—if he is able to remember all of the background—is utterly engrossed in the story. His characters are all a little alien because the novels are set tens of thousands of years in our future, and new traditions and belief systems have had plenty of time to take hold. Still, the characters are basically human, and the loyalty and respect for tradition many of them show make the heroes very sympathetic; in contrast, the Harkonnens and their ilk are very obviously evil.

Other Herbert books worth a look: Herbert wasn't as prolific as some other science fiction authors, but all of his books that I've read have been quite good. Start with *Dune*, and go from there.

2.) *Friday* by Robert A. Heinlein

Robert Anson Heinlein wrote with an almost unwavering quality that gives fans the confidence that any novel with his name on it will be worth the money. This natural ability led to many Hugo and Nebula awards as well as his selection as a Grand Master of Science Fiction (the most prestigious Nebula) in 1975. Heinlein has a very distinctive philosophy in which love for and unwavering trust in family and close friends and respect for all life are very important. He deals with the sexual side of life without going into details and always displays a healthy sense of humor.

Friday is the story (and the name) of a genetically superior human being, an Artificial Person. Friday, a strong female in a genre stereotyped for its lack of such characters, is a secret courier for a clandestine organization, a corporate intelligence agency.

Other Heinlein books worth a look: All of them. I highly recommend *The Puppet Masters*, *The Number of the Beast*, and *Stranger in a Strange Land*.

3.) *The Hitch-Hiker's Guide to the Galaxy* by Douglas Adams

The most successful combination of science fiction and comedy ever, the *Guide* started out as a BBC radio show, penned by Adams and aired in 1978. Since then, he has converted the radio scripts into novels and added two books to the "increasingly misnamed Hitch-Hiker's Trilogy." These books are without a doubt the funniest I've ever read. The original radio shows are available on tape and CD and are worth a listen if you like the books. There was also a series of BBC-TV episodes starring two of the original radio cast members, which I haven't had the pleasure of seeing.

The series opens with the main character, Arthur Dent, lying in front of bulldozers that are about to level his house to make way for a hyperspace bypass. He and his friend, Ford Prefect, escape the imminent destruction of Earth by hitching a ride on one of the ships that is demolishing the planet.

Other Adams books worth a look: Besides *The Hitch-Hiker's Guide to the Galaxy*, *The Restaurant at the End of the Universe*, and *Life, the Universe, and Everything* (the original trilogy), *So Long, and Thanks for All the Fish*, and *Mostly Harmless*, Adams has written and co-written other books, most notably *Dirk Gently's Holistic Detective Agency* and *The Long, Dark Teatime of the Soul*. All are quick, fun reading.

4./5.) *The Caves of Steel* and *Foundation* by Isaac Asimov

Objectivity becomes impossible here because Asimov is my favorite author. I would recommend any of his 470+ fiction and non-fiction books; as far as I can tell, he has never written a bad one.

The *Caves of Steel* is the first book in Asimov's *Robots* series and is basically a whodunit set after the resi-

dents of Earth have been driven into underground cities due to overpopulation. *Foundation* is the first book in the series of the same name, which covers the fall of a Galactic Empire. It started as a series of large short stories in a magazine in the 1940s and eventually earned Asimov a special Hugo award, "Best All-Time Science Fiction Series."

Asimov wrote with a distinctive style, though some critics considered it a lack of style. He used descriptions sparingly, making sure the reader knew what was necessary but little more. This quality makes his writing very accessible.

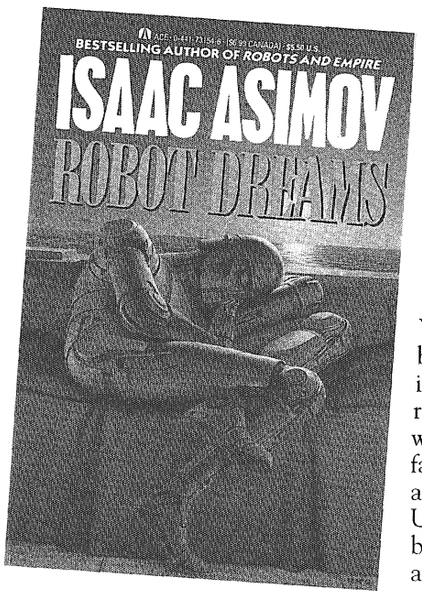
Other Asimov books worth a look: Oh, boy. With almost 500 books to choose from, you'll understand why I'm reluctant to recommend just a few. Besides the series mentioned above, he has written countless other novels and short stories. A person who both understands science and can write clearly is rare—think about your physics textbook—and Asimov was one of the best popularizers of science.

6.) *To Your Scattered Bodies Go* by Philip Jose Farmer

One of the most unusual stories (and titles) listed in this article, this is the first in a series of books about a world onto which a large portion of the human race has been resurrected.

Farmer's style is, like Asimov's, based on the "what you see is what you get" principle: there's enough mystery supplied by the plot, and the descriptive style shouldn't add to the confusion.

Other Farmer books worth a look: Besides the Riverworld series (which, quite honestly, is at least one book longer than it should have been), books by Farmer can be hard to come by. The only other one I've been able to find has been *The Lovers*, a ground-breaking novel about an alien love affair. Don't worry, it's not a romance book.



7.) *Rendezvous with Rama* by Arthur C. Clarke

Arthur C. Clarke is one of the most technically exacting and thoroughly imaginative authors on the planet. His *2001: A Space Odyssey* and its sequel were made into big-budget motion pictures, and he has received Nebula and Hugo awards as well as scientific awards for his invention of the communications satellite in 1945.

The *Rama* series is a less popular but no less impressive story about man's first contact with alien technology.

Other Clarke books worth a look: There must be at least 60 of his books available, and all are worth a read.

8.) *Moving Mars* by Greg Bear

"Hard" science fiction is marked by its attention to technical and scientific details central to the plot. Greg Bear is thought by many to be the best example of what's good about hard science fiction. Without exception, his novels are richly detailed and frighteningly imaginative.

Moving Mars is the story of Casseia Majumdar, a college student who, because of her family's political beliefs, has been "voided" by the university.

Other Bear books worth a look: Novels like *Eon*, *Eternity*, *Blood Music*, and *The Forge of God* are all highly recommended.

9.) *Ringworld* by Larry Niven

You can guess the setting of this book from the title. That's right, it's an artificial planet shaped like a ribbon and placed around a sun, with an incomprehensibly large surface area. This novel and its sequels are set in Niven's "Known Universe," a universe he created the background for and wrote quite a bit about.

Niven's style could be described as moderately hard. Most of the time his stories are character-driven, but he tends towards long descriptions of aspects of the Ringworld.

Other Niven books worth a look: *Ringworld*'s sequel, *The Ringworld Engineers*, and his most recent novel, *Ringworld Throne*.

10.) There are so many other authors out there who can write good science fiction that I had to leave this last spot open. On the quick and easy side of things, *Star Trek* and *Star Wars* novels are, though generally considered "light sci-fi," almost always well-written.

There are quite a few anthologies of short science fiction printed every year, which can be a time- and money-saving way to find authors you like. There are also several magazines of short science fiction on the market. ★

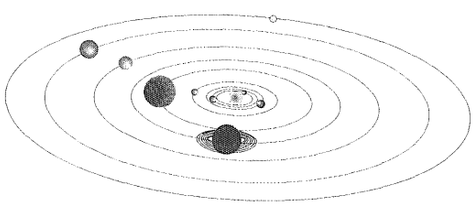
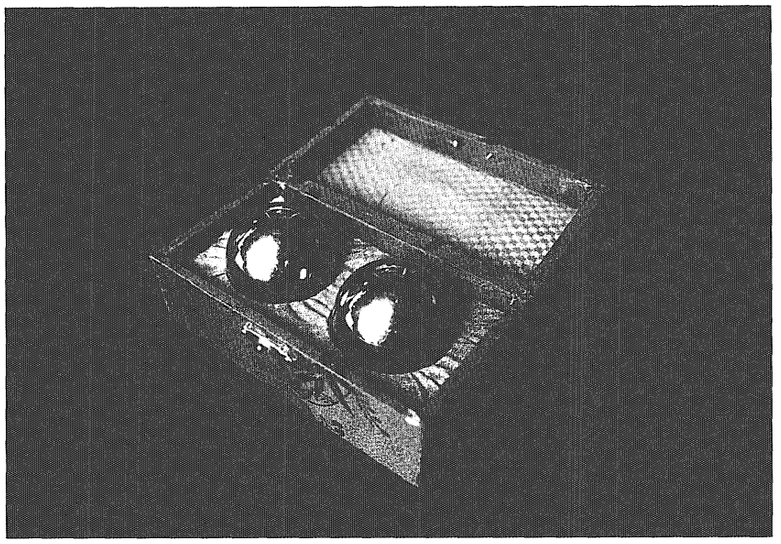
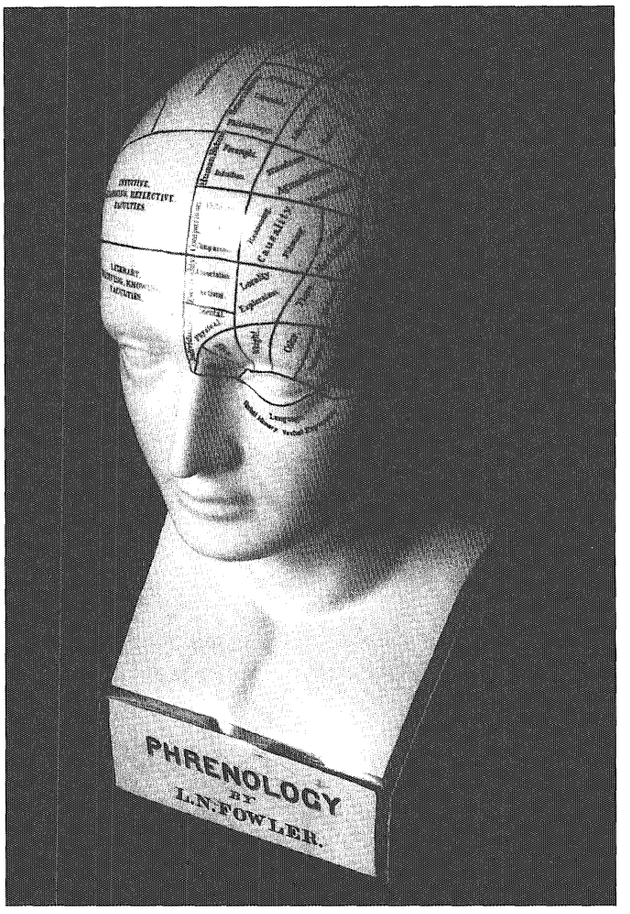
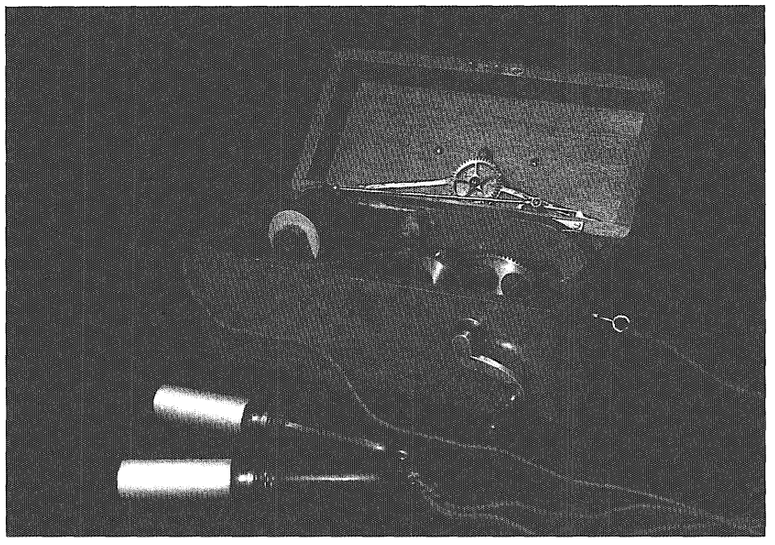


PHOTO ESSAY

by Kenei Sato







The Museum of *Questionable*

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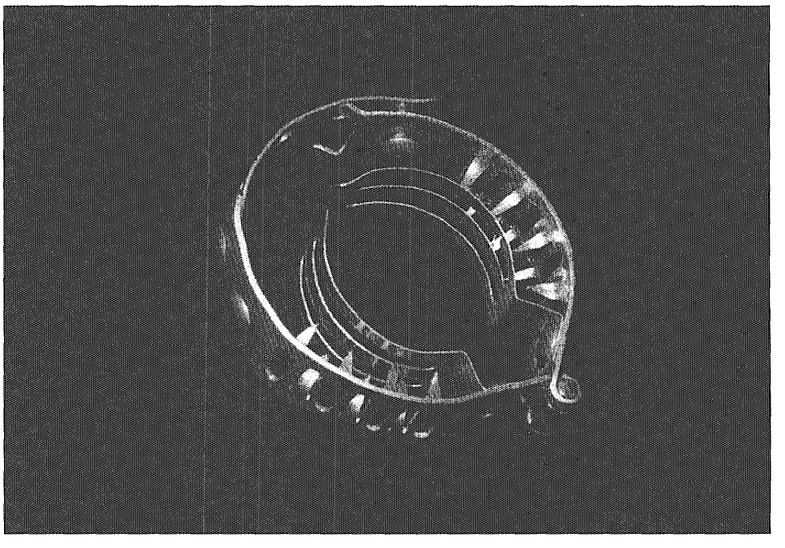
HAND EXERCISE BALLS are ancient Chinese hollow balls said to strengthen the hands and health in general.

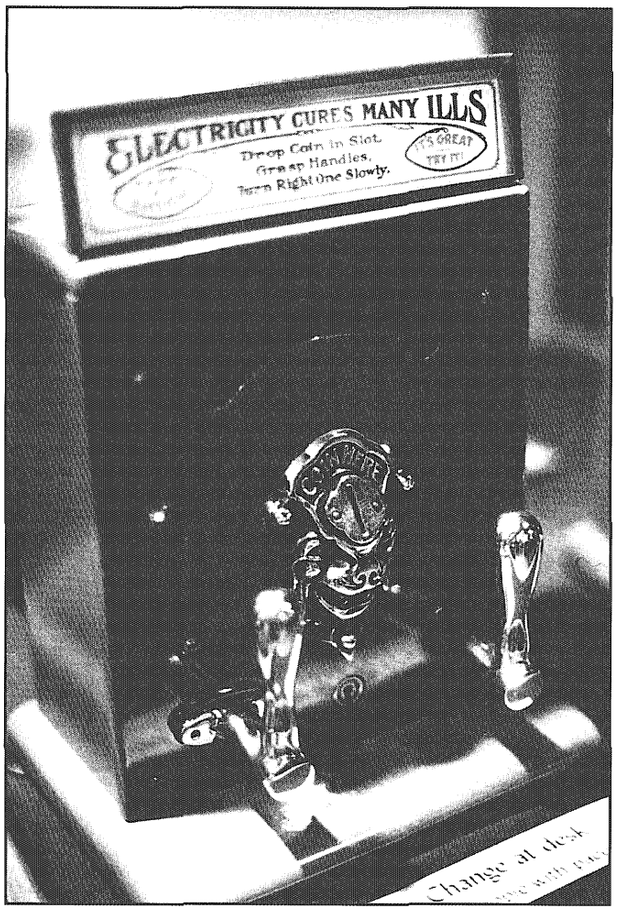
The PSYCHGRAPH (1798) was invented by Viennese physician Fronz Joseph Gaull after he "found" that people with high foreheads were more intelligent than others. The map on the bust shows where all character traits are allegedly located.

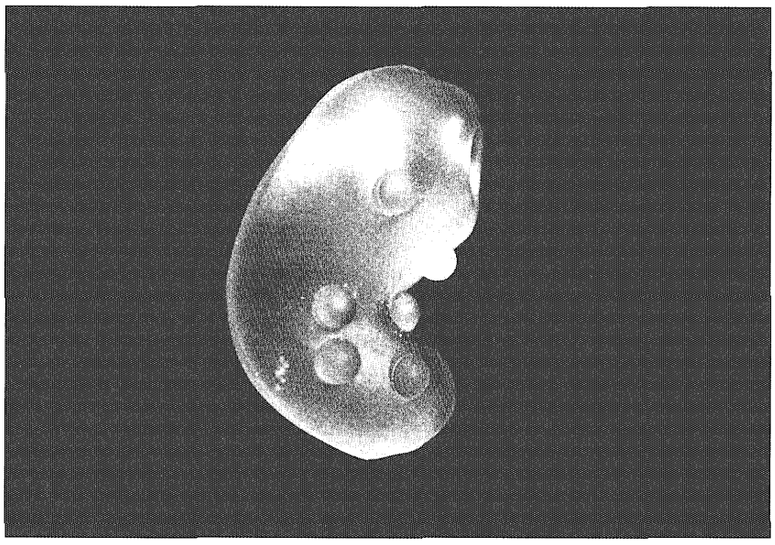
The DAVIS & KIDDER STYLE HOME MAGNETO (1854) created electricity by turning the crank and claimed to cure arthritis and many other diseases.

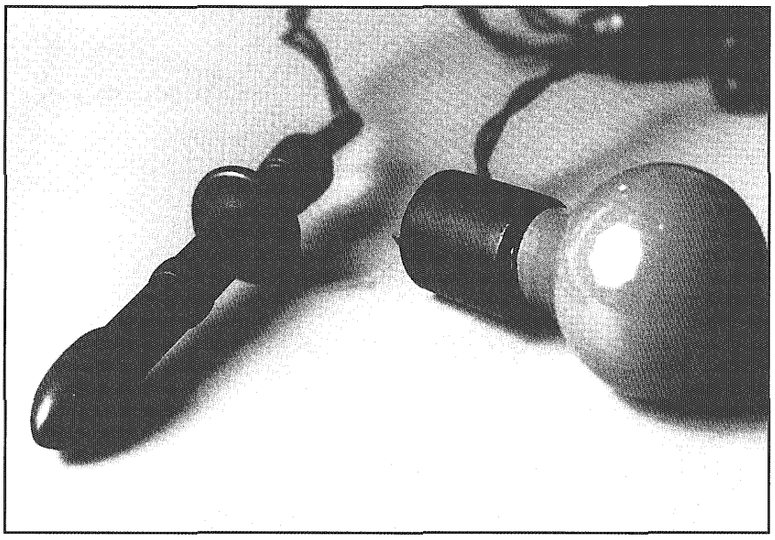
AMOROUS DREAMS was supposed to be most useful in the early stage of Spermatorrhoea and, according to the advertisement, is "adjustable to any size of organ."



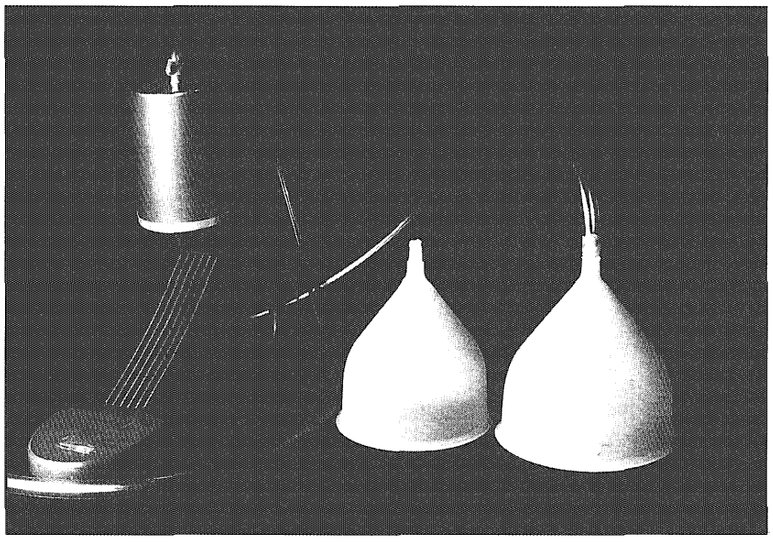
The Museum of Questionable Medical Devices is located at 219 S.E. Main Street in Minneapolis.







Medical Devices



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The ARCADE DEVICE (1910) allegedly provided high-frequency electricity to strengthen the heart.

ACU-STOP 2000 plastic ear pieces (1995) claimed to aid in weight loss by pressuring nerve endings in the ear in order to stimulate a feeling of fullness in the stomach. Retail price was $39.95, production cost was 14 cents.

The PROSTATE GLAND WARMER claimed to ". . . furnish a constant heat to the rectal anatomy, causing a gentle stimulation of the capillary blood vessels and the resultant improved local nerve condition."

The FOOT OPERATED BREAST ENLARGER PUMP (1976) was offered in three sizes and produced a strong suction meant to enlarge a breast. All change was only temporary, however, and left bruises and discomfort. Four million women ordered the $9.95 device.

THEIR FINEST HOUR

BY BRUCE A. BROMBEREK

"REPORT," commanded Queen Isabella. With a simple gesture, her handmaids and attendants scurried aside, allowing the messenger to advance.

Grand Marshal Ferdinand approached the throne with the confidence of his office tempered by the realities of his position. Ferdinand found it impossible to forget that his predecessor died on this very spot, and that someday, when he should displease his queen, he too would be dispatched. A Grand Marshal was appointed for life, however short that life may be.

At the base of the throne, Ferdinand assumed the proper deferential position. "My Queen, I have good news to report. Our patrols report no contact with the enemy, and our long range scouts report equally good news." Ferdinand paused, nervous that his next words would be his last. "I believe we have achieved détente."

Queen Isabella studied her Grand Marshal with a long calculating stare. Her cold eyes drilled into his being, searching for any hint of deceit. "Very good Ferdinand. I see that you learned a lesson from Balboa and Cortéz," the Queen said dispassionately. "If you said that we have achieved victory, I'd be holding your head right now. The empire cannot tolerate incompetence in its officials." After a long moment, Queen Isabella smiled. "You may yet live to die of old age."

Her smile faded as she paused to contemplate the situation. Ferdinand waited, holding his breath, knowing that he was not out of danger yet. "Expand the patrols, it is too soon to let down our guard. Report to me when they return." Ferdinand left, relieved, hearing the dismissal in his queen's command. The Queen's orders were not questioned; another lesson from Cortéz.

The Queen then dismissed her handmaids and the royal court. She needed to be alone with her thoughts. *The empire is weak*, she thought. *Too weak to cope with this strange new enemy. What we need is time.*

She knew it was misfortune that brought the weakened empire in contact with this new enemy. The civil war which had put Isabella on

ILLUSTRATIONS BY JOE SCRIMSHAW

the throne over her sisters had depleted the resources of the empire as well. The foraging party sent out to gather food and materials never returned. The Queen and her Marshals believed that the missing group must have been ambushed by renegade warriors loyal to one of the vanquished pretenders to the throne. An entire regiment was sent to investigate and retaliate. The regiment was decimated, but not by a band of renegades. The few warriors that survived told tales of fearsome creatures with powerful weapons.

The Queen replayed the situation in her mind. The empire had been too weak to enter into a full-scale campaign at the time. Instead, the Queen had opted for small patrols to continue gathering resources for the empire and scouts to collect information. And, for a time the empire began rebuilding with captured supplies, while the enemy remained relatively unconcerned with the empire and its location.

Unconcerned, that is, until an overzealous Grand Marshal Cortéz and Field Marshal Balboa staged a punitive raid on the enemy. Their raid was an attempt to restore the "honor" of the empire. It failed, resulting in the complete loss of two regiments. Cortéz and Balboa paid the Queen with their lives for their foolish and hasty actions. Since the raid, all of the empire's patrols and scouts have been harried and attacked, with continual heavy losses.

Until now.

Queen Isabella knew what needed to be done to preserve the empire. She called for her Prime Minister. Cervantes arrived quickly, more out of respect than fear. He had been with the Queen since the early days of the civil war and knew promptness was demanded.

"Cervantes, take my eldest daughter away from this castle, away from the empire, and into hiding," she ordered.

"But my Queen, the risks..." Cervantes pleaded.

"I understand the risks too well. By allowing my daughter independence, she could be used as a pawn by certain factions unhappy with my reign, precipitating another civil war."

Cervantes nodded, having seen such a course of events.

"However, I sense that the course of the war will be changing soon, for our ill no less. And I fear for the future of the empire. For that reason, I am willing to take this risk. Go, leave now, and take Esperanza away from here."

"As you wish, my Queen."

Cervantes left quickly, leaving the Queen alone to wait for the inevitable.

The inevitable arrived with the evening dusk.

"My Queen, the enemy is upon us! They have found our location and have broken through our defenses. Quickly, we must get you to safety!" Ferdinand cried, bursting into the Queen's chambers.

Queen Isabella remained calmly seated on her throne. "There is no safe place outside of these walls, Ferdinand."

Sounds of battle could now be heard in the throne room. Ferdinand was distressed at his Queen's apparent

lack of concern. "But the danger my Queen...."

"I am well aware of the danger," she answered deliberately. "But if I am not safe when surrounded by the entire forces of my empire, where will I be safe? My warriors will die to the last to defend me. For that reason alone I must stay, if only to see them during their finest hour."

"But the empire..."

"...will live on after us if they fail. You, however, will live only long enough to know the magnitude of your failure." Queen Isabella delivered this final comment with utter scorn and contempt.

Any reply from Ferdinand was cut off by the rising clamor from the battle outside. Except that the sounds heard were no longer the sounds of battle. They were the sounds of death, the screams and cries of warriors dying by the hundreds.

"You had promise, Ferdinand. Pity it has to end this way. I think you can hear now how badly you have failed," said Queen Isabella as she rose up, and in one swift fluid motion impaled the Grand Marshal through his neck.

Mists from the battle drifted into the throne room. Queen Isabella finished removing Ferdinand's head, then returned to her throne to wait. Within seconds, the death that had decimated her warriors, the death that made their finest hour a futile effort, the death that destroyed her empire, came for her.

"I'm tellin' you Wally, those little buggers were vicious. I've never seen wasps attack like that before. I sprayed one, stepped on it, and it still tried to get up and fly at me. If you hadn't come along with that second can of insecticide, I'd probably still be in there gettin' stung," Ed said, pushing the janitor's cart. Wally, still holding the spray can in his hand, followed Ed out into the hallway.

"That's because you use that cheap stuff. Ed, never sacrifice on quality." Wally tossed the can of insecticide to Ed. He pulled the door closed and picked up his mop. "But what I want to know is, how did they get into the air vents like that? I've been chasing them all over the building for weeks. Never thought to look in the air vents." Wally shook his head. "Smart little bastards."

"Hey, don't forget to lock the door. You know how they get all uptight about that, always afraid someone's gonna steal somethin' or other," Ed said as he pushed the cart down the hall towards the elevators.

"Almost forgot." Wally nodded in agreement. He turned and locked the door, oblivious to the word on the glass in front of him. Stenciled on the frosted glass, in block letters, were the words "Research & Development." And below that were the words "Genetic Engineering Lab".

He pulled the wet mop out of the bucket and plopped it on the floor. Whistling the "Battle Hymn of the Republic," Wally went back to mopping the floor. ★

FIFTY-DOLLAR VISION

BY MICHAEL P. BELFIORE

JAMES HIVELY stood at the rail and watched sailboats bob on the black waters of the bay two hundred feet below. The late-afternoon sun was hot on the side of his face. Behind him, children shrieked on the roller coaster, now distant, now close, as they went around the track. A merchant on the boardwalk hawked his wares.

"Don't," said a man beside him. "It can't be that bad." He was about James's age, thirtyish, a fringe of black hair showing beneath his narrow-brimmed hat. He stood with his hands in his pockets looking out over the bay, a rolled up flimsiscreen jutting from the side pocket of his blazer.

James realized his knuckles were white on the railing. He took his hands away, embarrassed. "Thanks for your concern, but it isn't necessary."

"I've been there," said the other man. "Standing right where you are now, thinking about how the boardwalk and the apartment blocks would look tumbling past my feet, the bay rushing close. Maybe I'd even get a glimpse of a weekend captain's mouth hanging open before the water turned everything black."

"You'd do better someplace else," said James. "The fall probably wouldn't kill you, and somebody might fish you out before you could drown." He shoved his hands in his pockets and hoped the man would go away.

The man was unperturbed. "There. You've at least thought about it."

"Who hasn't?"

"Maybe just a little more lately than usual?"

"Look, I told you I'm not planning to jump, so why don't you take your misguided concern elsewhere and leave me in peace?"

The man looked at him out of the corner of his eye. "Lost your job, didn't you?"

James stared.

The man nodded. "Saw it in your eyes, bro. I'm telling you, I've been there."

James swallowed, looked away. "I'd be doing all right if my investment opportunity had worked out, if my partner hadn't run out on me with the money. I was *this* close." He held out a thumb and forefinger. "This close, and I'd be sitting pretty right now, and they would have had their money back with interest."

The man chuckled. "What'd you do, steal from your company?"

James flushed. "Listen," he said, "why don't you just step over this railing here and get it over with?"

"You're right," said the man, serious again. "I shouldn't laugh." He withdrew a cigarette from his breast pocket. "It happens to the best of us. We all screw up. We've all, at one time or another, been had." He sucked on the cigarette until the other end flared, then blew smoke at the sky. "Question is, what do you do about it?"

"I take it you have the answer."

"Let's just say I know what it's like to be in your shoes. But I also know what it's like to find direction in my life. Over there." He pointed at the boardwalk behind them.

James turned, squinted into the sun. Kids with balloons, lovers, a man on a bicycle blazed with pale evening fire. A merchant stood in front of his shop and harangued passers-by. "Visions! Get your visions here! All your questions answered! Personal enlightenment, power and knowledge! Fifty doll-aaaars!" He was a man with coppery skin, long black hair festooned with feathers and beads.

"The hawker?" said James. "What about him?"

"That's my spiritual advisor."

"Your what?"

"I'm serious. Enlightenment can come from some pretty strange places."

"Enlightenment."

"Watch." The man flicked his cigarette over the railing. It tumbled end over end until the wind caught it and it was blown over the water, gliding until it was too small to be seen. "That's you, still burning, still alive, but heading for the water. Without a vision, you're heading straight down. But with a little spiritual help, you can go for miles."

"Sounds like superstitious nonsense."

He shook his head. "Not at all, not at all. Used to be, sure, divination and prayer was all you could do to find your true potential, but Running Buck has science on his side. It's just a matter of tapping your subconscious for what you already know. That can be done with today's technology."

"Well, I'm broke anyway, so it's a moot point."

The man grinned. "But that's the best part of all! It's only fifty dollars a vision. Lucky for us, he's not in it for the money. Fifty dollars, and look at me." He spread his arms. "New job, a girlfriend. Nothing to it."

ILLUSTRATION BY ROGER LOOTINE

James looked at him.

"Come on, I'll introduce you. I'm Carlos, by the way."

"James," said James, allowing himself to be led across the boardwalk.

"Carlos!" the hawker called. "Come for another *hanblechia*?"

Carlos shook his head. "I brought a friend. Like you to meet James. James, this is Running Buck."

Running Buck grasped James's hand. "For only fifty dollars, *kola*, you can have yourself a vision that will show you the way to a new job."

"How did - "

"I can see your pain, my friend, just as I saw his." He nodded at Carlos.

Carlos smiled, nodding.

"You see," continued Running Buck, "before the white man came, native peoples all over the Americas sought visions to reach enlightenment. They had to find them the hard way. They used—" he ticked the items off on his fingers "—drugs, sleep deprivation, fasting, extreme pain, exposure to the elements . . .." James drew back.

"No, no, listen to me, my friend. No longer. Thanks to the white man's technology, you can take the easy road. It's quick, it's painless, and best of all, it's only—"

"Fifty dollars, I know. Let me see how it works, and I'll think about it."

"Come in, come in, step this way."

"See you, Running Buck," said

Carlos, and gave a little wave. He winked at James. "Good luck, bro. You're on the path now." He walked away and Running Buck led James into the cool and dark of his little shop.

Most of it was taken up by a circular platform, about a foot high, surrounded by a waist-level railing. A black plastic helmet emblazoned with the image of a running deer hung from the railing. Cables ran from the helmet to a rack of electronics that took up most of one wall. Paintings of Southwestern American landscapes hung on the opposite wall.

Running Buck patted one of the electronic components on the rack. "This here's the heart of the business, what you call an electro-magnetic imaging scanner. It's gonna pull your vision from the universal life-force that surrounds us, and from your *nagi*, your subconscious. That information gets interpreted by this computer, *here*, and from there, fed to this image enhancer and amplifier. The fully processed vision is relayed to dual displays and binaural receivers in the helmet, giving you full color in three dimensions, plus stereo sound."

James rubbed his chin. Fifty dollars was only the price of a dinner. Of course, dinner was dinner, and these days he was lucky if he could afford even that.

But Carlos had said he'd gotten a new job. Even a girlfriend. If it was true, fifty dollars was nothing. James's hands trembled as he took his cash card out of his wallet.

"All right," he said. "I'll do it." He had the unpleasant feeling he was about to do something he'd later regret, but he handed over the card before his doubts could grow.

"*Washtay!* Good move, *kola*. You won't soon forget this experience. In fact, you don't ever have to forget it. For an additional fee, you can take home your very own digital copy."

"Just put me in this thing, before I change my mind."

"I'll record it for you, just in case." He led James onto the platform, and helped him with the helmet. "You'll have a 360 degree view. Just turn to look in any direction you like."

James had a last glimpse of the boardwalk through the open doorway before the helmet descended, and all was darkness and silence.

A glimmer. Green touched the edges of his vision, grew brighter. A birdcall. The buzz of insects. He stood in a forest of ancient oaks, the trees thick and widely spaced. The branches and leaves interlocked high overhead, and the light that filtered through was green. Fallen leaves and moss carpeted the ground. No other plants grew, and nothing moved.

James turned slowly. All around him was the same. Trees and moss, leaves and the green.

A flash of yellow caught his eye. He turned back. A wooden outhouse stood against a tree, the yellow paint faded and peeling. A half moon was carved into the side, up near the slanted roof.

James started forward, and ran into the railing. The sound of insects died. The green turned to black.

"What the hell? That's it?" He pulled off the helmet.

Running Buck stood on the boardwalk talking to Carlos and a young woman in a rumpled print dress. He turned at the sound of James's voice. He smiled and nodded, and came back inside. "Ah! All done, eh? How was it, my friend?"

"That was bullshit!" James flung down the helmet and stepped off the platform.

"Hey! Careful with that thing, that's big bucks!"

"What do you take me for, some kind of fool?"

"Hey, that's the real thing, my friend. You had yourself a vision. Now it's up to you to use it."

"But that wasn't anything! What am I supposed to do with that?"

"That depends, *kola*, on what you saw."

"I saw an outhouse."

"An outhouse?"

"An outhouse! In the middle of a forest."

Running Buck glanced behind him. The young woman peered around Carlos, who blocked her view of the shop. "Listen, friend, I'd love to talk with you about this, but I got a customer waiting here, so if you don't mind—"

"I want my money back."

"Okay, okay, take it easy. Tell you what. I don't usually do this, but I'm going to interpret your vision for you, free of charge."

"I'm listening."

Running Buck thought for a moment. "Okay, you're in a forest, right, all trees, and there's this outhouse."

"Yes?"

"Well, that's you. That's your life. The secret of your life is in that outhouse. All you got to do is open it up. Yes." He nodded, drawing out the words. "It's the outhouse of your life, my friend. Now, then—"

"What are you telling me, that my life is shit?"

"No, no—"

"I want my goddamn money back. In fact, I want to see your license for running this bullshit operation."

"Ah!" Running Buck struck the

palm of his hand against his forehead. "It's all clear now!"

"What the hell are you talking about?"

"Of course! Why didn't I see it before? Listen. You got to meditate."

"Meditate?"

"Yes! That forest, all that green, that's the peaceful center of us all. That's the part that's in touch with the Earth Mother."

"The Earth Mother."

"You can only get there by meditation, my friend, and once you do, you'll get to that outhouse. You'll get to that place of shit that's fouling the peace in the center of your heart. And once you do that . . .." He paused, and looked at James intently.

James let out his breath. "Yes?"

Running Buck spoke in a near whisper. "Once you do that—" he made a quick grabbing motion with one hand "—you'll be able to scoop it out and toss it aside like the offal it is."

He took James by the arm and led him out onto the boardwalk. He stood with the sun at his back and pointed down the row of shops.

An elderly Japanese man with a shaved head stood in front of one of the shops. He wore a black kimono, and he bowed at passers-by. Each time he bowed, a gong sounded from inside his shop.

"That's Honto-roshi," said Running Buck. "Tell him I sent you."

James shrugged his arm free. "No way. You think I'm going to go for this crap again?"

"Roshi!" called Running Buck.

Honto-roshi looked over, smiled. He approached with a rolling walk, the fringe of his kimono gliding over the pavement.

"This here is James," said Running Buck to Honto-roshi. "He's looking for enlightenment."

"Ah, Jimmie-san," said Honto-roshi. He stopped in front of James and bowed. "You come to the right place."

James glared at him. "What bullshit."

"Of course it is," said Honto-roshi, smiling.

"What? You agree?"

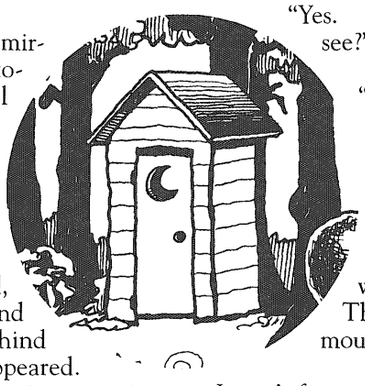
"Come over to my stall. I will show you."

James glanced behind him. Running Buck and Carlos and the young woman had disappeared into Running Buck's shop.

"Do not worry, Jimmie-san," said Honto-roshi. "He is not going anywhere. Come. I will make everything clear." He turned and glided back down the boardwalk.

With a last backward glance, James followed him.

Honto-roshi's shop was a bare room, rice paper walls. An ornate gateway of dark, polished wood, gilt highlights against the back wall, provided the only color.



"It is all smoke and mirrors," said Honto-roshi, "a liberal application of gadgetry, a light sprinkling of philosophy, and there you have it, a quite lucrative business." He made a grand, sweeping gesture, and the rice paper behind the gateway disappeared. Behind was a mountain, green in the springtime. A stream gurgled soothingly, a lake sparkled in a valley far below. Wind rippled the grass, carrying with it the scent of flowers and cool mountain air.

"That's very nice," said James, impressed in spite of himself.

"Come outside," said Honto-roshi, and stepped through the gate.

James hesitated for the barest moment, then followed him.

They stood on the grass beside the stream, James blinking in the bright sunlight. All around were mountains, grass and flowers, the air crisp and clear. The gate stood rooted in the ground, the side facing them weathered and the polish faded, the bare white room dimly visible on the other side.

"This is amazing," said James. "Running Buck's operation is nothing compared to this."

Honto-roshi shrugged. "You get what you get for fifty dollars."

James glanced at him sharply.

"Go stand there, in the water," said Honto-roshi. "It will help clear your thoughts. Take your shoes off first."

James sucked in his breath as he stepped into the stream. The water was frigid, clear as glass. He curled his toes around the pebbles on the bottom and tried to keep his teeth from chattering.

"Look at the sky," said Honto-roshi. "What do you see?"

"It's blue."

"Yes. What else do you see?"

"Little puffy clouds."

"Good. This is your *koan*, your subject for meditation. Keep it with you always. Little water and big sky. They meet on the mountain."

James's feet grew numb. He shivered uncontrollably, and a dull, throbbing ache began in his back teeth and spread to his temples. He suddenly felt ridiculous. "What does this have to do with anything?"

"A man went to the gates of a monastery," said Honto-roshi, "and asked for a *sanzen* with the master. When he was brought into the master's room, the master asked him

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Beauchillard's MASTERPIECE

by J. COLBURN
illustrations by Adam Turmin

Beauchillard is old now, almost 35. He's giving his 100th lecture. "There is a moment of equilibrium in this text. It's when the sparrow walks under the moving car and becomes a man." His book *The Night Copies Itself* was the first example in history of true equilibrium. Now all texts are examined for this quality. Beauchillard also creates science problems and has invented many organisms. For example, the tie organism. It is a creature that lives only to stop the train. It hovers in the sky, waiting for the blissful moment when it can fit into its particular slot as the train comes in. The tie organisms are small and purple and have some intelligence.

Of the professor's early organic inventions, his pet feeding system was by far the most popular. The leash of an animal was made of a single organism that grew from four feet to almost sixty during the course of a weekend. Admittedly, the organism was rather snakelike, but it was genetically bred to dislike contact with other animals, so that the dog would not get strangled by his living leash.

If a pet owner went away for the weekend, he would place bowls of food at spaces the dog would be able to reach after a certain number of hours. The marketing brilliance of the leash organism was the tie-in with "Living Plastic."

This earlier invention was used to cover the bowls of dog food, so that squirrels would not get into them. Thin sheets of it were spread over the food like plastic wrap. The "death" of Living Plastic could be carefully controlled and its life span chosen to coincide with the growth of the leash, so that by four o'clock on Saturday, the food was uncovered and the dog could reach it. And the best thing about Living Plastic was that it acted as a nutritional supplement. After dying, it would become hard, break apart, and fall into the dog food.

"I like to surround myself with living things," the professor has often

said. He talks about the old days of his people. "There was a girl who was walking home with a young man. They had taken a short cut through a grove of birch trees. It was a spirit-prison. The girl saw one of the spirits, digging in the earth. It was a man, and he appeared to be digging a grave. She took off running, and the boy, who hadn't seen the spirit, chased after her. Through a supreme act of fear, she turned into a deer and bounded off. The boy was heart-broken. He returned to the town and told his story. Many years passed. It was time for the boy to become a man and marry. He went by himself to the woods to ask for help from the spirits. A deer appeared next to him, a full grown doe. It nuzzled his ear. The boy killed himself and was reborn into the sky. On that night, a new pattern emerged in the stars that has been there since."

Beauchillard wheezes in his office, surrounded by a dusty language of artifacts. "I am working on something rather astounding. I think it will be the last of my organisms." At this he looks out the window. Pause for effect, a nod to the drama that seems to follow him. "Viruses, microbes, bacteria are such old-fashioned stuff. We must think big. We must race through complexity to reach the ultimate goal of simplicity." He pounds a bony finger on the desktop. His shirt is stained down the middle with this afternoon's vegetable soup. His eye catches a small box. He picks it up. "This here, this is a very precious gift. Do you know who gave this to me?" His eyes twinkle. "The mayor of New York. After my invention of the Self-Destructive Sewer Organism. He gave me these." He opens the box to reveal two perfect golden ovals. "These were the eyes of Charlie Chaplin, preserved and then coated with gold." He chuckles.

"But all this," he sweeps his hand, "is past. That's what offices are about. My workshop is about the future."

I follow him to the basement of the arts and sciences complex where he introduces me to many students, all of whom seem to be working on his projects.

"This is where the real work is done. Where the life-forms mingle."

We walk to large metal door at the far end of the laboratory. 'Authorized Personnel Only' is painted on it in red letters.

"Now hold my hand as we go in here," Beauchillard says. His hand is hard and small. Behind the steel door is a tiny waiting room. He opens another steel door and we pass through into the darkness.

"My experiment," he says. His voice comes from beside me but I can't see him. The room is darkness itself. There is a single small point of light that does not illuminate the room. I move toward it instinctively. I don't know if it is at the center of the room, because the room itself is unfathomable. But I gravitate easily toward the small light.

"You see, it is the 'darkener.'"

We are close to it now, but farther than arm's reach.

"It takes the light from the room. Very simple. My organism eats light and shits darkness."

I stare at it.

"There are hundreds of light sources operating in this room right now. I got the idea from a dream. You will want to touch it, but don't."

We are closer to it now, but there is no way to measure distance. All reference points have been wiped out by the singular darkness.

"Actually I got the idea from TV and from a dream. A dream of a TV. The way we stare dumbly and gather in semi-circles around the television, adjusting our brainwaves to match its frequency. The darkener is like a TV that says no word, and doesn't say it over and over. A single image that is imageless because it

Continued ▶ from p. 25

has eaten the source of all images."

His hand moves up my arm and covers my eyes. Relief and disappointment move through me in equal parts.

"Do you hear anything?"

I listen to the darkness rushing toward the light. The disembodied voice of wind, eerie in the stillness. I nod my head.

Beauchillard guides me back to the door. As he opens it the waiting room dims, and then regains itself with the closing of the door. We open the second door and walk back through the laboratory.

"Now you will ask me the purpose of my experiment. You will try to uncover corporate sponsorship, military applications, promises to third-world rulers. I expect this. So to cut you short, I will tell you. It is for me, and only me. It is my greatest achievement. And my last organism. It makes others obsolete, don't you think?"

"Yes," I said. "The darkener."

"I showed this to you because it was time. Time for a plan to be engaged. I'm not so young, you know."

I make a faint gesture of protest.

"No, really. It's time for me to make my statement. Time to paint my masterpiece, as it were."

I stumble in the bright lights of the hallway.

"Are you all right?" Beauchillard stops and examines my face.

"But if you can make a darkener, can you make a lightener? It would solve so many problems."

He smiles. "Of course you realize I have thought of this. But it's not so easy. You can't just put it in reverse, you know. There are some problems, genetically. Philosophically. The question becomes is darkness a form of energy, or the absence of energy? No. I have not been able to produce a lightener."

We walk the skyways until we arrive back at his office.

"I'm afraid I have to go now."

"What's the purpose of the darkener?""

"The darkener is here for my pleasure. Only this."

"I don't get it."

Beauchillard smiles and walks into his office, leaving me alone in the hallway. I hear him humming from behind the door.

There is a grayness to my thoughts.

I walk back to the basement and wander into the laboratory, taking notes. My head swims with the idea of darkness. It can only be that Beauchillard is a fool, blindly creating life forms, working without clear intentions.

I can think of hundreds of sinister applications for the darkener. And none that seem helpful.. The students busily work at projects, still associating my presence with Beauchillard. It's easy to slip into the waiting room again.

The darkener is on the other side of the door. I take off my coat, thinking of how even the spectacular becomes boring with enough repetition. I slip through the unlocked door, into the rush of darkness, and move instinctively toward the light. I can feel my will lunging out of me and into the central glow, and my brain sticks on a single phrase.

"I don't need this light inside me," I think.

"I don't need this light inside me."

"I don't need this light inside me." ★

Continued ▶ from p. 23

why he wanted to become a monk. 'Roshi,' said the man, 'I wish to achieve *satori*, and solve my problems as you have.' The master boxed the man's ears. While the man was rolling on the floor in pain, the master asked him what his problems were. 'My ears are ringing,' said the man, 'and I can't see straight.'" Honto-roshi chuckled.

"I don't get it," said James.

"Keep contemplating the sky. Keep your feet in the water."

"All right. So?"

"Now. What is your trouble?"

"Well, I'm out of work, for one thing."

"Good, good," said Honto-roshi. "And I need an assistant. Will you work for me?"

James looked at him in confusion. "You're offering me a job?"

"You will work on commission. Thirty dollars a customer. Can you start tonight?"

"Of course! What do I do?"

Honto-roshi chuckled and clapped him on the shoulder. "Put your shoes on and follow me, Jimmie-san. I will show you the ancient secrets."

With the sun gone, the boardwalk was lit by old fashioned street lights shaped like moons. James waded through the stream of pedestrians to the rail, where a man stood reading a flimsiscreen. The screen's pale glow illuminated the man's hands and the side of his face.

James sauntered up beside him and pretended to study the water below. "I wouldn't do it, if I were you," he said, trying to keep the hint of glee from his voice. "Jump, I mean."

The man looked up, and grinned. "Hello, James."

"Carlos? You're still here?"

Carlos rolled up the flimsy and the glow faded as he shoved in the pocket of his blazer. "I knew the roshi needed a disciple. I'm glad it's you. You'll do well here."

James narrowed his eyes at him. "You *work* for Running Buck, don't you?"

"Don't be mad. You got what you wanted out of your vision, didn't you?"

James looked at him. "Yes," he said finally. "Yes, I suppose I did." He smiled. ★

CARTOON

by Joe Scrimshaw

WRITERS WANTED

Minnesota Technolog is looking for writers (as well as illustrators) for the 1996-1997 school year. We're seeking IT undergraduate and graduate students who'd like some experience writing for publication! We have several beats in mind, including the environment, ethics, new technology, personal profiles and features, editorials, and personal reports on the specific projects you're working on for school.

Although our editorial board mainly consists of creatures from outer space, we've been known to work well with humans. If you'd like more information, or would like to come in for an informal interview with the editor, please leave a cover letter, a resume and any available writing samples in an envelope outside the *Technolog* office in Room 5, Lind Hall.

And, if you're not quite up to writing, but have interesting ideas for stories you'd like to see in upcoming issues of the *Technolog*, please jot them down on this form and drop it by the office.

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