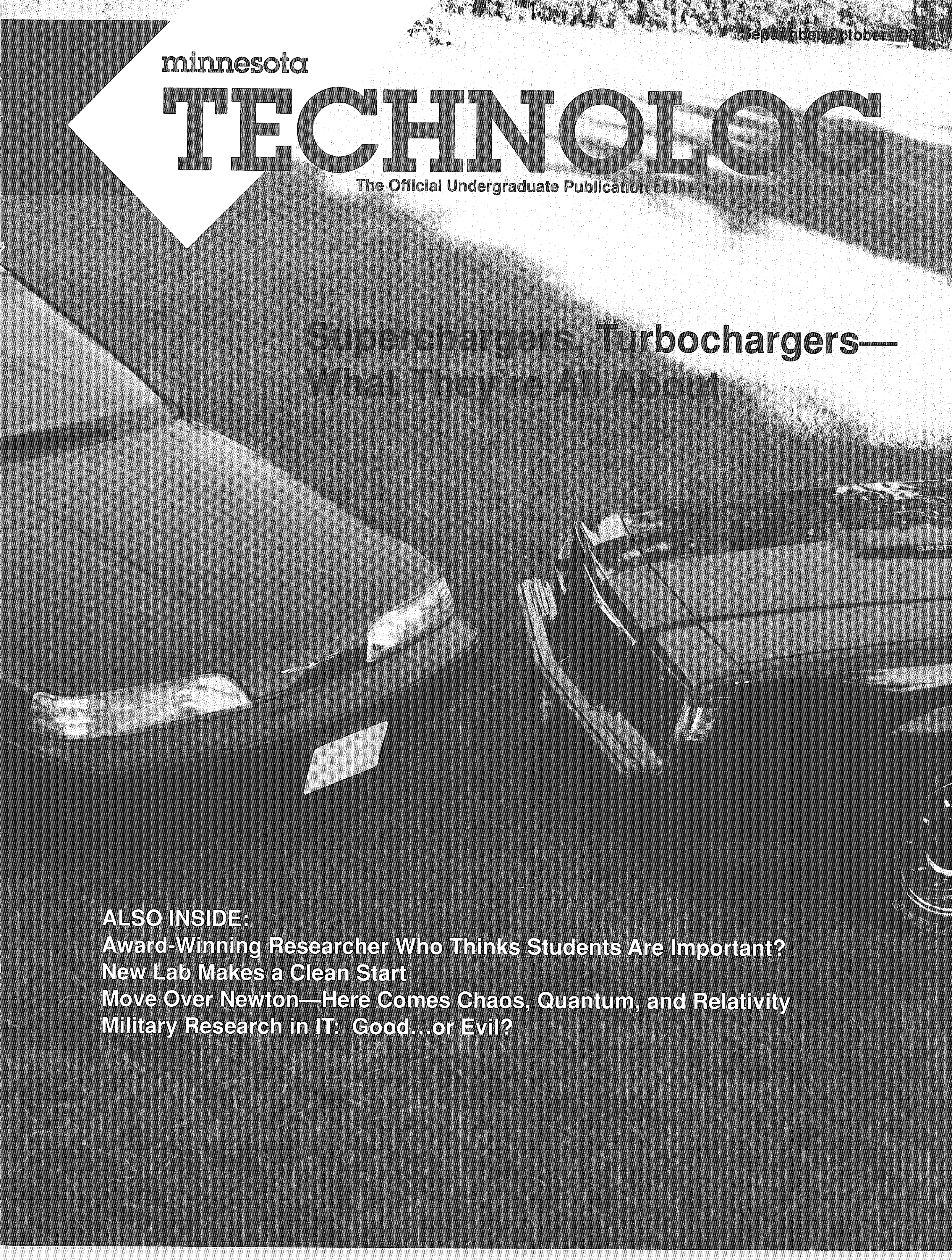
September/October 1989

minnesota TECHNOLOG

The Official Undergraduate Publication of the Institute of Technology



Superchargers, Turbochargers—What They're All About

ALSO INSIDE:
Award-Winning Researcher Who Thinks Students Are Important?
New Lab Makes a Clean Start
Move Over Newton—Here Comes Chaos, Quantum, and Relativity
Military Research in IT: Good...or Evil?

Get a Leg Up on the Competition

During dogged pursuit of your degree it's easy to forget the importance of being a well-rounded individual. In today's dog-eat-dog world, mastering your major field won't automatically make you the top dog. Indeed, industry recruiters dogmatically insist that communication skills matter just as much as technical expertise. In other words, to run with the big dogs, it's not enough to generate good ideas—you must be able to communicate those ideas as well.

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- Editing
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Application Deadline: Friday, October 6, 1989

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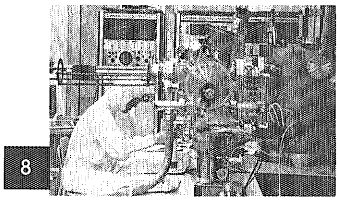

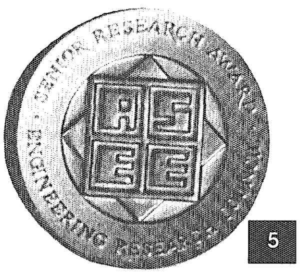

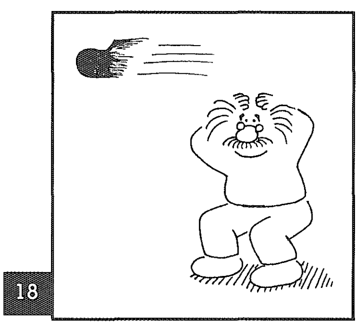

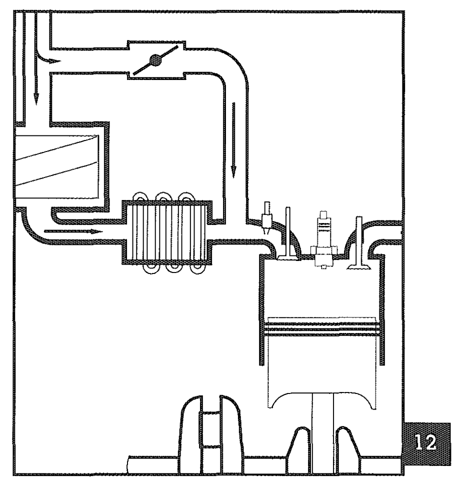

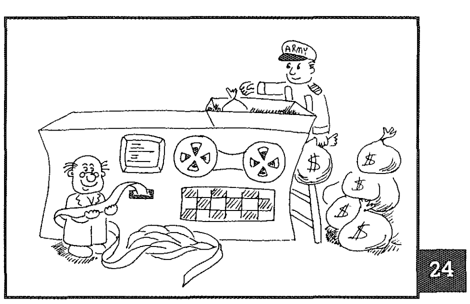

Departments

On the cover: 1989 Ford Thunderbird (left) provided by Freeway Ford in Bloomington. Special thanks to Todd Abel for his assistance. 1986 Buick Grand National (right) provided by Ron Mellum. Special thanks to Ron and his friends in the Minnesota Grand National and T-Type Association. These cars also appear on page 12, the first page of the cover article.

COVER PHOTO BY PAULA ZOROMSKI

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Minnesota Technolog, the official undergraduate publication of the University of Minnesota's Institute of Technology, is published six times yearly, twice during each academic quarter.

Help Wanted, 1999

by Loren Thomsen

IT students can solve a problem that's left industry and education leaders befuddled.

Will American scientists and engineers become an endangered species in the next century? Will the U.S. workforce lack the technical horsepower necessary to sustain our standard of living? Unfortunately, the answers to both questions will be "yes" if current trends continue. Most estimates claim that the United States will face a shortage of hundreds of thousands of engineers in the year 2000. Meanwhile, Japan is graduating engineers at a rate nearly double that of the U.S., nearly equalling our total annual output in spite of their smaller population.

Why will the supply of technical professionals fail to meet our projected needs? Fundamentally, the sheer number of young people entering the job market is shrinking. Furthermore, fewer and fewer members of this shrinking population are choosing careers in engineering or science; in contrast, the number of high school graduates choosing business careers has been steadily increasing for the past 20 years.

This dwindling percentage of technical graduates should not surprise us. Most high school students (especially females and minorities) have never been exposed to a role model who could spark an interest in the sciences, nor do they fully understand that preparing for a technical career begins with the math and science electives offered as early as the tenth grade. Only high school students with an intrinsic interest in math and science brave the educational grinder that leads to a satisfying technical career, and often it takes an enthusiastic teacher to germinate the small seed of interest that gets them started.

But why should IT students be alarmed that the supply of future engineers and scientists is drying up? In fact, won't we enjoy greater career mobility and larger salaries because of it? Yes, we will, but there's a strong argument that the shortage will hurt us more than help us:

- America's prosperity and national defense rest largely on technical prowess. Without enough scientists and engineers we'll find it progressively more difficult to compete in the world market. More and more products consumed in America will be researched, developed, and manufactured abroad.

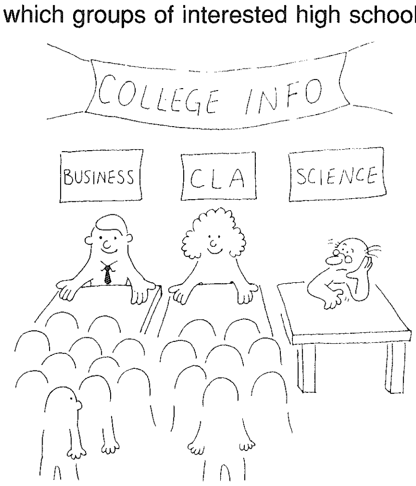
- Minnesota residents should be concerned about the viability of the numerous high tech industries in our state. If local companies cannot get enough qualified technical people within Minnesota, they will locate elsewhere—either overseas or other parts of the country where technical talent is more plentiful.

- Dwindling numbers of new engineers and scientists will diminish the prestige and influence of technical professionals. As we become more of a minority in the workforce, our influence on government, industry, and education will erode. The vitality of technical professions depends on new growth fueled by attracting bright, enthusiastic members.

In light of these facts, our own self-interest should make us want more high school students to follow us into the technical education pipeline. But what can we, as IT students, do about it? Isn't this a problem best left to industry, education, and government?

Maybe so, but so far they seem unable or unwilling to propose any sort of comprehensive solution. In searching for solutions, industry and education leaders fail to recognize that undergraduate students are well-positioned to attack the problem. By virtue of our work and academic experience we have the connections in high schools, technical colleges, and local companies that are necessary to take action.

To capitalize on our enviable position, I propose that IT student organizations coordinate one-day events during which groups of interested high school students spend half the day touring an industry site and and half the day touring the Institute of Technology. At the industry site the visiting students would have an opportunity to observe and question technical professionals in their work environment. On campus they would be offered a chance to question IT students about the preparation required for college-level technical education.



Although my proposal will require a great deal of work from students and industry representatives, the benefits will outweigh the costs for everyone involved. Participating companies get a chance to increase the future supply of technical talent as well as reap public relations rewards. Granted, their costs would be significant in terms of donated employee time and other expenses, but inflated salaries and understaffing caused by a shortage of engineers and scientists will be costly too.

Likewise, IT students will benefit from the experience of planning, administrating, and staffing a project of significant size and scope. Although the program may seem excessively demanding, IT students are undoubtedly qualified to carry it out. Furthermore, all IT student organizations contain a community service objective in their charter. Here's a chance for us to serve the community, challenge ourselves personally, and protect the future health of the science and engineering professions. ☐

LOREN THOMSEN is editor-in-chief this year. A Nordic supremacist from a small burg in the north woods, he rules the Technolog *office with an iron fist. In the future he plans on being a househusband, raising six kids, and becoming a freelance writer for* GIZMO!! *magazine. As editor-in-chief, he is forbidden by state and federal laws from writing or editing his own author-bio blurbs.*

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[Editor's Note: "Perspectives" will be a regular feature in Technolog. *Commentary found in "Perspectives" will be provided by students as well as representatives from industry, education, and government.]*

Spring 1989 Commencement Address

delivered by Ken Wagner

Ladies and gentlemen, faculty and administrators, fellow graduates:

Tonight I am thankful. I realize that many people have played a role in bringing me to this day, and this is the case for each of us who have graduated here tonight. Sacrifices were made by family and friends over the past years; our parents may have provided financial support; friends listened as we complained about how difficult a class was. The entire community has been backing us because Minnesota understands the importance of educating its people. We have a debt to pay, and as we embark on our careers, it is important that we reflect on this debt and our obligations.

We can start by considering how technology impacts our world and how new discoveries become a part of our lives. I had the wonderful experience of working in Africa for three months last year. I witnessed the building of bridges. I saw the slow but steady arrival of electric power to rural areas. These technologies are gifts from our world to theirs.

Repayment of our debt will require working closely with others; this will be a change for us. When finals week rolled around and the blue-books were handed out, we were alone. When the assignments were collected, our name was the one that stood at the top of that page. We became accustomed to working by ourselves. This must change, because graduates entering industry will become part of a team. That team will have a project, and that project will be part of an even larger project. The success of the team will be directly proportional to the ability of each of its members to work with one another.

Also, we have an obligation to the future. Science and technology are constantly evolving; superconductivity, control systems, and atomic power are developing before our eyes, and our education must evolve as well. One of the most important decisions we will face is whether or not to continue our education beyond graduation. We made a commitment to ourselves to work hard and earn our degrees. We faced temptations along the way. It was sometimes difficult to see the light at the end of the tunnel, and even more dedication will be required to continue our studies. The lure of industry and the money it offers will be hard to resist. I hope that those of us with an interest in graduate school will be true to the talent, ability, and curiosity that has brought us this far.

Most importantly, we are obligated to protect the environment. Our gifts are worthless if they are accompanied by pollution and health hazards. Our world is very small; we can't remodel and put on an addition. We hear scientists speak of a "global warming," the disastrous Alaskan oil spill threatens our wildlife, and we are producing toxic waste that isn't always stored properly. The world's problems are not caused by a lack of love but rather an excess of greed. We cannot allow important decisions governing modern technology to be made by those lacking a technical education. This means that we must influence all levels of management. Instead of contaminating lakes, let's pollute the decision-making bodies of America with people who have the technical understanding to say what is possible, what isn't possible, and most importantly, what just isn't safe.

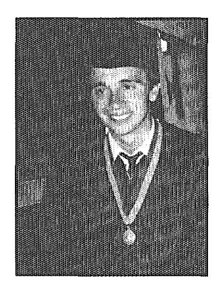
These may seem like monumental tasks and we will get stepped on occasionally as we start our careers. But we are not unarmed. In addition to our degrees, we bear self-confidence—a self-confidence built on years of hard work. Remember the late nights studying and the course you thought you would never get through. Think about the time you caught the flu on the Monday of finals week and still managed to pass your exam. Reflect on the achievements behind you when the challenges ahead of you appear too great.

"Instead of contaminating lakes, let's pollute the decision-making bodies of America with people who have the technical understanding to say what is possible, what isn't possible, and most importantly, what just isn't safe."

We are not here to celebrate the accomplishments of the graduating class—we are here to celebrate a bountiful display of potential. The challenges and our accomplishments yet lie ahead. With a positive attitude we say "bring them on."

This is the proper way for us to say thank you. This is the proper way to thank our families, our friends, and our professors. And this is the proper way for us to say "Thank you Minnesota" for making the Institute of Technology a college we can all be proud of. ☐

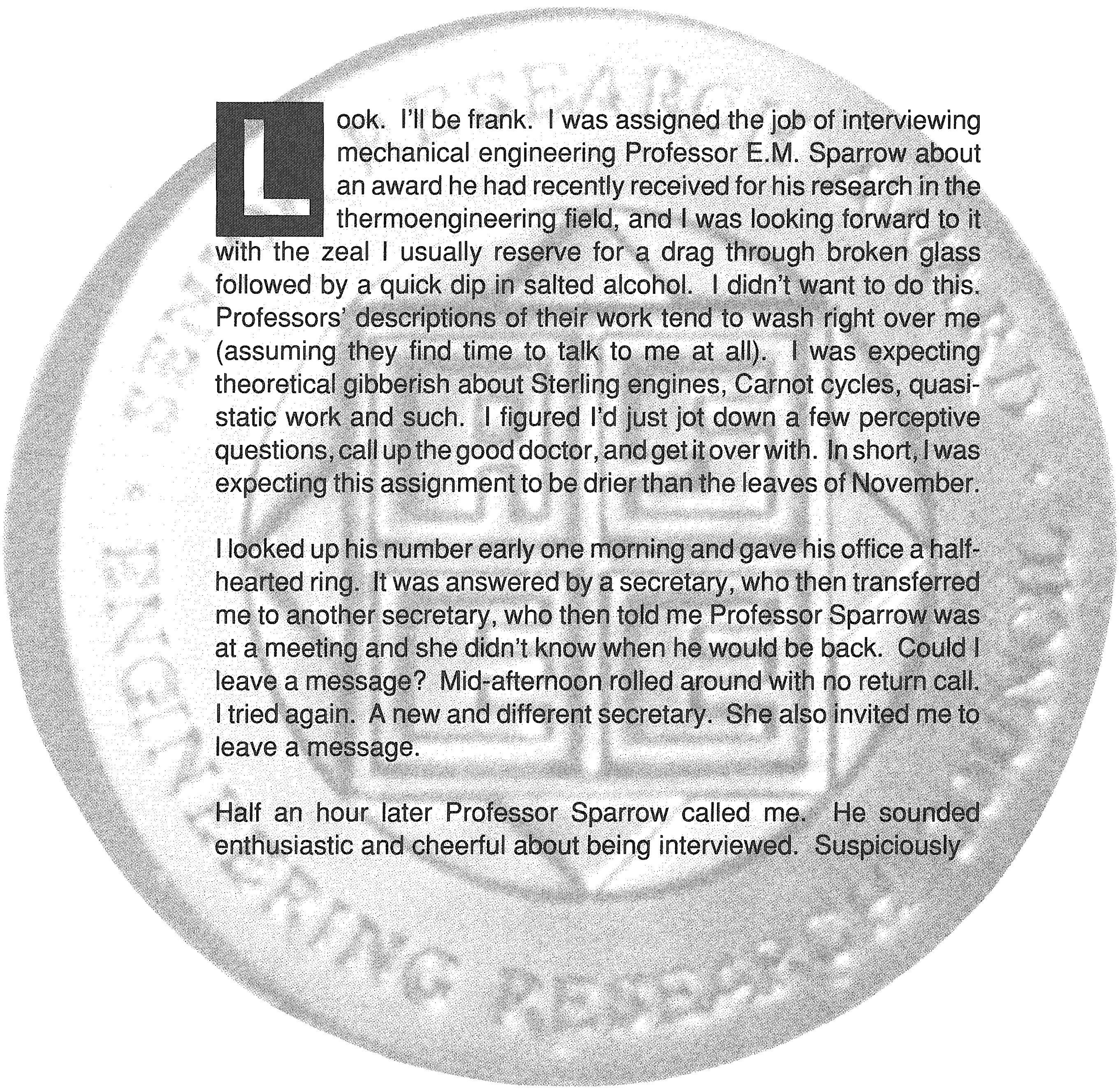
KEN WAGNER, last year's IT commencement speaker, had a 4.0 GPA, served on the IT Student Board, and was active in ASME. As a Navy officer, he will soon teach physics and math to nuclear power technicians in Orlando, Florida.



The Hundred-Hour Man

by Darin Warling

Can it be? A world-renowned researcher who feels teaching is his most important job? Meet Professor E.M. Sparrow.



Look. I'll be frank. I was assigned the job of interviewing mechanical engineering Professor E.M. Sparrow about an award he had recently received for his research in the thermoengineering field, and I was looking forward to it with the zeal I usually reserve for a drag through broken glass followed by a quick dip in salted alcohol. I didn't want to do this. Professors' descriptions of their work tend to wash right over me (assuming they find time to talk to me at all). I was expecting theoretical gibberish about Sterling engines, Carnot cycles, quasi-static work and such. I figured I'd just jot down a few perceptive questions, call up the good doctor, and get it over with. In short, I was expecting this assignment to be drier than the leaves of November.

I looked up his number early one morning and gave his office a half-hearted ring. It was answered by a secretary, who then transferred me to another secretary, who then told me Professor Sparrow was at a meeting and she didn't know when he would be back. Could I leave a message? Mid-afternoon rolled around with no return call. I tried again. A new and different secretary. She also invited me to leave a message.

Half an hour later Professor Sparrow called me. He sounded enthusiastic and cheerful about being interviewed. Suspiciously

PHOTO BY PAULA ZOROMSKI

enthusiastic, in fact, as if he were trying to get a good write-up from an intellectual, influential, top-drawer rag like our beloved *Technolog*. He asked what time was convenient for *me.* Strange, I thought, why would a professor want to do anything at *my* convenience?

We set up the interview for 9 o'clock the next morning.

I knocked on his door at precisely 9 o'clock the next morning. I had class at 10:15—a fail-safe excuse to politely escape his clutches if the whole affair became too painful. No need to offend someone who might be one of my future professors.

"Come in!" he yelled from within his office. I did. Busy typing, he apologized, "Sorry. . . . I'll be with you in a minute." I have waited for professors before, so I settled myself in for one long minute, roughly equal to the minute required for the rise and fall of the Roman Empire. Thirty seconds later he stopped typing, again apologized for not being ready, and handed me a sheet of background information about the research award that had prompted the interview.

He sat down at his desk and promptly began interviewing *me*: what was my name, how was I busying myself this summer, what was I studying, how did I choose my major, what were my plans for the future, was I headed to graduate school. . . . Long before I realized it, we were discussing his teaching philosophy, which happened to be one of my first questions. "Self," I thought, "you are a bonehead. You should have been taking notes the last ten minutes."

I had come carrying very big guns indeed: two pages of questions on his research and a spare concerning his background in case I ran short. But before I had a chance to fire the first question, he nonchalantly disarmed me and we spent most of the hour discussing teaching, education, and students.

Dr. E. M. Sparrow, recipient of the 1989 Senior Research Award of the American Society of Engineering Education (ASEE).

"The Student Should be Number One"

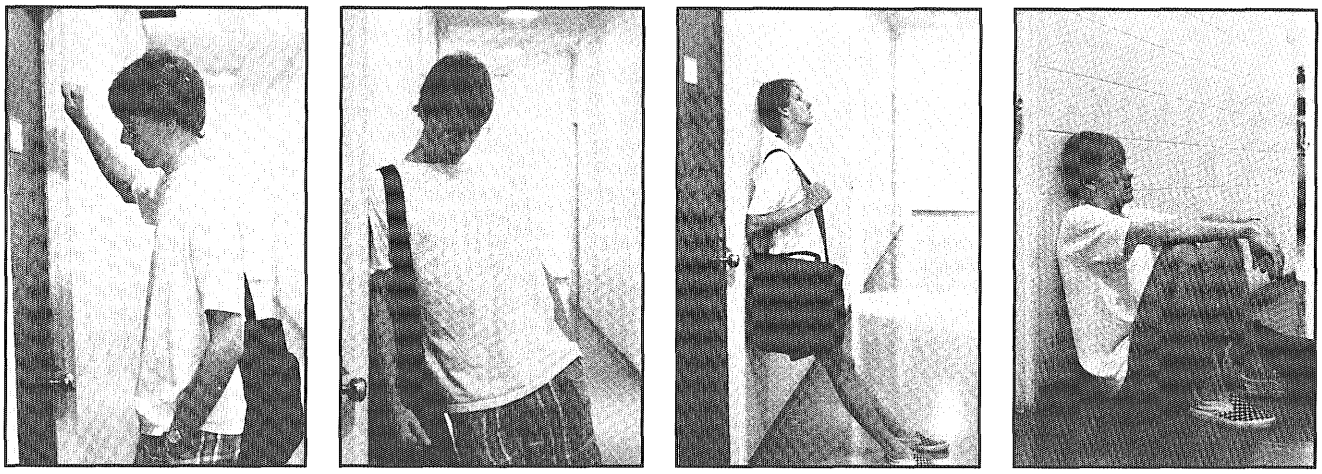
I discovered that Professor Sparrow is a man committed to his students. "In order to teach, you must first give your students a sense of enthusiasm and a sense of mission," he said, "then they'll learn what you're trying to teach them. But you must first feel this yourself before you can convey it to them." Furthermore, Sparrow believes teaching should be the first and foremost priority of university education. "Teaching does not just mean lecturing well," he said. "Rather, it is letting the students know that they count. Professors must be persuaded that teaching is important. All too often the focus is on research. . . . a balance is needed." In order to combat this, Sparrow believes the University must "broaden its reward system so that professors will be rewarded both for good teaching as well as good research." Though an outstanding researcher, he is proud that he won his national teaching award *before* his research award (he received the 1978 Ralph Coats Roe Award from the American Society for Engineering Education).

"Sparrow believes teaching should be the first and foremost priority of university education."

Sparrow projects his enthusiasm for teaching and learning by coming to class thoroughly prepared. "If I don't understand it, neither will the students," he explained. He plans lectures carefully, studying each one in an attempt to anticipate student questions. This intense preparation "conveys to the students how important they really are. The student should be number one." Sparrow believes, "All too often students rank their professors' concerns in the order of (1) publishing, (2) gaining research money, and (3) students."

I asked him what he felt students are lacking when they leave the University. "Communications skills," he replied. "Students leave here without the ability to communicate, both in speaking and in writing. The lecture system leaves no room for student presentation, and our undergraduate program does not allow for technical literacy." He went on to explain, "Literacy means knowing enough about other subjects to speak intelligently about them. . . . We all need a major discipline plus technical literacy in others. This allows for better communication between people and between fields." Sparrow feels that the student perspective of the world is often too narrow. "Students should respect themselves as professionals, have a broad view of their mission, be willing to participate in cross-disciplinary training, and be aware of their impact and the importance of their work on society."

Professor Sparrow occasionally logs 100-hour weeks on campus conducting his research, preparing for classes, and talking with students who drop by. He is justifiably proud of his research and teaching accomplishments, but remains quite modest. Rather than explain the results of all his years of teaching, he simply showed me the student evaluation forms from two classes he



Have you ever felt that you ranked dead last on a professor's priority list? Sparrow concurs: "All too often students rank their professors' concerns in the order of (1) publishing, (2) gaining research money, and (3) students."

taught last spring. Every form I saw had an "Excellent" checked in each category, and every comment was of the sort "Dr. Sparrow is far and away the best teacher I have ever had" or "I wish all professors were as good as Dr. Sparrow."

Renowned Researcher

Clearly an excellent teacher, Professor Sparrow is no slouch when it comes to research either. He was the recipient of the 1989 Senior Research Award of the ASEE, which recognizes "significant contributions to engineering research by pushing forward the frontiers of knowledge and perfecting and applying

> **"According to Sparrow, 'Students leave here [IT] without the ability to communicate, both in speaking and in writing.'"**

the latest scientific advances to engineering problems." Sparrow has been called "the most productive heat transfer researcher in the world for the last three decades" and has over 560 archival papers under his name. He is the most-cited mechanical engineering professor in the Science Citation Index, served as an editor for the Journal of Heat Transfer in the 1970s, and is also a past director of the National Science Foundation.

I wondered how he got into the heat transfer field. Sparrow credited it to "a person, an exceptionally exciting heat transfer professor. He was unusual; he related well to students and made it interesting. It was a joy to come to class." Professor Sparrow keys his work to timely, important applications within society: he began his career during the 1950s by studying efficient methods of extracting heat from nuclear power, just as nuclear power was becoming an important source of energy; during the 1960s he worked in spacecraft heat transfer; during the 1970s, the age of the energy crisis, he put his efforts into solar energy; during the 1980s his work has been in computer cooling; and during the 1990s Sparrow plans to begin cross-disciplinary work on human thermal problems in the bio-engineering field.

The large range of subjects his work has spanned makes it apparent that Professor Sparrow is a great believer in cross-disciplinary research. "Cross-disciplinary research is the wave of the future," he states, "therefore we should all prepare for it in our education." It is equally apparent that he is a great believer in finding solutions to important problems within society. "Heat transfer is a 'mature' subject," he explained. "In order to keep it important, tremendously relevant problems must be sought." Sparrow believes in searching for outward-looking ideas and applications. "Research must find important problems and improve the country's technology, because obviously the United States is no longer automatically number one. We must do useful things for the country and look out for her welfare."

Research usually results in research papers, while other activities result in a finished product: a chair, a new porch, a painting. It's tougher to get turned on by a research paper than a finished

Continued on page 21...

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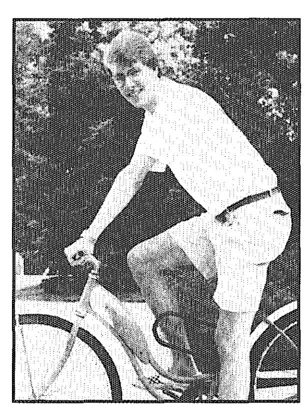
Writer Profile: Darin Warling

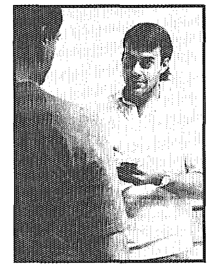
Darin is an associate editor for *Technolog* and spends his spare time double-majoring in mechanical engineering and computer science. Son of a veterinarian, he grew up in a small town in southern Minnesota. He misses going out on calls with his dad, kneeling in manure, reaching shoulder deep into cow vaginas to pull out stubborn calves.



PHOTOS BY PAULA ZOROMSKI

MEIS Comes Clean: New Facility Operational

by Steve Subera



MEIS's world-class clean room promises to earn IT a reputation for technical excellence.

[Editor's note: When writers cover new technology they often fail to see past the endless stream of impressive facts and figures thrown their way. Consequently, readers are not informed about the underlying implications of the technology. In-Depth Issues was initiated because of the concern that events touching the Institute of Technology were not being examined from the undergraduate viewpoint, a somewhat ignored commodity. Steve Subera's column will cover IT events and their impact, or lack of it, on the undergraduate.]

Just one year ago the Electrical Engineering and Computer Science Departments moved into their new building, abandoning the old, inadequate buildings they once occupied. Unfortunately, despite an occasional new building, the Institute of Technology continues to lose faculty members to other universities who lure them away with tantalizing offers of more money and better research facilities. There is, however, a multidisciplinary project within the new Electrical Engineering and Computer Science Building that has the potential for both attracting and retaining valued professors.

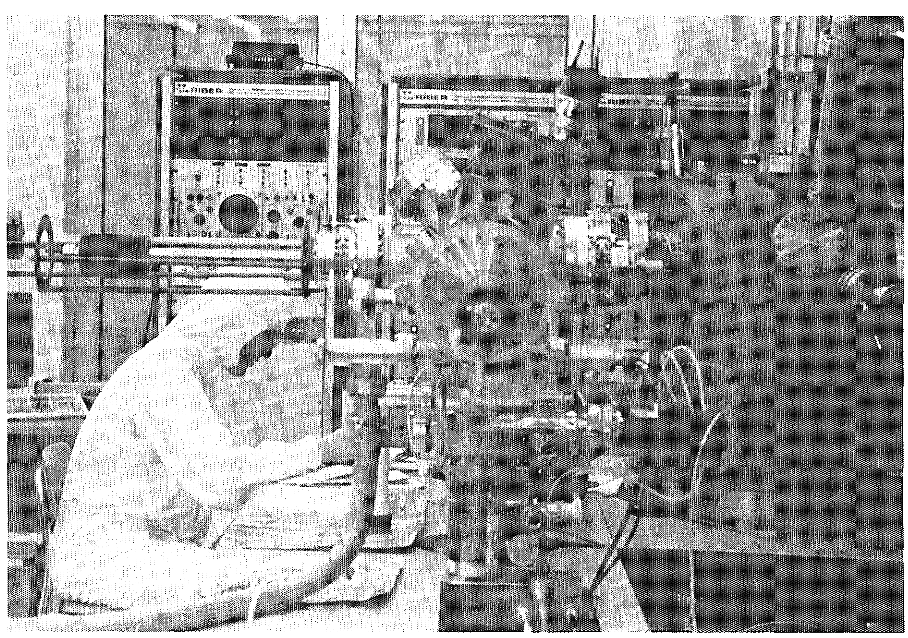
This optimism about IT's future is prompted by the new clean room in the Microelectronic and Information Sciences (MEIS) Center located on the first floor of the Electrical Engineering and Computer Science Building. The new clean room is spacious, not to mention clean. As in one-lonely-particle-per-cubic-foot-of-air clean. This new facility has the potential to attract many top scientists working in such fields as electrical, chemical, and mechanical engineering, as well as physics and chemistry. The lab will not only support semiconductor research, but also research in superconductors, magnetics, thin films, optics, and even clean room technology itself via contamination control and filtration studies.

In the beginning...

Stephen Gilbert, proud manager of the laboratory, was the driving force behind its design and construction. He has been with MEIS for eight years, having managed the clean room located on the fourth floor of the old Electrical Engineering Building. When the Electrical Engineering and Computer Science Building was originally proposed, it did not contain a clean room, but IT Dean Ettore Infante and former MEIS director Wallace Lindemann decided that if a world-class lab facility was added to the building, it could be used to bring contract money to the University.

The clean room's price was approximately $3 million, considerably less than comparable laboratories across the country. Gilbert attributed the lower cost to an initial design that held up throughout its construction. "In general, about halfway through construction, you go 'oh sh—' and you have to change some of the design. You forget something or something doesn't work out; there's a conflict," Gilbert explained. "Basically, we didn't make many change orders in the middle of construction and that significantly lowered the cost. Contractors tend to charge a premium for changes once you've started."

Clean rooms are relatively rare and entail many critical design specifications that require careful planning and management. Because of this, the lab was developed separately from the rest of the Electrical



Thad Johnson, sophomore in electrical engineering, is shown working with a molecular beam epitaxy device used to deposit thin films on substrates.

PHOTOS BY PAULA ZOROMSKI

Engineering and Computer Science Building. "We changed the way the U [University of Minnesota] and the state go about designing buildings," Gilbert said. Instead of accepting the overall lowest bid for the project, only those companies with enough technical competence were allowed to bid. Rather than having one single person in charge of the facility's design, a team of five (including Gilbert) shared the responsibility of getting the project off the ground, communicating frequently and sharing in the decision-making process. Finally, one other factor contributed to the design's success: the definition of both long and short term goals, which helped avoid the problems that crop up when no one has specified what the project's end product and interim results should be.

"The MEIS lab was originally designed to operate as class 10, but it has been certified class 1."

For the day to day operation of the clean room, Gilbert relies on a staff of both graduate and undergraduate students plus two full-time employees, and commends them for the excellence of the lab's operation. Eight undergraduate students currently work for him and he normally hires two incoming freshman each year. With few exceptions, he has kept all of them throughout their undergraduate career at the University.

Its Capabilities

Sandy Habermann, an undergraduate electrical engineering major, gave me a tour of the facility. I had been in the lab several months ago with Gilbert, but construction was still incomplete and gowning was unnecessary. This time I was required to wear a white, hooded jump suit (also known as a "bunny" suit), surgical gloves, and flimsy booties with elastic ankles. People are the dirtiest objects introduced into a clean room environment; by simply breathing, a person expels several hundred particles per minute.

Clean room environments are essential when working with the miniscule transistors and connect lines used in modern semiconductors, so a standard classification system has been implemented to let people know just how "clean" their clean room is. Each clean room is given a rating number which indicates the quantity of particles of a specified diameter (usually 0.5 micron) allowed per cubic foot of air. Hence, a class 10 clean room has no more than 10 particles floating around per cubic foot on the average (the typical hospital

"'They needed a two car garage and we've provided them with a 747 hangar.'"

operating room is class 10,000). Today class 10 is the rage, but class 1 facilities are being constructed, most notably by Intel Corporation. The MEIS lab was originally designed to operate as class 10, but it has been certified class 1.

Maintaining the extremely particle-free environment is accomplished by circulating large volumes of air through filters that are 99.9995 percent efficient. According to Gilbert, the air is recirculated every eight seconds, removing any recently-introduced particles from the room's atmosphere. He also noted that the air flow pattern of the entire facility can be changed, an extremely rare capability; usually only a small area or cubicle is designed for flow variation, but MEIS's entire lab has been designed for extensive experimentation in filter technology and air flow dynamics.

Vibration isolation is also critical in order to operate some of the clean room equipment. When working with such small dimensions, street traffic or even a person running down the hall can induce vibration in devices with only microns of tolerance. To prevent such problems, the clean room has been structurally isolated from the remainder of the building and rests on four concrete slabs anchored directly to bedrock.

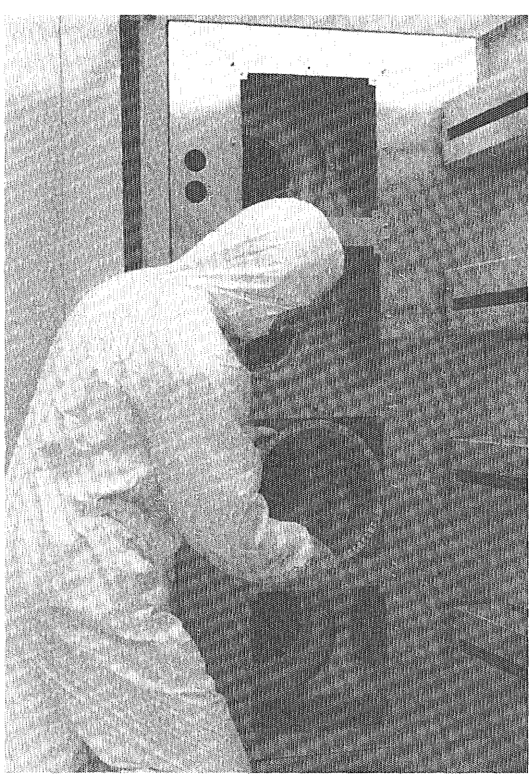
In the Future...

The original clean room on the fourth floor of the old Electrical Engineering building is contained in a relatively cramped 6000 square feet, as compared to nearly 9300 square feet in the new facility. The old lab will continue to be used for instructional purposes while operations are switched over to the new lab—at least until a decision is made on whether or not the old building will be renovated for use by the Mechanical Engineering Department. Students in the undergraduate Semiconductor Manufacturing Program (SMP) are currently using the old lab for hands-on experience in semiconductor manufacturing techniques while working in an actual clean room facility. The increasing use of clean rooms by various fields and the lack of new graduates with experience in lab operations has created a personnel gap that the SMP program seeks to fill.

Gilbert has received mixed reviews from the faculty, partly due to delays in completing the clean room and partly due to technology overkill. The laboratory currently exceeds the requirements of most of the department's researchers. "They needed a two car garage and we've provided them with a 747 hangar," Gilbert said. Having planned the clean room with foresight, Gilbert believes it will still be a technologically superior facility ten to fifteen years in the future.

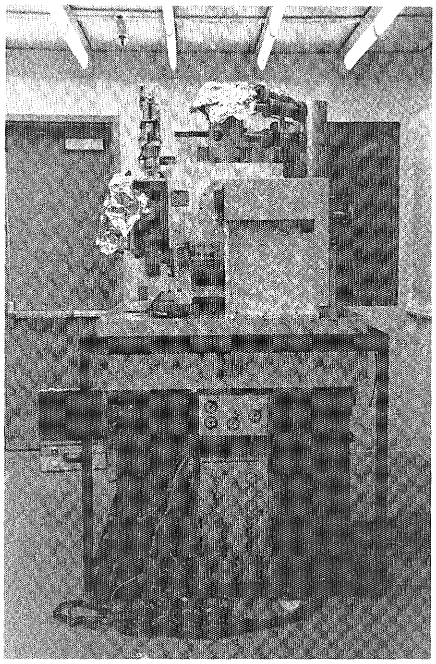
Potentially, the MEIS clean room will have a positive effect on the entire Institute of Technology. Conversely, it could remain a technical novelty if departmental and corporate support are not properly ap-

Below, Thad Johnson, wearing a "bunny suit," examines a diffusion furnace used to implant dopants (special chemical impurities) into a semiconductor's surface. Dopants alter the electrical properties of semiconductors.



Above, outside the clean room, Thad services a newly-installed diffusion furnace. The diffusion furnaces were purchased from Sperry (now Unisys) and refurbished.

PHOTOS BY STEVE HONG AND PAULA ZOROMSKI



An electron beam lithographer transfers circuit patterns onto the surface of a semiconductor wafer.

plied. The lab is capable of producing extremely beneficial faculty/corporate liaisons that would pump money into IT. This would directly affect undergraduate education: more money will result in the retention and possible expansion of faculty, reduced instructional costs, better equipment, and smaller class sizes. And an enhanced reputation for IT will improve employment opportunities for its graduates.

"The new lab could remain a technical novelty if departmental and corporate support are not properly applied."

However, the University's administration must keep in mind that the new clean room in itself will not be the Institute of Technology's panacea. Successful projects following on the heels of the new clean room are necessary. □

STEVE SUBERA, unabashed Wisconsinite and veteran Technolog *writer, is a second-year EE senior. He doesn't like it when IT administrators don't return his phone calls.*

How to Buy a Car with a Blown Engine

by Paul Kim

Did your friends express sympathy when you told them your car had a blown engine? Supercharged engines (referred to as "blown" by car enthusiasts) and their turbocharged counterparts, are technology's answer to horsepower hunger.

Late summer. The only way to escape the heat is a long drive hours after the sun is down. Out on the fringe of town you and your supercharged Ford T-Bird are stopped at what seems like the last stoplight on Earth. As you wait, a pitch black, turbocharged Buick Grand National slides up beside you. The driver stabs at the throttle, extending a throaty challenge.

You glance over, casually assessing driver and machine. He too is measuring driver and machine. Your eyes lock, narrowing to Eastwoodesque squints. The road beyond Earth's last stoplight is dead-straight, and your hand slowly tightens on the shifter.

The crosslight turns amber. You rev hard, the engine's torque rocking the car. When the light turns green your tires break loose, straining to grip the asphalt. Your T-Bird leaps ahead of the big Buick, supercharger force-feeding its launch.

Checking the rear-view mirror, your triumphant smirk starts to fade. The Grand National is closing the distance in a hurry. A big hurry. Scant seconds later its black hood is pushing past yours, the eerie, high-pitched scream of the turbo sounding like crazed laughter.

A touch dramatic perhaps, but the performance difference between a typical car and one sporting forced induction is, well, dramatic. All internal combustion engines work on the same basic principle. An air / fuel mixture is drawn into the engine cylinders, then compressed and ignited. The resulting explosion drives the pistons down, turning the crankshaft and, ultimately, the car's drive wheels. To produce more power, a greater quantity of the air/fuel mixture must be burned. One way to accomplish this is to use bigger cylinders, meaning, of course, a bigger engine. Because most drivers don't want or need a lot of power at all times, a large, fuel-hungry engine is not desirable.

The alternative is to force-feed the engine a denser air/fuel mixture. Although more fuel can be delivered by a carburetor or a fuel injector, more air can't enter the engine without the aid of a compressor of some type. These compressors take the

PHOTO BY STEVE HONG

form of either turbochargers or superchargers. Each has its advantages and disadvantages in the quest for greater power.

Superchargers—Separating the Wheat From the Chaff

The most popular supercharger design is the Roots type, introduced in 1864 by brothers Francis and Philander Roots and originally intended to separate wheat from chaff. Though far removed from its agricultural past, the supercharger used in the Ford Thunderbird's 3.8 liter V-6 is based on the same principle. Essentially a mechanical air compressor, the supercharger is driven by a belt connected to the engine's crankshaft and controlled by a computer chip.

The Thunderbird's supercharger is built by the Eaton Corporation and employs a pair of intermeshing, three-lobe rotors. Spinning in opposite directions at 2.6 times the crankshaft speed, the rotors will turn 15,000 rpm at full boost. Air is forced through the spinning rotors in high-speed pulses (Figure 1). No actual compression takes place within the rotor housing, but the displaced air pulses pile up, one upon the other, creating true compression downstream.

Despite a supercharger's seeming simplicity, it possesses some inherent problems. Air tightness within the supercharger must be maximized in order to achieve the greatest efficiency. Eaton attains this by using very close-tolerance machining. Noise is another problem in the Roots-type design, caused by the air pulses themselves. Eaton uses rotors twisted 60 degrees from end to end to lessen the pressure fluctuations and quiet the supercharger. Another problem is pre-ignition.

"Though the Thunderbird's supercharger may tap as much as 10 percent horsepower at full boost, it will return an increase of up to 50 percent horsepower."

When air is compressed, its temperature rises, increasing the possibility of premature detonation when the fuel is mixed in. To prevent this, an intercooler (a radiator-like device), is used to reduce the temperature of the air being drawn into the supercharger (Figure 1). To increase fuel

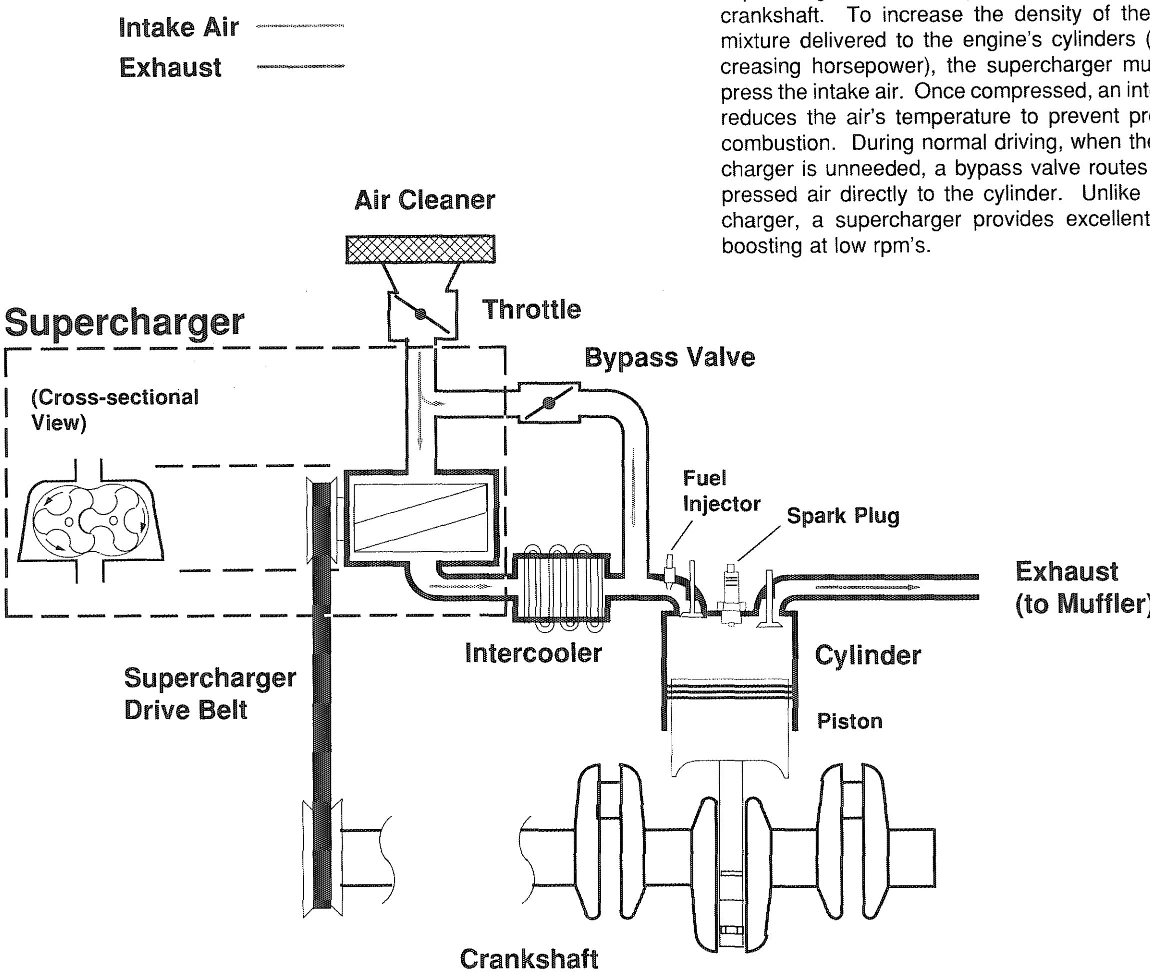


Figure 1. Example of a supercharger system. The supercharger is driven by a belt connected to the crankshaft. To increase the density of the air/fuel mixture delivered to the engine's cylinders (thus increasing horsepower), the supercharger must compress the intake air. Once compressed, an intercooler reduces the air's temperature to prevent premature combustion. During normal driving, when the supercharger is unneeded, a bypass valve routes uncompressed air directly to the cylinder. Unlike a turbocharger, a supercharger provides excellent power-boosting at low rpm's.

efficiency, a bypass valve diverts air around the supercharger when its power-boosting skills are not needed (Figure 1). Even with the bypass valve open, the supercharger still drains about 0.5 horsepower from the engine.

Though the Thunderbird's supercharger may tap as much as 10 percent horsepower at full boost, it will return an increase of up to 50 percent horsepower. Output is increased from 140 hp at 3800 rpm to 210 hp at 4000 rpm, and torque increases 46.5 percent from 215 ft.lb at 3200 rpm to 315 ft.lb at 2600 rpm.

Turbochargers—Harnessing a Lot of Hot Air

A turbocharger approaches the air compression goal in a manner much different than a supercharger. The engine's exhaust gasses are channeled through a turbine that shares a common shaft with an air-compressing turbine (Figure 2). Essentially, the turbocharger harnesses the momentum of the exiting exhaust gas to power an air compressor. Like supercharged engines, a bypass valve helps improve fuel efficiency by directing exhaust gas around the turbo when it is unneeded.

The greatest drawback of the turbocharger is its long throttle response time, known as "turbo lag." Unlike a supercharger, which is tied directly to the crankshaft and begins compressing air as soon as the throttle is depressed, a turbo must pass through a sequence of events to begin compression. When the throttle is pressed the engine's rpm's begin to climb. Increasing rpm's create greater exhaust gas pressure. The pressure must build to a degree sufficient to overcome the turbine's inertial moment before compression of the intake air begins. The time between when the throttle is punched and compression begins is the problematic "lag."

One way to quicken throttle response is to employ two small turbos instead of a single large one. Because less exhaust gas pressure is required to overcome the inertial moment of the smaller turbines, throttle response is improved. Another strategy is to lower the inertial moment of the turbine by using a lighter material. Aluminum has been tried in the past, but virtually melted in the turbo housing due to extreme heat. The solution Buick engineers applied in the Grand National's turbo is ceramics. Though very lightweight and able to withstand heat stress, the ceramic turbine is somewhat disadvantaged by being very brittle. In fact, minute metal fragments suspended in the exhaust gasses cause

ILLUSTRATION BY VINCE GREEN

numerous micro-craters on the turbine surface, possibly leading to turbo failure. Titanium, which is lighter and stronger than steel, seems an ideal turbine material and is one candidate for the next generation of turbochargers.

A different approach to the turbo-lag problem is the use of a variable-rate induction system for the exhaust gas driving the intake turbine. Imagine this as a shutter placed at the opening of the turbo's exhaust gas inlet. When the driver nails the throttle the shutter will be barely open. A small opening at the end of a large pipe increases the velocity of the air being forced through (the Venturi Effect). As engine rpm's increase, the shutter will open progressively wider, allowing exhaust gas to flow freely. This complex method of improving throttle response costs about two to three times that of conventional turbos, but is the strategy Dodge chose for the 1989 Shelby Shadow CSX.

"Superchargers grant off-the-line, get-it-now power. . . .Turbochargers reign supreme where flat-out top speed is the objective."

Oh. . .Which to Choose?

Turbocharger or supercharger? Each has a very different way of delivering the power performance-minded drivers desire. Superchargers grant off-the-line, get-it-now power, which is the key to their dominance of drag racing. Turbochargers reign supreme where flat-out top speed is the objective. Events like the Indianapolis 500 and Formula One racing reward the turbocharger's brand of high-rpm power delivery. It's unlikely a buyer will use either the Ford or the Buick for such events (barring the occasional stoplight sprint) so other pros and cons must be weighed with their performance characteristics.

Because a turbocharger spins much faster than a supercharger (up to 100,000 rpm), it requires lots of fresh oil and a complex cooling system. As a result, the oil change frequency is more critical with a turbo than with the less finicky supercharger.

A turbocharger is compact, even with its exhaust plumbing and heat shielding, a

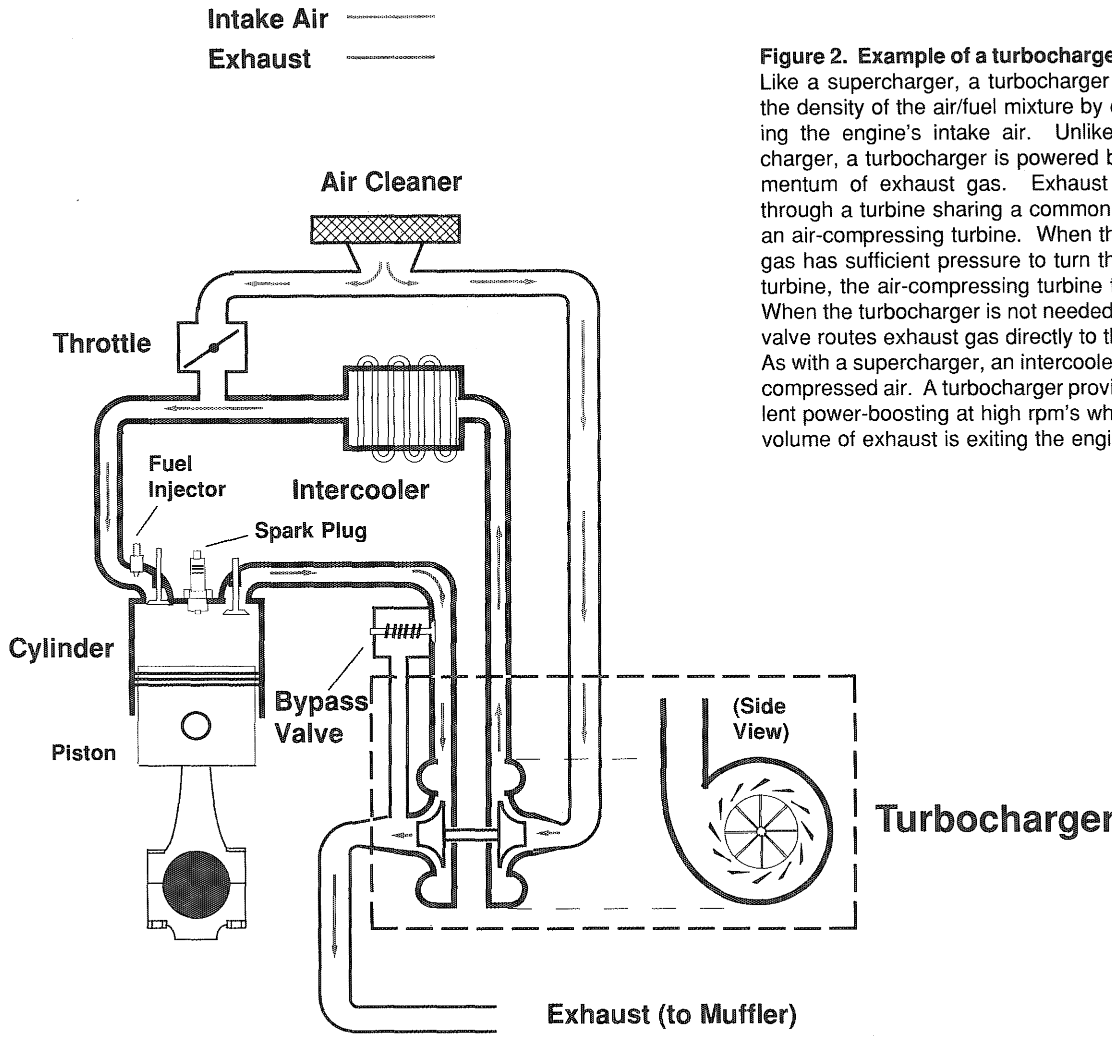


Figure 2. Example of a turbocharger system. Like a supercharger, a turbocharger increases the density of the air/fuel mixture by compressing the engine's intake air. Unlike a supercharger, a turbocharger is powered by the momentum of exhaust gas. Exhaust gas exits through a turbine sharing a common shaft with an air-compressing turbine. When the exhaust gas has sufficient pressure to turn the exhaust turbine, the air-compressing turbine turns also. When the turbocharger is not needed, a bypass valve routes exhaust gas directly to the muffler. As with a supercharger, an intercooler cools the compressed air. A turbocharger provides excellent power-boosting at high rpm's when a large volume of exhaust is exiting the engine.

clear advantage over the large and heavy supercharger. Also, a supercharger must be located near the crankshaft, a problem for modern automobiles with an aerodynamic emphasis. Unfortunately, downsizing a supercharger is not a good answer because its size is directly related to the maximum boost it can provide, especially at high rpm.

Clearly, room for engineering improvement exists in each system. Or maybe a combination of the two would yield the best performance. This is the approach Toyota will take with the 1990 MR2 and Celica GT. A supercharger will handle low rpm duties, and a turbo will take over as the revs climb. Will the performance of such cars outweigh their complexity and cost? To many it's a "who cares?" question. But for those with the need for speed the answer will always be "YES!!" □

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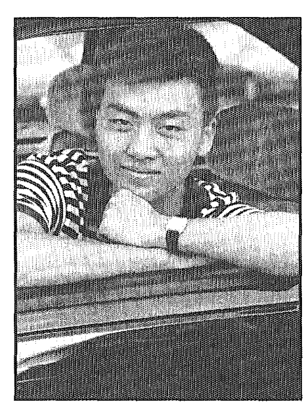
minnesota TECHNOLOG

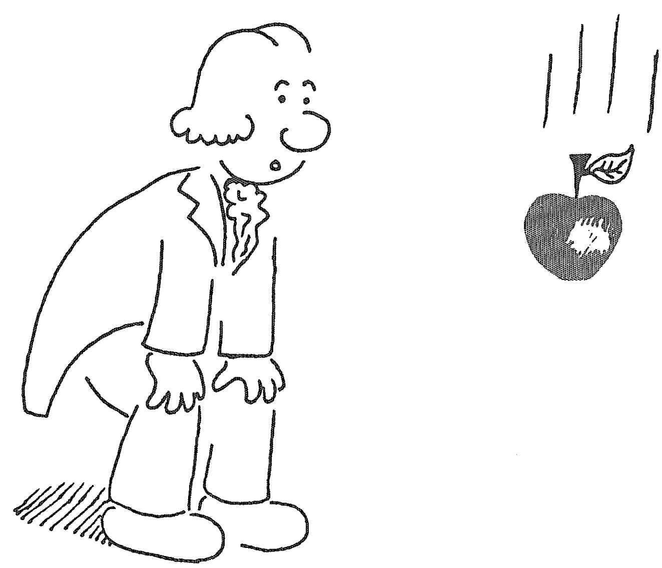
Writer Profile: Paul Kim



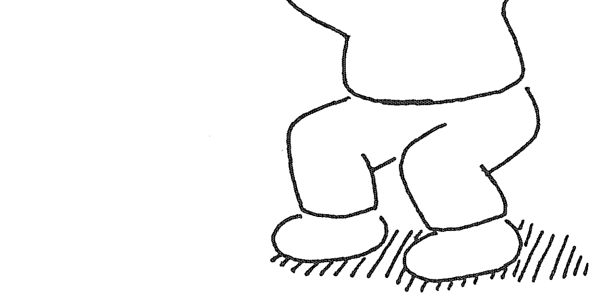
Paul Kim, a sophomore in mechanical engineering, is secretary of the IT Board of Publications. In his spare time he peruses paramilitary pulp fiction, his current favorite being *Strike Force #9: The Armageddon Assault*. He is presently plotting a paramilitary overthrow of the ITBP presidency.

Nature Defies Newton

by Sadasivan Shankar



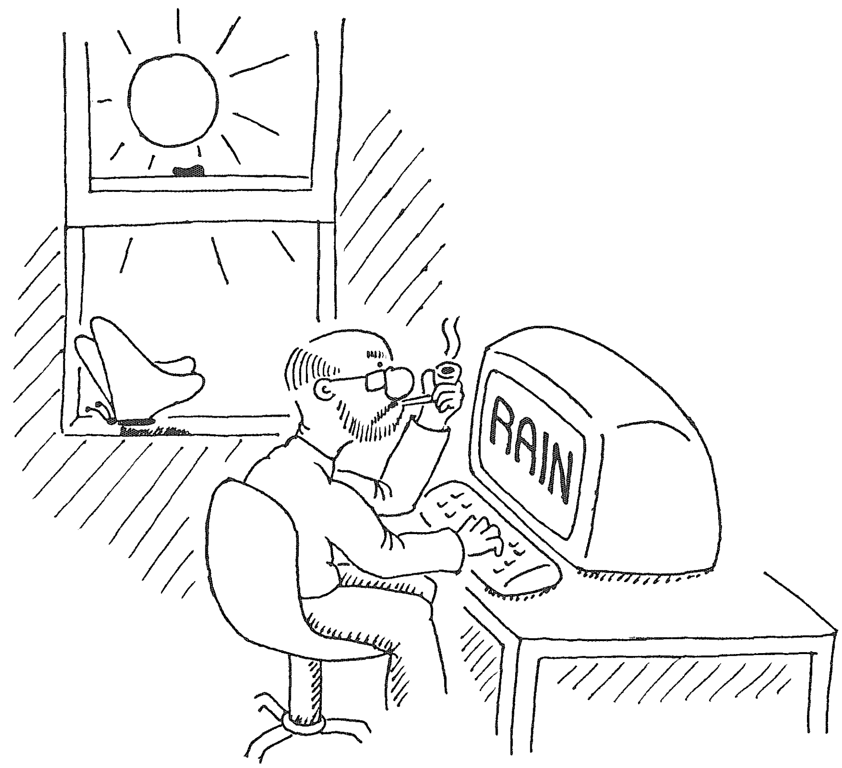
The apple falling predictably toward Newton's feet suddenly hangs a hard left and accelerates into the future. Will we ever catch up?



1900. German physicist Max Planck stepped to the speaker's podium at the meeting of the German Physical Society and presented his unorthodox ideas on black body radiation. Planck asserted that black bodies do not emit radiation at all frequencies because the energy of electromagnetic waves can exist only in discrete packages or "quanta." Each package's energy content is proportional to the frequency of the corresponding wave. Even Planck himself was skeptical. Why should the radiation be emitted in discrete packages? The small group of physicists at the meeting was alarmed and excited following the talk. Can energy actually be packed like matter? Planck's presentation marked the birth of a particularly difficult child of physics—*quantum mechanics.*

1905. A young physicist published three papers in volume 17 of *Annalen der Physik*, the third of which later came to be known as the "special theory of relativity." In it, young Albert Einstein postulated that space and time are relative and depend upon the frame of reference in which an observer is placed. Einstein further postulated that the speed of light (about 186,000 miles/sec) is an absolute constant. No matter how fast you move, the speed of light will always appear the same to you. The special theory of relativity posed difficult questions to the physics community. Does this mean we have defined the upper limit for velocities? Can space and time shrink? Thus was born the second difficult child of classical physics—*relativity.*

1961. Edward N. Lorenz, a meteorologist at the Massachusetts



Institute of Technology, was staring at his weather-simulating machine on a foggy winter morning. He was trying to duplicate an old run where the machine had stopped midway. Lorenz resumed the run after entering the pre-interruption conditions. The machine should have continued simulating the weather on its old path, as if nothing had happened. Instead, the patterns were diverging so rapidly that after a few months of simulated weather they bore no resemblance to the old forecast. The meteorologist could not believe his eyes! Frustrated, he tried again and again. Each time the new pattern diverged from the old and assumed a new identity.

What could be happening?

Unknown to Lorenz, the rounded-off conditions he had used to restart the simulation had caused the rapid divergence between the old and new runs. Inaccuracies in the third decimal place led the old and new simulations down entirely different paths. Once again classical science seemed unable to model nature. Lorenz had stumbled into the world of *chaos.*

When Worlds Collide: The Decline of Classical Mechanics
Although seemingly unrelated, the incidents mentioned above have one thing in common—together they managed to overthrow the dominance of classical mechanics. Newton and his successors (Euler, Lagrange, Laplace, Hamilton and Jacobi) had based centuries of scientific progress on the principle of determinism. Determinism states that a particle's motion can be completely and unambiguously predicted if its position and velocity at any given instant are known (assuming the phyical laws governing that motion are known). As noted mathematician Jules Henri Poincare wrote, "For Newton, a physical law was a relation between the present state of the world and its condition immediately after, which are related by differential equations."

Newton and other classical physicists believed that physical laws are valid for any particle traveling at any velocity. To their way of thinking, the motion of celestial bodies and subatomic particles follow the same physical laws. For them, any particle can travel faster than light if a large enough force is applied to it.

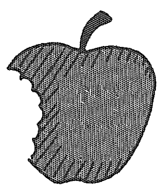
Unchallenged for many years, determinism came under attack in the late 19th century. James Clerk Maxwell, a gifted Scottish physicist, cast doubts on the then absolute second law of thermodynamics. The second law of thermodynamics states that isolated systems tend toward disorder, but Maxwell showed that this law was subject to probability. In other words, while the molecules follow the law as a whole system, they are capable of violating the second law at an individual level. The final quantitative proof of the stochastic nature of mechanics was provided by the Austrian physicist Ludwig Boltzmann. The Boltzmann equation showed that it is not possible for a spontaneous process to reverse itself on a macroscopic scale, and that the process always moves toward a higher entropy level. This directly contradicted Newtonian mechanics, which allows any process the freedom to retrace its previous path. Thus developed the

ILLUSTRATIONS BY BYUNGHO HAN

science of statistical mechanics, whose methods were eventually applied to quantum mechanics.

The Special World of Space and Time

While Maxwell and Boltzmann undermined classical thermodynamics, Einstein questioned our very understanding of space and time. The consequences of his special theory of relativity seem contradictory when compared to what everyday life has taught us to expect. The unfamiliar world of the special theory becomes evident as we move closer to the speed of light. An example: If two students, one on a moving train and the other on a platform, simultaneously observe the passage of time (with identical watches) and measure the length of the same train window, they will find discrepancies between their readings. As compared to the student on the train, the student on the platform will claim the window length shorter and the passage of time greater. As the train approached the velocity of light, the student on the platform would observe the window's length shrinking to zero. To the moving student, the passage of time and the length of the window would remain constant. The concepts of absolute space and time are abolished in the world of relativity. Objects become shorter, time slows, mass increases, and we can no longer depend on those concepts that were considered invariable until this century.

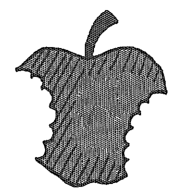


Einstein's subsequent theory of general relativity attacked Newton's law of gravitation, which held that gravity is a point force acting between masses. Einstein explained gravity in terms of field theory and further startled physicists by stating that light photons (which have no mass) are deflected by a gravitational field. This explained such astronomical anomalies as the bending of starlight in the vicinity of large masses (like the sun).

Chaos: Helter Skelter?

While quantum mechanics and relativity grew from physics, chaos originated concurrently in several very different fields. In fact, the manner in which chaos crosses traditional boundaries between disciplines is one of its most striking features. Since the late 1960s chaos has been applied to fields as disparate as population biology and fluid turbulence, and has been used to model everything from snowflake patterns to Wall Street economics.

Unlike quantum mechanics and relativity, chaos is a phenomena we routinely encounter. Chaos governs everyday objects and events people can easily perceive. For instance, consider two friendly neighbors Fred and Barney. Barney leaves for work 30 seconds before Fred, speeds through a yellow light, and proceeds to work without delay. Fred, however, is stopped at the light. This minor delay deposits Fred in the middle of a huge traffic jam and he arrives at work one hour late. As a result, he misses a big meeting and is fired from his job at the quarry. A seemingly small difference in departure times caused an enormous, unpredictable difference in each individual's outcome.



Ironically, the sensitive dependence of chaotic phenomena on initial conditions creates a kind of determinism. A strange form of order can be found lurking within chaos. The degree of irregularity and catastrophe remains constant over different scales. Over and over, the same irregularity gives rise to the resulting chaos. In other words, it is the recurrence of well-defined patterns that results in chaos.

The Future

Where do we go from here? How many more laws lie waiting to be discovered? Will time travel someday be possible? Are there particles like tachyons that travel faster than light? Do matter and energy co-exist in forms other than observed states? Is there a unified force governing nature? Classical science has given us extraordinary insight, but new theories are needed to further unravel the mysteries of nature. As noted physicist Richard Feynmann has said, "Nature is like a chess game. Occasionally, one move is made known to us. Based on that we have to understand the rules of the game." ☐

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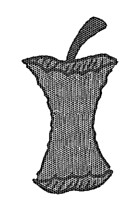

minnesota **TECHNOLOG**

Writer Profile: Sadasivan Shankar

Sadasivan Shankar is in his third year here at the U and is currently working on his Ph.D. in chemical engineering. He's an intellectual, a philosopher, and a fan of both British literature and popular science. Best of all, he's winner of this issue's "Get a Leg Up on the IT Dean" contest. Mr. Shankar wrote his article as promised and submitted it on time.

The Hundred-Hour Man
Continued from page 7...

product, which Sparrow thinks is leading to a crisis in higher education: too few students go on to graduate school. "Bachelors are not specialists," he explains. "They don't know as much as those with higher degrees, but they can work in the largest range of fields. Doctorates are purely specialists and know a huge amount about one particular thing, and therefore can hold jobs in fewer areas. Masters are the best of both worlds: they have more knowledge than a bachelor, they are less specialized than a doctorate, and they can hold nearly the range of jobs as a person with a bachelor's degree."

Sparrow is particularly proud of the research he has done with his graduate students. He says his research was "not done by one person. . . . it was a group effort, non-competitive, and everyone pitched in to help the others. I was simply their cheerleader. I got them together and let them go. . . . they provided the energy." As a result, he has been the advisor to a phenomenal 68 Ph.D. theses and 95 master's theses.

In Professor Sparrow I had found a man with both outstanding research credentials and a profound sense of caring for students. He is enthusiastic and entertaining to listen to, and I really didn't want to leave when my hour was up. Unfortunately, I had class. In spite of my worst fears, the interview had concluded without a single mention of the Carnot cycle. □

Student of the Skies

by Jeff Conrad

Unsure if you've got the "right stuff" to pursue a private pilot's license? *Technolog*'s resident fly-boy explains what's needed.

"Cleared for takeoff," crackles over your radio. You push the throttle wide open. Engine roaring, your plane speeds down the runway. The airspeed rapidly climbs, forcing you back into your seat. The hangar buildings slip out of your field of vision, leaving only a few hundred feet of runway before you. Speed still increasing, you feel the plane start to lift off the runway signaling you to pull back the yoke. As the plane ascends, the runway disappears below you, leaving only a tilted landscape and the bright, blue sky in its place. At 3500 feet you throttle back the power, and the plane's nose levels off. Congratulations, you've just made your first flight.

Why might you learn to fly? Perhaps you're interested in aircraft or enjoy the exhilaration of flight. Maybe you're intrigued by the physics of flying. There are a host of reasons to learn to fly, and you don't need an extensive background in aeronautics to pursue your desire. However, a technical background will enable you to learn the basic principles with less trouble. For example, you'll likely grasp the trigonometry of navigation and the principles of lifting surfaces more easily than someone lacking technical training.

Technical training or not, the basic requirements to become a student private pilot are easily met. You must be at least 17 years old, speak and understand English, and possess enough coordination to drive an automobile. If you can drive a car, you can probably learn to fly.

Time and Money

The price tag for earning a private pilot's license is about ten times that of an automobile license. Total costs range from $1200 to $2000 or more, depending on where you rent a plane, how much you invest in texts and equipment, and how you arrange to pay for it all.

Before granting a private license, the Federal Aviation Administration (FAA) requires at least forty hours of flight time, twenty of them "dual" (with an instructor) and twenty "solo." Students typically log 62 hours of flight time before taking their FAA Private Pilot Checkride—the last step to attaining a license.

The School of Flight

Flight training can be broken into two categories: those skills learned on the ground, and those skills learned in the air. During ground school, students learn such flight basics as aircraft mechanical systems, navigation, meteorology, and avionics/communications.

"A technical background will enable you to learn the basic principles with less trouble."

Actual flight training puts into practice all the principles learned on the ground. You'll cover pre-flight aircraft inspection, taxiing (maneuvering the plane on the ground), takeoffs, landings, cross-country navigation, radio procedures, and various air maneuvers.

Flying Locally

A good strategy for the ever budget-minded student is to join a flying club. A phone call to any of the metro airports (Flying Cloud, Anoka, etc.) will yield the names of several of these. Flying clubs usually charge an initiation fee, plus monthly dues, but you can recoup your investment by taking advantage of their reduced rental and instruction rates. You'll also enjoy the company of other flight enthusiasts.

An alternative to flying clubs is a Fixed Base Operator (FBO). Check the Yellow Pages under "Aircraft..." and you will find many Twin Cities locations where you can hire an instructor and rent a plane.

Taking to the Air

Before jumping into flying lessons, it's a good idea to spend some time in the air to see if you really like it. Most pilots are willing to take you up, especially if you offer to help pick up the tab. Many FBOs offer coupon specials for introductory flights, but ask them for a deal, even if you don't have a coupon.

Once you speed down that runway and wing your way into the sky I'm sure you'll be back for more. □

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minnesota TECHNOLOG

Writer Profile: Jeff Conrad

Sophomore Jeff Conrad is currently majoring in mechnaical engineering. He's editor of *IT Connection*, which means he gets his own desk while the *Technolog* associate editors go without. He secretly aspires to be chief editor of *Technolog*. HE MUST BE STOPPED!!!

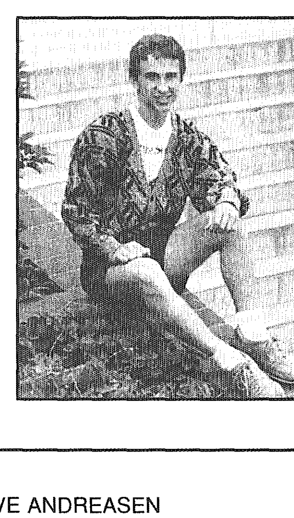
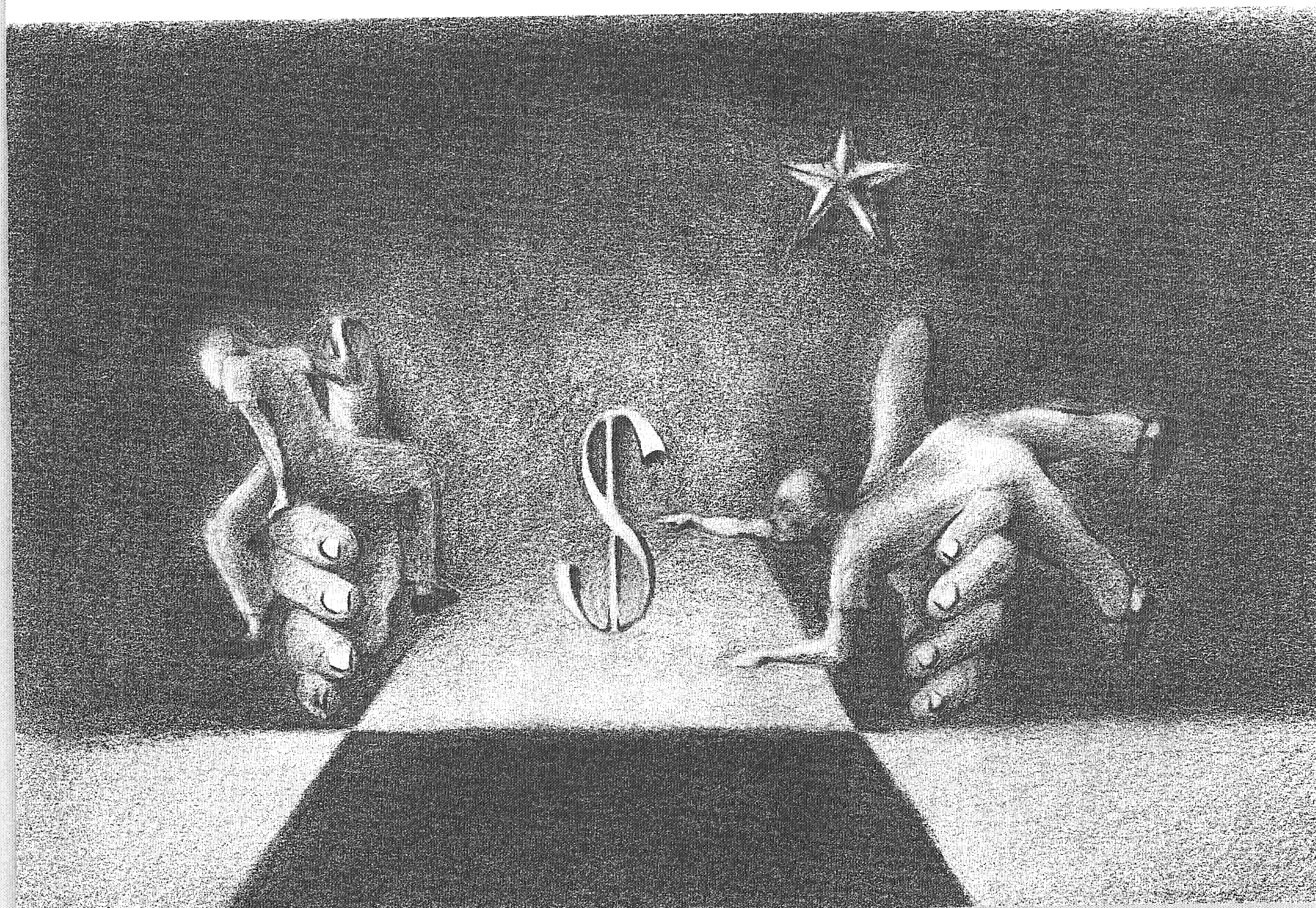


PHOTO AT RIGHT BY DAVE ANDREASEN

The Search for Truth (and Cash)

by Zack Miller

In the contest for research funding, some play the game eagerly, others feel like pawns. In this article, the opposing camps square off on the issue of defense-funded research.



Uncle Sam wants you!

To do his research.

You've got the brains, he's got the cash. The relationship seems fairly straight-forward.

But wait! Uncle Sam's fattest wallet is labeled "Defense." You don't mind if your research may have a military slant, do you?

Well, do you?

As an IT undergrad, it may be difficult to see why this is an issue for you. "Hey," you say. "I just want to get through my bachelor's degree so I can a) go to grad school, or b) get a job that pays enormous amounts of money."

That's fine. Pretty normal, really. But chances are good that you'll find Uncle Sam and his fat wallet lurking about on either path you choose. Now, do you really want his money?

The University of Minnesota's Department of Mathematics recently proposed that Uncle Sam, in the guise of the U.S. Army, slip the University $65 million for a new computing research center (see sidebar). This proposal (which the Army accepted) has rekindled debate over the relationship between universities and the Department of Defense (DOD).

The military presence on campuses, in the form of research money, is hardly a new phenomenon. A relatively minor player during the 1930s, the military's interest in and use of academic research increased sharply during World War II. In fact, military money funded the development of the first U.S. computers at Harvard and the University of Pennsylvania. Successful efforts were made after the war to keep federally-funded academic research at levels close to those attained during wartime. The onset of the Cold War in the 1950s and the Sputnik "scare" served to entrench the presence of defense dollars on U.S. campuses.

During this post-WWII period most universities adopted the policy of permitting only unclassified research, and most of the research that was done was of a "basic" nature. As the 1950s wore into the 1960s, basic research declined in favor of application-oriented research. This trend encountered a heavy setback during the late 1960s and early 1970s when anti-war sentiments forced weapons research off many campuses.

Fast-forward 20 years to the present and college campuses are again embroiled in the military-research-on-campus debate. Spurred by the deep defense pockets of the Reagan and Bush administrations and Reagan's "Star Wars" challenge to the scientific community, defense research is at an all time high. By the end of 1988, the DOD ranked second in overall funding for academic research.

They've got the cash. You've got the brains.

Unfortunately, moral, political, and social issues keep popping up along with all that cold, hard cash. Does accepting DOD funding imply an agreement and endorsement of their goals? Or are they just another source of research funds? Should colleges take a political stance against the arms race or remain neutral? Does an emphasis on military research slant the curriculum in the same direction? Is the university's function to educate, or to train for specific jobs? The questions could go on for pages, but the chances that a clear-cut right or wrong answer would emerge are slim.

Because the answer is a rather slippery one, very few people take a hard yes or no stance on it. Although there are researchers who feel there should be absolutely no military funding on campus, there are also those who want to work specifically on defense-oriented projects. Both of these extremes, however, are in the minority; most academics fall somewhere in between, usually into one of two broad schools of thought.

The "Social Conscience" School of Thought

The "social conscience" school of thought tends to be more concerned with the moral and political issues of research funding than it does practical issues. It believes that an emphasis on defense research has a broad negative effect on both the university and society at large.

One of the primary concerns of those subscribing to this position is the effect of military research on the curriculum. Carl Barus, Professor Emeritus of Engineering, Swarthmore College, in an *IEEE Technology and Society Magazine* article, states that:

> Professors teach what they know. They write textbooks about what they teach. What they know that is new comes mainly from their own research. It is hardly surprising, then, that military research in the university leads to military-centered undergraduate curricula.

This argument raises the possibility that colleges are not simply preparing students for a career in engineering and the sciences, but training defense specialists also. The fact that more than 40% of this country's scientific personnel are employed in defense-related jobs may lend some validity to this point.

In a similar vein, there is concern that continued prominence of DOD-funded research creates an atmosphere of acceptance for the arms race. Because information about campus research is passed to the public via the media, this may be perceived as an endorsement by the academic world of the current military build-up.

Universities are often looked upon as public opinion leaders and seekers of truth. Similarly, University of Minnesota math professor Mark Feshbach sees the university as a special place where the emphasis should be on long-term research undertaken purely for the pursuit of knowledge. Feshbach sees this as being at odds with the military's short-term, application-oriented goals. He fears that an excess of military money in the math department would skew research in favor of defense goals at the expense of long-term, non-applied research.

"More than 40% of this country's scientific personnel are employed in defense-related jobs."

ILLUSTRATION BY JOHN TOPIC

Army Contract Divides Math Department

Some professors cheer, others jeer...

To most IT students the sound of a "$65 million grant" has a pleasant ring to it. It's surprising, then, that this sweet-sounding sum is creating a great deal of unrest within the very department that will seem to profit most from it—the Department of Mathematics. What gives?

The University applied for this Army-sponsored grant last spring and competed with six other universities. Now that the University has been selected, a new independent center within IT will be created. Officially it will be called the "Army High Performance Computing Research Center," and its primary thrust will be basic research.

The grant money will cover a five-year period and funding breaks down as follows: $8.5 million for unclassified University research, $26.5 million for the center's equipment, and $30 million for subcontractors to Army labs. Though the grant would be divided among several departments within IT, the bulk of it would go to the Math and Computer Science Departments. Math professor George Sell, who will direct the center, feels the grant will have a tremendous positive impact and support many students.

Math professor George Sell: "A lot of the people whose opinions you may have read in the *Daily* were just misinformed."

So why are so many math and computer science professors upset about it?

One of their concerns centers on the $30 million earmarked for subcontractors. As part of the grant, the Army asked that researchers be placed in their labs to operate some of the equipment. This would likely be classified research, and IT does not want to put its own people there. To fulfill the requirement the University will have to subcontract an outside agency to fill the Army positions.

While Sell sees this as simply an administrative role for IT, some of his colleagues view it very critically. Math professor Mark Feshbach states that "this proposal, from the point of view of the Army, seems to have as its goal helping Army weapons labs. To this they've grafted on some University research and equipment funds. The University is being asked to act as a prime contractor." In doing this, Feshbach believes that the University is "going way beyond what most universities would be willing to do." He cites as evidence the fact that only six schools were in contention for the grant and that none of them were major, first-line universities such as Stanford or MIT.

The other major criticism is based on the belief that the proposal was not processed properly. Feshbach and others feel that because the grant is so large in scope and will affect the whole department, more professors should have had a voice in it. Some professors are upset that no one, beyond the few directly involved with it, have seen the proposal. Sell, who was the principle investigator for the proposal, says it was handled routinely. Those parts affecting various faculty were made known and discussed. It must also be pointed out that the Freedom of Information Act forbids grant proposal information from being released before the grant is awarded. In summary, Sell feels that "a lot of the people whose opinions you may have read in the *Daily* were just misinformed."

Math professor Mark Feshbach: "This proposal, from the point of view of the Army, seems to have as its goal helping Army weapons labs. To this they've grafted on some University research and equipment funds."

Misinformed or not, nearly 40% of the Math Department's faculty sent a letter to University President Nils Hasselmo and IT Dean Ettore Infante stating opposition to the grant.

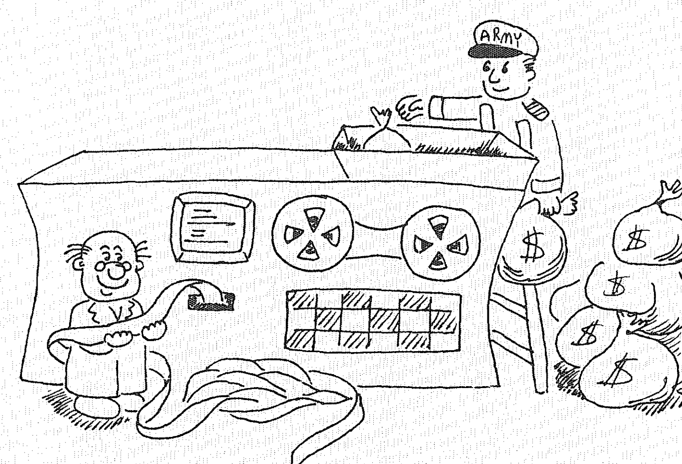


ILLUSTRATION BY BYUNGHO HAN   PHOTOS BY DAVE ANDREASEN AND SUE LUEDTKE

If universities are public opinion leaders, then what kind of message are they sending by lining up, hands out, at the DOD doorstep? Though very few academics will suggest that universities should take a strong political stance, many feel it would not be out of line to lobby Washington for more funding from non-military sources.

Concerns are also expressed that the defense emphasis ultimately hurts the economy and our competitive position in the world marketplace. When one considers the booming economies of Japan and West Germany (each spending only a small portion of their gross national product on defense) , it may be, as Feshbach points out, that "we are wasting our scientific talent on military research." Some believe that it is our military research that makes the United States technically powerful.

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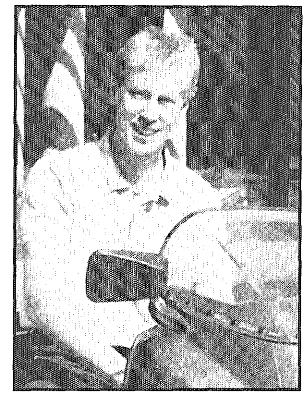
Writer Profile: Zack Miller



Zack Miller, one of *Technolog*'s associate editors, is a junior majoring in journalism. Born and raised in the great state of Iowa, he has also written for *Midwest Rider, Official Journal of Agrarian Motorcycle Gangs*. We haven't heard of it either.

The "Academic Freedom" School of Thought

Though possibly sharing some of the concerns discussed above, the second major school of thought holds the academic freedom of the individual researcher in highest regard. Ultimately, the decision to either accept or reject a research project should be left to each person individually; he or she alone must wrestle with the project's possible implications.

Researchers who hold this view tend to see the military as just another funding source and give less consideration to any social dimensions that these defense dollars may possess. University math professor George Sell:

"'[Science] is like a knife. If you give it to a surgeon or a murderer, each will use it differently.'"

> I don't think there is anything unethical or immoral about it [military-sponsored research]. It's a purely fabricated argument to say that the same research, if funded by the NSF [National Science Foundation] is morally good, and if funded by the Army is morally bad. . . . There is no basis for such a claim.

Similarly, Werner von Braun asserts that "science does not have a moral dimension. It is like a knife. If you give it to a surgeon or a murderer, each will use it differently."

Sell also feels there is no validity to the claim that military funding skews research and curriculum. While conceding that "you have to tailor your proposal to the audience," he points out that researchers typically pursue their own interests. Because the military may take an interest as well is not sufficient reason to avoid or abandon research.

In fact, it could be argued that much of the technology taken for granted today has grown out of military-funded research. In opposition to the economic concerns mentioned earlier, some believe that it is our military research that makes the United States technically powerful.

Since research is the backbone of advanced degrees, researchers must generally go where the money is. They point out that it is the American public and political process that determine where the vast quantity of government research money is spent; if the national emphasis was on the environment or civilian goods, that's where the research dollars would be. Just like everywhere else, researchers must work within the system in order to accomplish their scientific goals.

So, who's right?

Perhaps both, maybe neither. Ultimately each member of the scientific community must choose his or her stance. As a member of that community, it is vital that you consider why it is you're studying science and how you will wield the knowledge you gain. Uncle Sam and his bulging billfold will not go away. Your paths will cross. ☐

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Trivial Grains of Knowledge...

by Darin Warling and Loren Thomsen

1. What was the first American automobile to come factory-equipped with a turbocharger?

2. What was the Buick Regal GNX supposed to be the last of?

3 What does MEIS stand for?

4. Of the many deans in IT, which dean failed to provide *Technolog* with an article that was supposed to appear in this issue?

5. For 50 bonus points, how many times does the word "dog" appear in this magazine?

Answers:

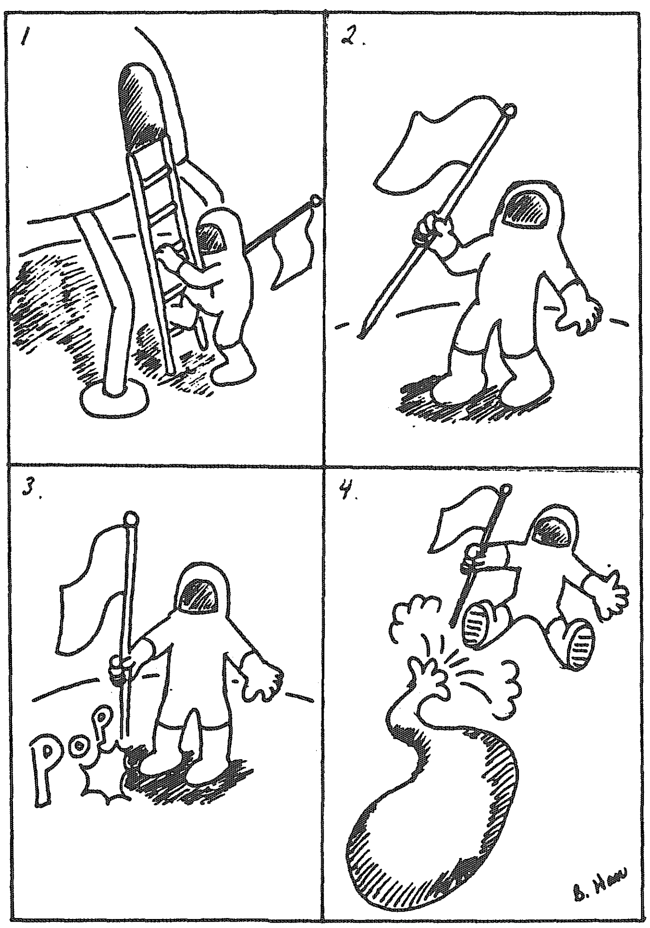
1. The ill-fated, air-cooled Chevrolet Corvair was the first car to come equipped with a turbo as a factory option, beginning in 1963 with the advent of the Corvair Spyder. The turbo was only available until 1966, when handling problems and consumer activist Ralph Nader began hurting Corvair sales. Production of the Corvair was stopped completely in 1969.

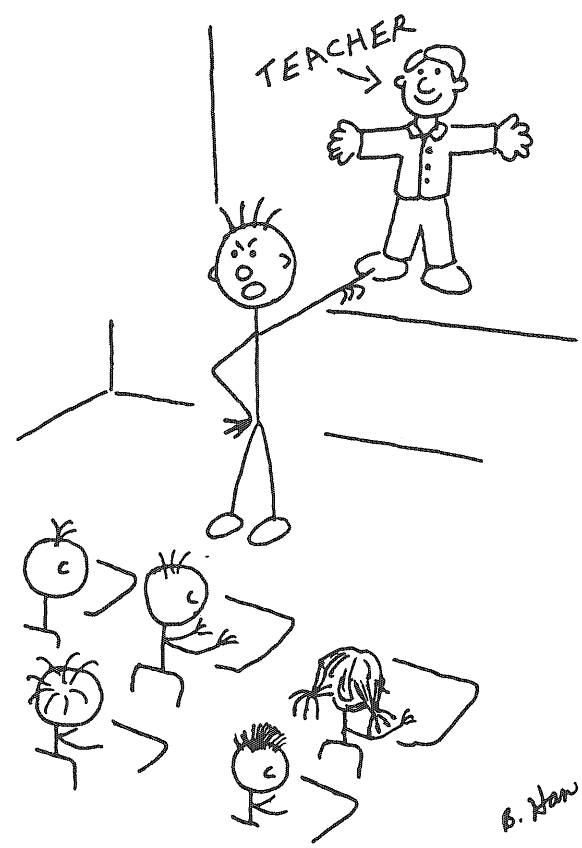
2. The Buick Regal Grand National X, a limited run of high-powered luxury cars that were last produced in 1987, was, according to Buick, the last rear-wheel-drive car that Buick would ever produce.

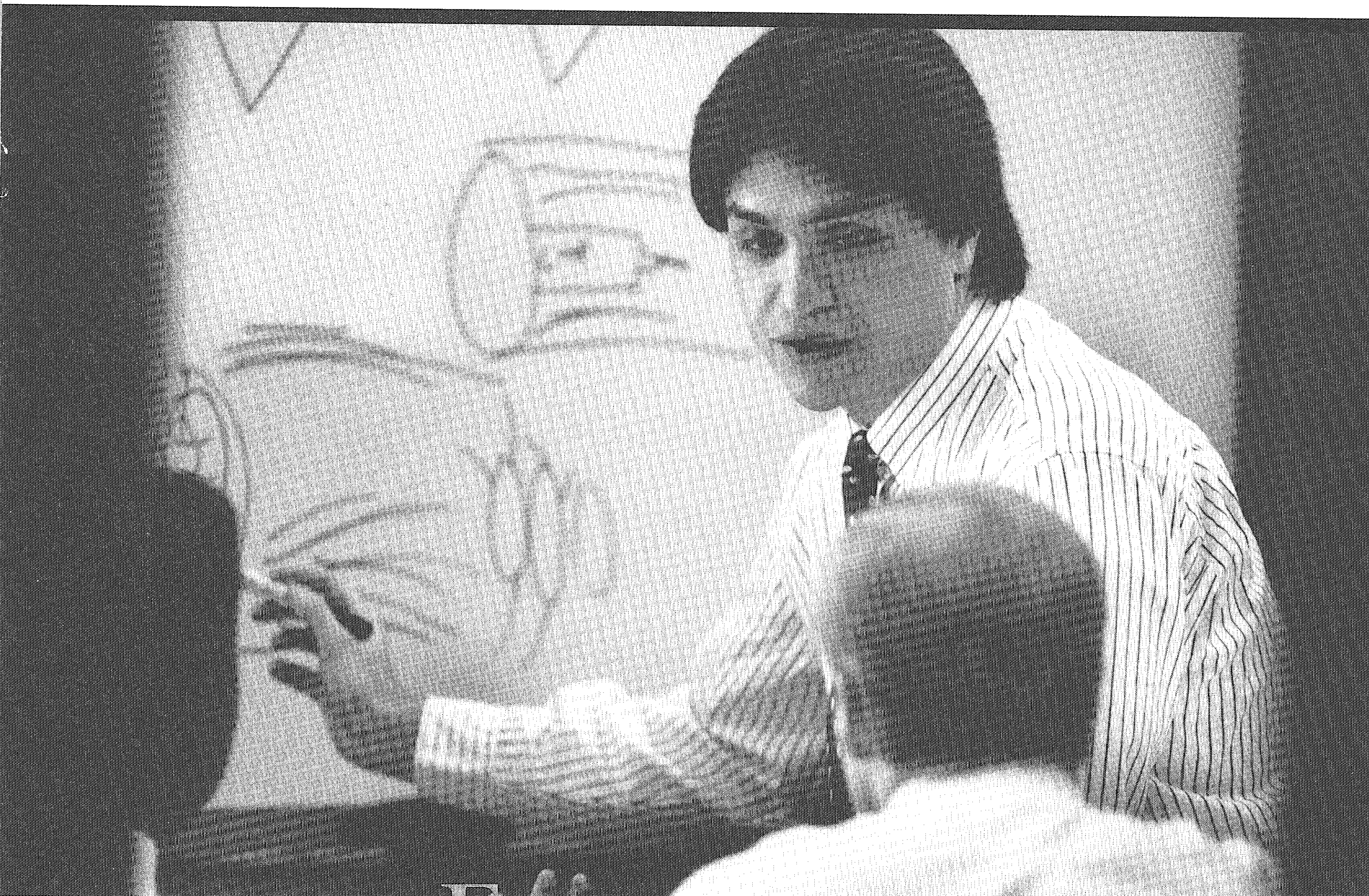
3. MEIS stands for "Microelectronic and Information Sciences." Either you skipped "In-Depth Issues" and headed straight for "Diversions," or you didn't read it closely enough. Go back and read it again.

4. *Technolog* was stiffed by the dean of all deans, Dean E. F. Infante. Special thanks to Dean Infante for sharing his views with IT undergraduates.

5. 537.2 times.







Why? **Why** has it taken so long to address the "greenhouse effect?" **What** impact will computerized financial, health and personal records have on privacy? **Where** will nuclear proliferation end? **When** will the AIDS crisis be solved? **Who** will make the decisions on these issues? **How** will we pay for it?

And you may ask yourself. . . what role will I play on these questions of global importance and interdependence—questions about health, environment, security and communications. After all, today's students are tomorrow's decision-makers. And today's crises and challenges won't wait.

There are students asking why. **STUDENT PUGWASH USA** is a national student group that asks the tough questions about science, technology and society. The group takes its name from the Pugwash Manifesto of 1955 issued by Bertrand Russell and Albert Einstein. It was their hope that the ethical implications of technology and science be seriously addressed by those doing the research as well as those making the decisions.

Campus-based student chapters at colleges and universities across the nation strive to educate themselves and others about the urgent concerns first expressed by Einstein and Russell. Chapters are assisted by the national office which provides organizing support as well as a newsletter and an internship directory.

"*We have to learn to think in a new way*," states the Pugwash Manifesto. Students working together to tackle tough questions and pursue new answers is what Student Pugwash is all about. We start by asking why. Why not ask about us? Write or call us at the address below for more information or get in touch with the chapter contact on your campus.

FOR INFO ON UPCOMING CONFERENCES AND EVENTS CALL 202-328-6555

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Loren Thomsen
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November/December 1989

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The Official Undergraduate Publication of the Institute of Technology

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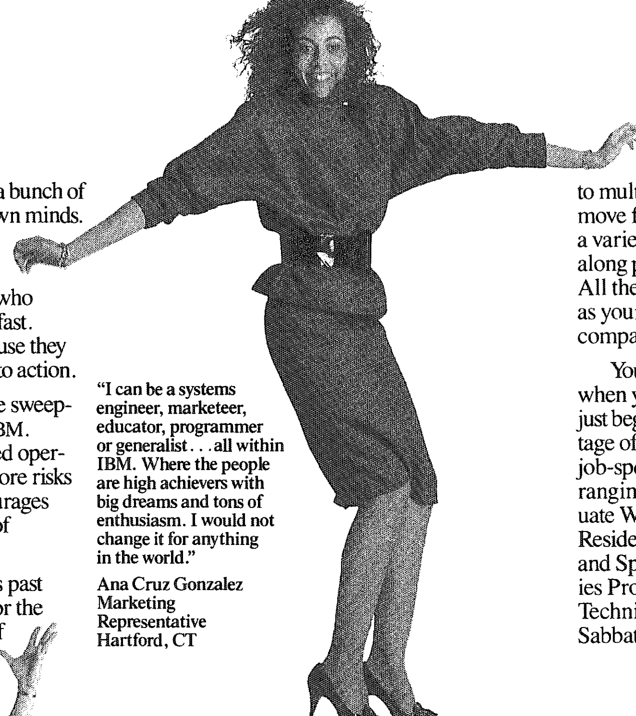
INSIDE:

At IBM, outstanding people don't stand still.



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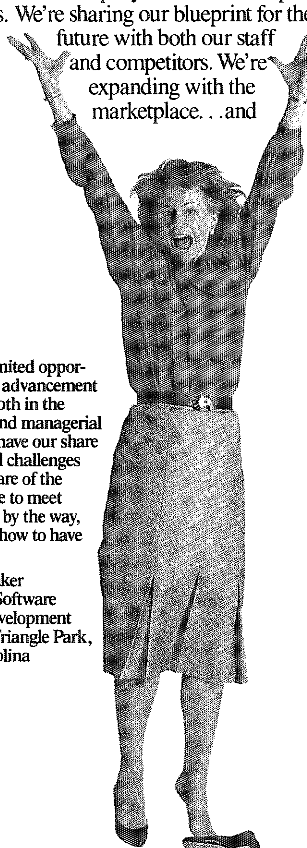

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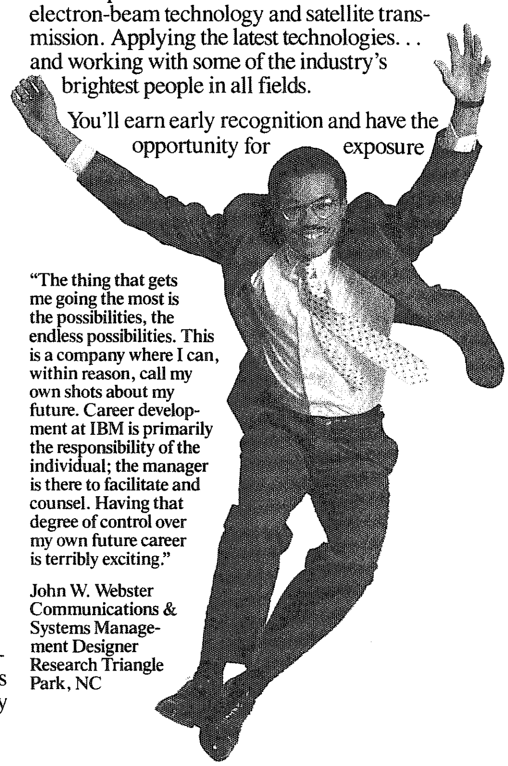

"The thing that gets me going the most is the possibilities, the endless possibilities. This is a company where I can, within reason, call my own shots about my future. Career development at IBM is primarily the responsibility of the individual; the manager is there to facilitate and counsel. Having that degree of control over my own future career is terribly exciting."

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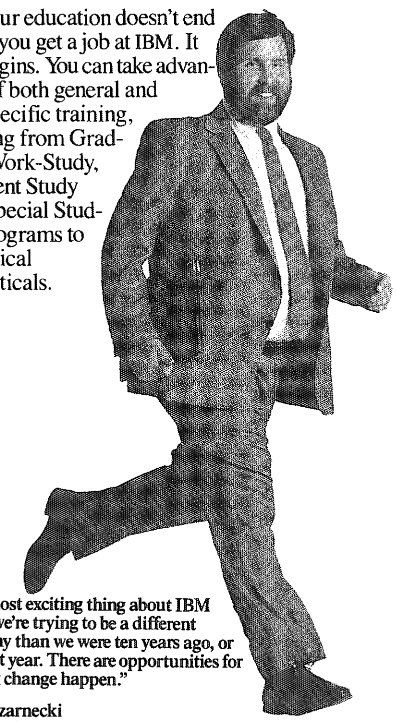

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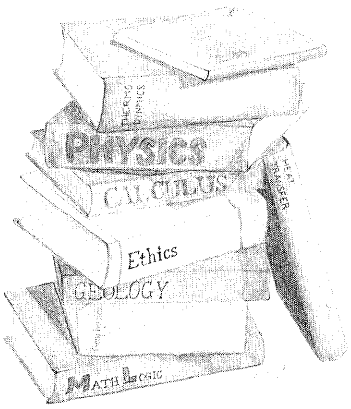

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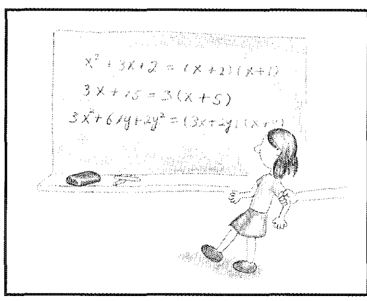

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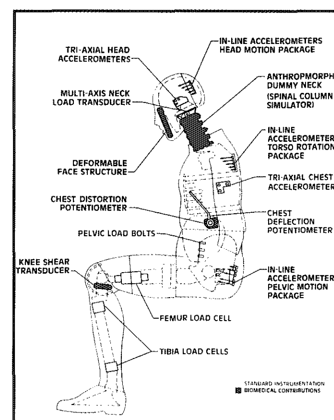

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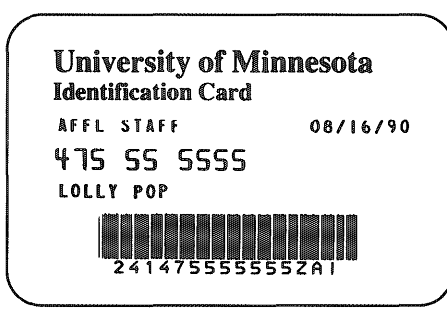


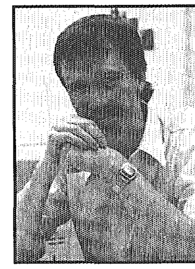
24

Departments

COVER ILLUSTRATION BY JOYCE RAJENDREN

Putting It on the Line

by Loren Thomsen



Though no gulag exists for corporate dissenters, exile is almost certain.

Imagine you're a senior engineer working for a subcontractor on a project administered by the federal government. Aware of a potentially disastrous defect in your company's product, you labor for many months to bring your employer's attention to the problem. Your concerns are ignored.

Inevitably, the problem becomes a crisis. Along with other expert engineers, you strenuously argue against the use of your company's product under conditions that are particularly unsafe. Under pressure from the project's federal administrators, management overrules the engineers' unanimous recommendation. The next day your company's product fails due to the known defect. Seven people are dead.

Later, contrary to management instructions, you truthfully testify on the flawed decision-making process that lead to the catastrophe. Though you're applauded by the public, your coworkers ostracize you. After a demotion and six months of workplace hostility, your job becomes unbearable. You take extended sick leave, are diagnosed as suffering from post-traumatic stress disorder, and undergo two years of psychiatric treatment.

Sound like a far-fetched scenario? Not really. It's exactly what happened to Roger Boisjoly while employed by Morton Thiokol, supplier of the Shuttles' booster rockets. It's likely that some of us will eventually find ourselves in a similar situation. Imagine your employer is doing something incompetent or unethical, but refuses to heed your objections. How will you handle it? Will you blow the proverbial whistle? And are you prepared for the consequences?

Compared to non-technical employees, engineers are especially obligated to brave the perils of whistle-blowing because they may work on flawed products or processes that can kill. A car's brakes might fail, the bridge might collapse into the river, the chemical plant might release toxic fumes, or the garage-door safety circuit might malfunction, crushing a child.

Granted, most products or processes will never be 100 percent safe no matter how much design effort is lavished on them. Occasionally we will have to let superiors, government regulators, or customers define acceptable risk. Nonetheless, setting cases of calculated risk aside, situations remain that clearly mandate whistle-blowing. For instance, whistle-blowing is obviously necessary if your employer is breaking the law. Perhaps they're violating safety or environmental regulations, intentionally or out of ignorance. Or perhaps they're defrauding customers by falsifying test results in order to meet specifications.

Outright illegality is relatively rare, but you might encounter an employer that's incompetent or reckless, blinded by stupidity or self-interest. In fact, most engineering failures are caused by fundamentally flawed designs, not deliberate violation of regulations. You might assume that negligence or

illegality cannot survive among intelligent, law-abiding engineers, but groupthink can create work environments where illegal, unsavory, or incompetent practices are accepted as normal.

The Pain of Whistle-Blowing, and How to Avoid It
Although whistle-blowing is widely admired, its tragic consequences for the individual whistle-blower are not well publicized. Civil engineer Bertrand Berube, whistle-blower in the Reagan administration, holds (in his own words) "the dubious distinction of being the highest-ranked employee to be fired by the federal government." Based on his experience in both industry and government, Berube outlines the ruthless methods used by employers to squelch whistle-blowers:

• Directly discredit the whistle-blower. Accuse the dissenter of insubordination, disloyalty, or incompetence. Make outrageous charges regarding sexual habits, insanity, and thievery.

• Demote or isolate the whistle-blower to set an example and to deny the dissenter information about the problem receiving unwanted attention. Withdraw resources such as computer access or subordinate staff.

• Put the whistle-blower in charge of solving the problem, then make certain he or she fails. Subsequently demote or fire the whistle-blower for being incompetent.

• Rather than fire the dissenter, cleverly contrive a way to eliminate the whistle-blower's job. Deny that you're intentionally firing an overly scrupulous employee.

Continued on page 14...

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ILLUSTRATION BY BYUNGHO HAN

The Day the Earth Threw Up

by Congressman Gerry Sikorski

When we were growing up, the year 2000 was science fiction shorthand for "some far distant era." It was filled with clean, pristine cities and effortless interplanetary travel. Today, we understand that the year 2000 may well be full of leaking toxic waste dumps, climatic chaos, poisoned water systems, and an overloaded ecosystem that teeters on the verge of collapse.

For our grandparents, environmental challenges consisted of watersheds and county dumps, keeping the landscape litter-free and stopping forest fires. For our children, the environmental challenge is much more desperate. The very survival of our planet hinges on our success or failure. Unless we act now, 21st century whales may wear "Save the Humans" t-shirts.

This war is for the life or death of our planet, and it's as personal as the Big Mac millions of us ate last night. Indeed, that Big Mac may have been made from Amazon-grown beef brought to you as the result of burning tropical forests needed to create pastures for those cattle. Those same forests are the source of 40% or more of the planet's oxygen. Moreover, those burning forests emitted plumes of smoke that account for over 20% of the planet's carbon dioxide. That Big Mac may have exacerbated the global warming that threatens to turn our nation's breadbasket into a barren wasteland, and our coastal cities into cement reefs.

But do we need to worry...now?

Let's turn back the clock a few months to August 1, 1988. Future historians will observe that on that day, while we complacently munched our Big Macs:

- Temperatures reached all-time record levels in 23 major cities across the country. August 1, 1988, was the apex of the hottest summer on record, in the hottest decade on record.

- On August 1, 1988, over 150,000 acres of rain forest, at the rate of 110 acres a minute, disappeared forever.

- On August 1, 1988, an entire species of plants and animals disappeared from the face of the earth, as it did today, and yesterday, and every day this year.

- On August 1, 1988, over 70 urban areas across the United States failed to meet minimal standards for ozone and carbon monoxide reduction, putting at least 80 million Americans at risk.

- On August 1, 1988, more than 176,750 tons of sulfur dioxide and nitrogen oxide—the equivalent of 4,144 fully-loaded freight cars—were shot into the skies of North America. They will later return in the form of acid rain.

- On August 1, 1988, in the words of George Bush, "The earth spoke back." Threw up is more like it.

CONGRESSMAN GERRY SIKORSKI (D-MN) has represented Minnesota's 6th District since 1982. He graduated with honors from the U with a BA in political science. In 1973 he earned his law degree from the U of M Law School.

The Challenge: The Greenhouse Effect

We are beginning to realize that the hot, dry summer of 1988 may have been the beginning of an endless summer, a fundamental disturbance of the earth's atmospheric equilibrium caused by air pollution. Global temperatures are in imminent danger of increasing at a rate faster than the earth has experienced in the past million years or so. In 18,000 years, the Earth has warmed 4 or 5 degrees. In 50 years we will have cranked up the barbecue by another 9 degrees.

This is not science fiction. James Hansen, head of NASA's Goddard Institute of Space Studies and one of America's leading meteorologists, says he is 99% certain that rising levels of greenhouse gases are now affecting the earth's climate. John Firor, director of advanced studies at the National Center for

ILLUSTRATION BY JOYCE RAJENDREN

Atmospheric Research finds a "spectacular convergence of scientific opinion" on global warming. "There is just no disagreement that we're in for rapid heating. The only question is how much."

An increase of just a few degrees in global temperature could be catastrophic. By the time the high school graduates of 2000 reach middle age, this is the scenario they face: Widespread flooding drowns the coastal cities and countries of the world as ocean levels rise due to melting polar ice caps. Simultaneously, water levels in the Great Lakes and other inland bodies drop severely due to rapid evaporation. Groundwater supplies have been depleted through overuse as rainfall declines. Fertile agricultural zones that formerly served as the world's breadbaskets have become burning deserts as the temperate zones shift closer toward the earth's poles.

This scenario is a real possibility because the emissions that create acid rain and smog also accumulate in the upper atmosphere, forming a pollution layer that traps heat from the sun like the glass panels of a greenhouse. Emissions would have to be slashed 60% to even slow recent warming trends. Emissions are currently projected to double in the next 40 years.

On top of this, the destruction of our tropical rain forests compounds the overload of carbon dioxide and smoke particles in the atmosphere. The carbon that is locked in rain-forest trees is released into the air by the most popular deforestation method: slash and burn. And since trees consume carbon dioxide and release oxygen, the loss of these trees also destroys the planet's capacity to absorb carbon dioxide.

There are now three distinct seasons in the Brazilian Amazon: two of them, the rainy and dry seasons, are nature's doing, and the third, *las queimadas* ("the burnings"), is the handiwork of humans. According to a recent report by the Institute for Space Research, "the dense smoke [of] Amazon burnings...has spread over millions of square kilometers, bringing health problems to the population, shutting down airports, causing...accidents on the riverways and on roads, and polluting the earth's atmosphere."

"On August 1, 1988, in the words of George Bush, 'The earth spoke back.' Threw up is more like it."

The Future: Challenge or Calamity

Global warming is only one among many environmental problems we face. Sum all of the problems up and you get what's called an environmental crisis. What can we do to save our planet, ourselves, and our children?

The Chinese character for "crisis" is a combination of the characters for danger and opportunity. Perhaps from the blazing fires of environmental destruction has risen a phoenix of opportunity. The escalation of the environmental crisis has spawned an increase in public awareness and created a popular mandate for real action. Indeed, the demand for proper and prudent management of our natural resources has never been greater.

The time for action is now. We must view the looming environmental crisis as a challenge rather than a calamity. We cannot be so concerned with bottom lines and penny-pinching and assigning and avoiding blame that we turn challenge into disaster. Every day we delay dooms a measurable amount of our wildlife, our wilderness, our crops, and even our fellow human beings. Every day we delay cranks up the pressure on our fragile planet another notch. And every day that we have the ingenuity and the capacity to address the environmental crisis, and do not act on it, is a day too late. Our nations, our peoples, and our children deserve more than a destiny of dirty air and devastated resources. □

Fear and Loathing in the Land of the Bland

by Frank McQuarry

Some things are too real to be ignored. Look upon this and shudder:

You are sitting at a table in the study commons, frantically pounding the buttons on your calculator. This frenzied activity comes to a dramatic halt when a nerd swaggers by the table and kicks diodes in your face. You look up, startled. "What the...," but before you can finish your sentence, he whips off his glasses and brandishes them at the tip of your nose. "Oh my!", you think, a queasy nauseous feeling building in your stomach. "His lenses are so thick they make mine look puny in comparison."

You feel your knees shake. An uncontrollable shiver travels up your spine as you watch him slowly slide those enormous Coke-bottle glasses back onto his huge predatory beak. Then the nerd speaks:

"If one assumes Euclid's 5th postulate to be false, then it can be shown that the square of the hypotenuse of a right triangle is not necessarily equal to the sum of the squares of the remaining

FRANK McQUARRY is a junior in EE. Fearful of reprisals from the geek mafia, he refused to be photographed. Frank's motto is "No pain, no pain." Frank wrote this article while watching pro wrestling. We recommend that all of our writers do the same.

NO PHOTO AVAILABLE

legs." The nerd clicks his gleaming Naugahyde heels together and continues his stroll through the commons, hunting for yet another target.

You are left writhing and convulsing from the stark fear and intimidation of the experience. Your ego is a quivering puddle of hot Jello on the dusty floor. You can no longer study. You feel your educational career is over. It is time to die. You have just fallen victim to an IT Honors student.

Yes! The IT Honors students, that brutish gang of geeks who terrorize the unsuspecting halls of higher education in institutions across this great nation. They are the horrible murmuring and giggling in the back of every classroom, striking cold dread into the heart of every professor and every student. Professors dread being corrected even as they open their mouths to utter a theorem. Normal students fear there is no calculator in existence that can bring them a passing grade on the cliff-like curves set by these hyper-intellectual dweebs.

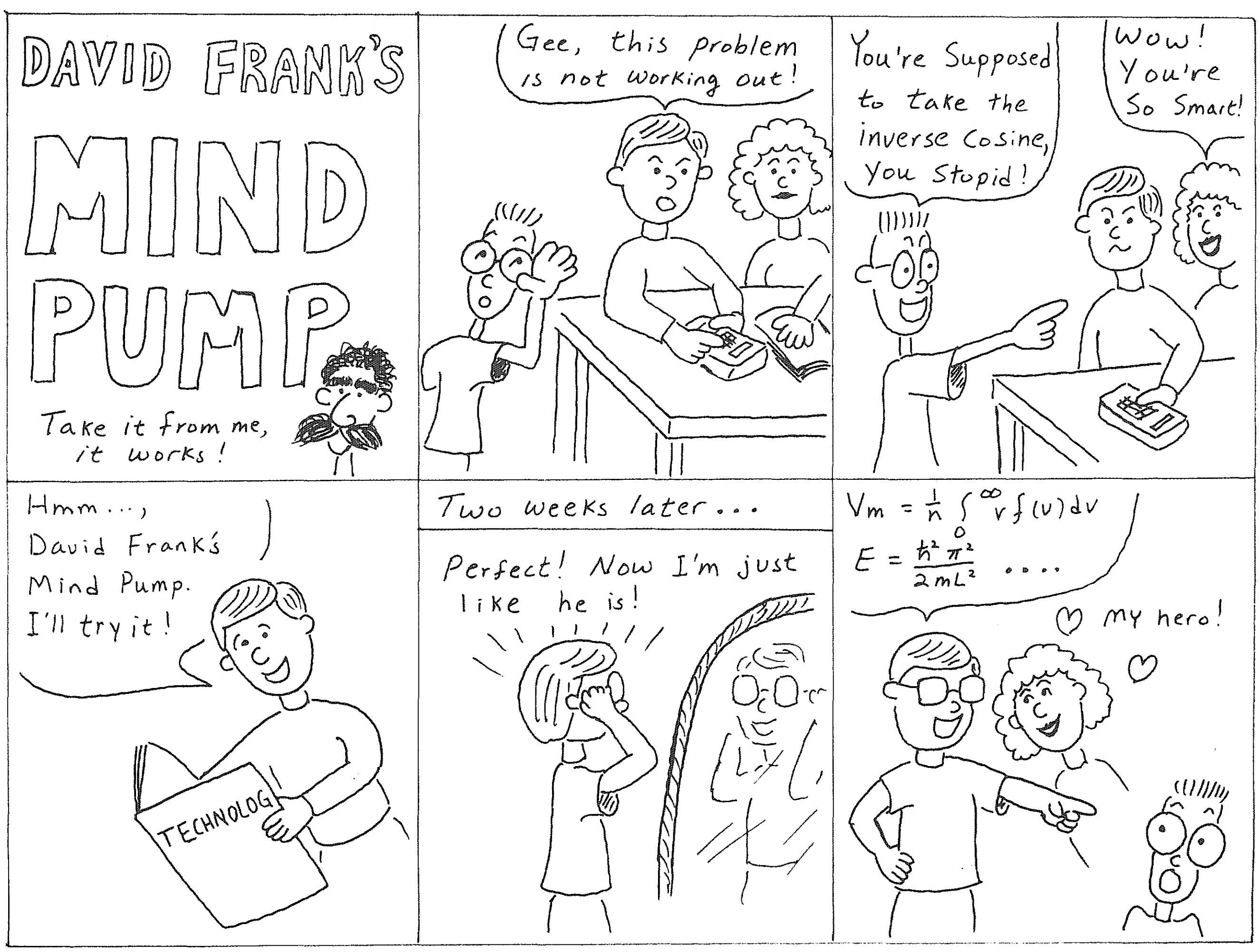
Their fearful power reaches even beyond the classroom. The IT administration is so completely kowtowed to the influence of these students that a special sequence of classes has been created for them. Known as "The Honors Program," it was specifically designed to keep Honors students a single, well-organized unit by allowing them to have special Honors-only conclaves. This gang of geeks is so deeply entrenched into the structure of our educational system that there is no way to extricate them from our midst.

But don't despair! There is hope! Nothing can destroy them, but there are measures you can take to prevent yourself from becoming just another statistic in this plague of horrors.

The basic idea is to emulate an Honors student's dress and behavior. Through the divesting of individuality, it becomes impossible to distinguish a normal student from an Honors student. If effectively camouflaged, you cannot be identified as a non-nerd.

The first subject that needs to be addressed is fashion, or actually, lack of it. The object is to meld like a spotted Holstein on a dairy farm. Today's well-dressed nerd chooses attire in the vein of the sartorial splendors birthed during high-school days. You may want to purchase T-shirts that advertise heavy metal bands or sport the words "Coca-Cola" written in elegant script. Do whatever it takes. Just look around to see what everyone else is wearing and buy more of the same. Furthermore, do not use a satchel or briefcase to carry your books. Carry a backpack loosely over your right shoulder. You never know when you will need to suddenly drop the extra weight to escape attack.

And now literature. Put it away. Fiction has no place in IT. Flaunting any interest in literature is to request to have your fingers



connected to a charged capacitor. It's not a pretty sight. If you must read fiction, do so secretly, and do so at your own peril. You can, however, safely conceal this vice by learning to talk calculators. The ability to speak comprehensively about calculators will fool everyone. No one will suspect you of desiring to lie under a tree somewhere, memorizing passages of "Wuthering Heights."

Reactionary politics is a great way to make any nerd think your head is a proverbial ball of concrete, and reciting the Pledge of Allegiance while turning red is a handy skill to utilize when flag-burning or other unpatriotic subjects are mentioned. Throw the word "liberal" out of your vocabulary. The correct term is "the L-word." And if you are ever in imminent danger and need to look totally ignorant in a hurry, learn how to brandish words like "faggot," "chicks," "wimp," and the ever-popular phrase, "kick ass." Your mastery of these words will determine how well you fit into the IT social scene.

But droll fashion, reactionary politics, and the exclusion of literature will be the least of your traits. They are nothing when compared to the single most important element of nerd conformity: personality. If you have one, get rid of it. Having an even moderately noticeable personality is like wearing a flashing neon sign that reads, "Pummel me with your cerebrum."

Of course, there is one more possibility. If you know how to giggle, are vicious in nature, and have an intellect that could embarrass a Cray, then you may not need to masquerade. You may be genuine Honors material. Details on joining the Honors program can be obtained by writing to the director of the program, Dr. David L. Frank, and asking for a free information packet. Imagine. You and Dave kicking up diodes in the study commons, together. □

2D Thinking in a 3D World

by Kathryn Janda

Science and technology are irreversibly shaping our world in increasingly profound ways, affecting our security, our economics, our environment, and our health. As each new development makes its way from the laboratory into society, we struggle to adapt to the changes it creates in our world. Unfortunately, our academic system has not adequately prepared many students to face these changes. Scientists and engineers may exit academia without ever taking a course that examines the social and ethical effects of their work. Neither humanities nor social science nor philosophy courses focus on how technology influences our world and its cultures. This deficiency leaves students dangerously ill-equipped to use their knowledge both appropriately and effectively.

The transition from student to working professional is a critical one, especially for scientists and engineers. The basic procedures built into the scientific method can hamstring an understanding of the social context that surrounds every technical career. In elementary physics, students are instructed to add up all the forces acting on an object in order to determine which way, if at all, it will move. To make this easier, the teacher gives the object only two dimensions and removes all the "negligible" forces like friction and air resistance. Students know that these problems are merely models, that "frictionless planes" and "perfectly elastic collisions" do not exist outside of textbooks, but such simplified problems teach students to be more familiar with textbook problems than the real world. As a result, students develop problem-solving skills that aim toward finding the single "right" answer rather than the "best" answer.

Too many technology policy decisions, whether they're made by businesses or by governments, are in danger of being approached like elementary physics problems; they either don't take into account all the forces involved in the problem or they assume that there will be only one right answer. A recent editorial in *Technolog,* entitled "Tradeoffs," describes one type of ethical dilemma that faces graduates who pursue professional positions outside of academia. The editorial presents a management situation that demands a recent graduate to select one of several immediate actions, none of which is clearly correct. The writer recommends that the graduate should choose a response based on instinct, and suggests that such instincts could be sharpened by "grappling with moral dilemmas before they occur." Although a problem may have no clear-cut solution, is the most appropriate response really instinctive?

Grappling with moral dilemmas does improve decision-making skills, but it is difficult (if not impossible) to think up a dilemma and then subsequently struggle with it. The most difficult and realistic problems are the ones that include elements beyond our prior personal experiences, and an instinctive response to the situation might actually be a very bad response.

For this reason, students must do more than invent management crisis scenarios to prepare for their personal role in the professional world. To develop decision-making skills equal to the situations they are likely to face, students must reach beyond their own experiences and take new ideas seriously. To learn new ways of thinking, students should broaden their horizons, looking to other disciplines, nationalities, and eras for ideas.

A new facet can be found in each new perspective, all of which will aid the problem-solving process. There are educational programs that address science and technology on international, interdisciplinary, and intergenerational levels, but such a formal pursuit of social and ethical understanding is not for everyone. What all students should be aware of is that science and technology are global enterprises, and the more you learn about the complex social fabrics that technology affects, the better your decision-making skills will be. □

KATHRYN JANDA graduated magna cum laude *and Phi Beta Kappa from Brown University in 1988 with degrees in EE and English Lit. With these credentials we feel she should be out working in industry, earning some real money, instead of working for Student Pugwash USA.*

The Sixty-Dollar-per-Quarter Question

by Dave Ofelt

Several years ago at the University of Michigan, engineering students returning for fall semester were informed they would pay an extra fee to fund a new computer facility. Initially, the students complained bitterly about the new fee. However, the complaints subsided soon after the semester started. The students discovered that the new computer facility was fully stocked with personal computers they could use whenever and however they wished. Furthermore, since professors knew all students had access to computers, they incorporated computer use into the curriculum. Soon, liberal arts students asked if they could pay the fee in order to get access to the facility. To satisfy such student interest, the fee and the facilities were eventually instituted campus-wide. Now the University of Michigan is folding computer facility costs into tuition, acknowledging that computers are an integral part of teaching.

Several other engineering schools have also established mandatory fees, including Iowa State University, the University of Iowa, Pennsylvania State University, the University of Nebraska, Texas A&M, and the University of Texas. Each of these schools has a mandatory fee ranging from $3 per credit to $200 per semester.

Last spring, Jim Albers, lab manager in the Computer Science Department, toured the student-funded computer facilities at the University of Iowa. When he returned to Minnesota, he spoke with Associate Dean Russel K. Hobbie about Iowa's program. They agreed that the benefits of such a program were enormous, and decided that a campus-wide computing facility would improve the education of all students at the University of Minnesota. Dean Hobbie wrote Vice Provost V. Rama Murthy (who holds responsibility for computing facilities) a letter suggesting that the University join other schools in providing computer access to all students. Murthy asked Dean Hobbie to chair an ad hoc committee on computing fees. This committee (consisting of two deans, three professors, and two students) met several times over the summer and produced a report in late September.

Based on the findings of the ad hoc committee, the report recommended that the University set up a campus-wide computer facility consisting of 40 computer labs spread across campus, with each lab containing 40 machines. The mix of computers would be approximately 50% IBM PC and Macintosh, 30% IBM PS2 and Macintosh II, and 20% Sun workstations. Each student would also have a mainframe account that provides electronic mail service and permanent storage. LUMINA access would also be included, as well as access to several other databases that the library currently cannot afford.

This kind of computer access would allow professors to plan coursework that requires computer tools. The University would provide all software that the student would need for classes, including word processors, graphing programs, spreadsheets, and specialized "courseware." Upon graduation, students would find that they've been using the same software used by most employers, thus increasing the marketability of everyone graduating from the University.

Who could argue with such a good thing? Many of you, once you learn that it would cost $60 per quarter. During four years at the University the total cost would add up to $720. However, if you consider the price of home computers these days, this is inexpensive. For those students who have computers already, a modem pool would be set up to provide access to the University's network from home. Also, these students will often need to use the computers on campus anyway, since some classes will use programs that will not run on the particular machine the student already owns.

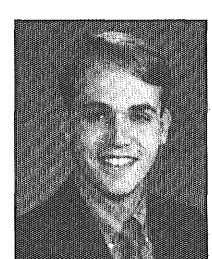
"They agreed that the benefits of such a program were enormous... a campus-wide computing facility would improve the education of all students at the U."

For those students who are understandably paranoid about the University's handling of money, this quote from the report should be reassuring: "No fee should be collected from students unless the computers are in place and functioning." In particular, the proposal recommends that the computer facility be installed during a summer in order to have the whole system up and working when students return in the fall, at which time students would begin paying the mandatory fee.

The committee's report was sent to the Provost's office, which at this time has made no response. Implementation of the proposal seems to be stalled. Adoption of such a plan will require broad discussion in the University community, strong student support, approval by the Regents, and a great deal of planning and effort. The needed University-wide discussion has not yet begun, mainly because the report has not been referred to campus committees.

If you have questions or comments about the report, or would like a copy of it, stop by Lind Hall 23 and talk to the IT Student Board. Student interest in the proposal is essential to its survival. ☐

DAVE OFELT is a fifth-year senior double-majoring in electrical engineering and physics. He's president of Tau Beta Pi, member of the IT Student Board, and member of Triangle fraternity. He used a computer where he works to write this "Perspectives" piece.



Questions of Conscience

by Jim Willenbring

Ethical dilemmas push engineers and scientists where technical textbooks fear to tread.

Man is an animal with primary instincts of survival. Consequently, his ingenuity has developed first and his soul afterward. Thus the progress of science is far ahead of man's ethical behavior. — *Charlie Chaplin*

No doubt about it. The rate of technological development is phenomenal. Reports state the amount of information we are acquiring is increasing exponentially. New technology is growing explosively, especially in areas that have profound effects on people, society, and our environment. A large part of an engineer's knowledge becomes obsolete after only five years if he or she doesn't keep pace.

How can you keep everything in perspective, especially when sailing uncharted waters? Mastering technical knowledge is difficult enough, but understanding the social impact of new products, processes, or research adds even further difficulties. How you deal with these social issues and the way you perform your work are embedded in your *ethics*.

"Ethics don't concern me now," you say. "When the time comes and I am faced with an ethical decision, I'll just go with the values I grew up with. It's simple—don't lie, cheat or steal."

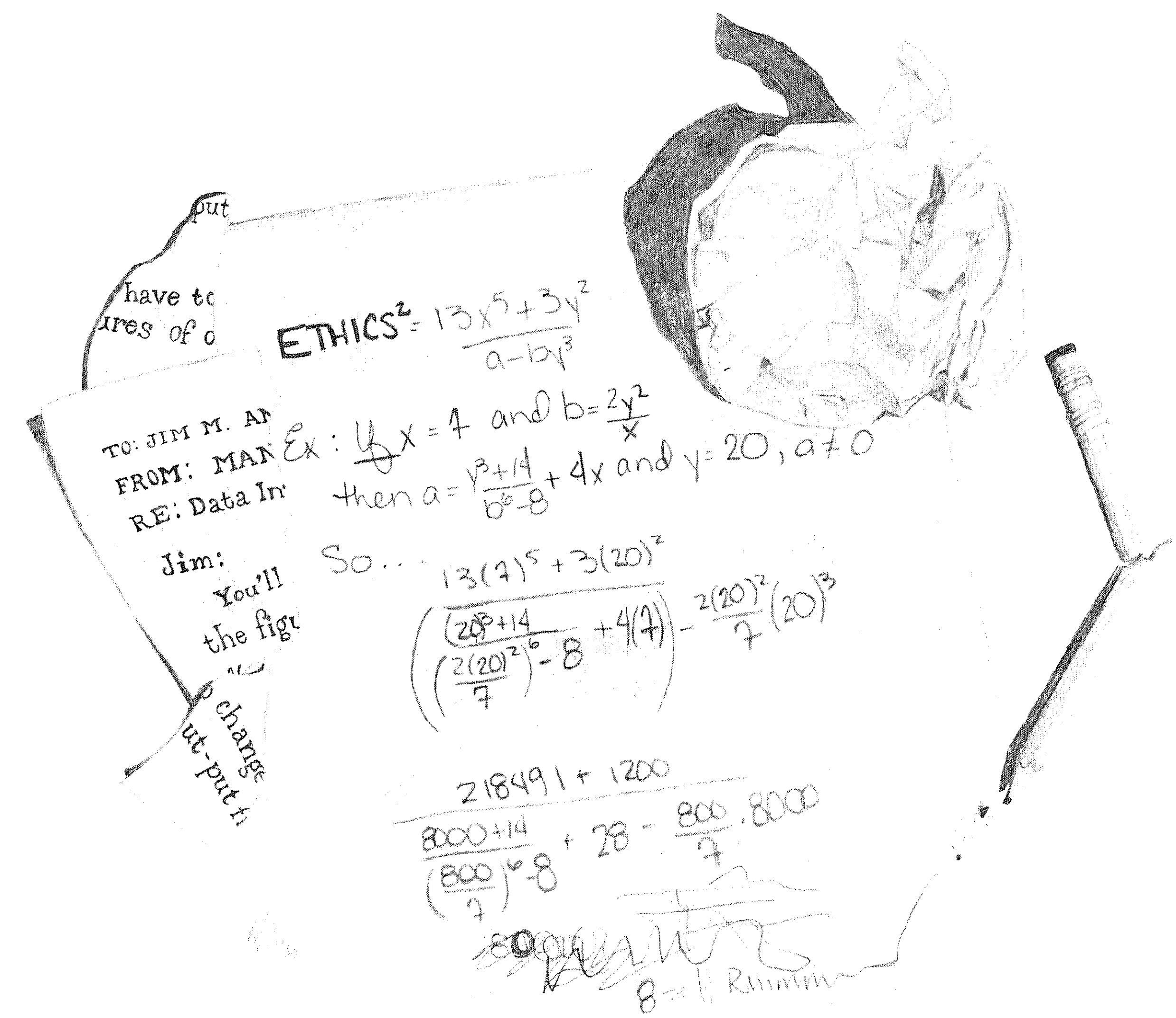


ILLUSTRATION BY JOYCE RAJENDREN

So, what do you do when your manager at your first job walks into your office and asks you to "fix-up" some test results? Basically, you can do one of four things: 1) accept the assignment and falsify the data, 2) politely decline and ignore what is happening, 3) decline and confront your manager, or 4) decline and report it to officials inside or outside the company.

A Voice from the Past

You are a scientist working as part of a team at a large research laboratory. Because of the economy and company politics, several scientists you worked with closely had their jobs eliminated. Fortunately, all of them were able to find other research jobs with different companies. You have kept in touch with several of them.

Today you receive a phone call from one of them regarding an experiment the two of you had worked on before she left. She needs the results for one of her current projects and asks if you will send her copies. When you ask her why she doesn't repeat the experiment, she replies that she doesn't have the proper equipment and doesn't want to "reinvent the wheel." This scientist is working for a company that is not in competition with yours in any way.

You will be attending a meeting of your professional society tonight and are supposed to talk to her. What will you do?

According to Jean Smith, a reliability engineer at Medtronic Blood Systems, Inc., this is a classic example of whether to follow orders or stay true to your ethical beliefs. "In today's more enlightened culture, people are not willing to accept the excuse of following orders," he says. "You are expected to resist. If you resist to the extent that your manager says, 'If you want your job, you are going to have to do it,' at least you made them aware of it. Some people would say that you should have notified a higher authority. What I've noticed is that it's a no-win situation. If you report it, you better be prepared to find another job. It's the whole issue of whistle-blowing."

Ethics Defined

A man is truly ethical only when he obeys the compulsion to help all life which he is able to assist, and shrinks from injuring anything that lives. — *Albert Schweitzer*

Typically, unethical behavior in science involves the reporting of incorrect, altered, or fabricated data. Researchers may stoop to these levels for any number of reasons—to get published, obtain grant or support funds, gain prestige, etc. Though engineering ethics is based in research, the actual practice of engineering applies this research to the creation of products or processes that affect society more directly.

"'Engineering is embedded in the physical world, and the answers to the ethical problems that arise in that world cannot be handled by engineering thought structures.'"

Smith defines ethics as how honest you are to yourself, to your company, to your profession, and to society. If these ideas are relatively clear to you, the solutions to obvious ethical dilemmas materialize quickly. It's the subtle predicaments that many people lose sleep over (see the "ethical dilemma" sidebars).

Perhaps a more encompassing definition of ethics is one given by University of Minnesota Professor William Marchand of the Department of Rhetoric:

> The study of ethics is how people organize their obligations toward others. The big question is how we decide what groups will be allowed into our ethical domain. If you can convince people that trees have certain rights, then you have certain obligations toward them and are going to have to take care of them. The more the world is complexly intertwined, the more difficult it is to pull out a piece of it and act as if that piece has no relationship with the other pieces. If the piece you pull out is an individual piece having no relationships, it can be treated unethically because it has no ramifications. But if the piece you pull out is locked to other pieces, then your ethical behavior must begin because it causes waves that affect everyone's lives.

Taking a different approach, Samuel Florman in *The Civilized Engineer* states that being a competent and conscientious engineer goes a long way towards being an ethical engineer. Citing studies that show about half of all technological failures are the result of engineering incompetence, Florman promotes conscientiousness as the key. "The greatest threats to moral engineering are carelessness, sloppiness, laziness, and lack of concentration," he writes. "An engineer may start out honest and high-minded but become immoral by falling prey to one or more of these sins. On the other hand, an engineer who starts out by being conscientious must end up being honest, since competent engineering, excellent engineering, is in its very nature the pursuit of truth."

But is being a good engineer enough? University Professor Jim Holte of the Department of Electrical Engineering doesn't think so. He believes that the best ethical solution for a problem won't come from engineering formulations. Those quali-

The Omitted Test

As the director of marketing for a new implantable product that your medical company has developed, you have been informed that an important test was omitted in the development of the device, which has been scheduled for release next week. The government regulatory officials did not catch the omission.

You have already prepared and distributed advertising and marketing brochures and set up the distribution plan for product shipment beginning Monday. The product is the latest in new technology and your customers are eager to receive it.

Engineering has told you the problem the test checks for is not likely to appear. However, the only way to confirm this is to run the test, which will require about four weeks. You must decide whether to release the product for sale without the test being performed, or to hold off pending test results. Which do you choose?

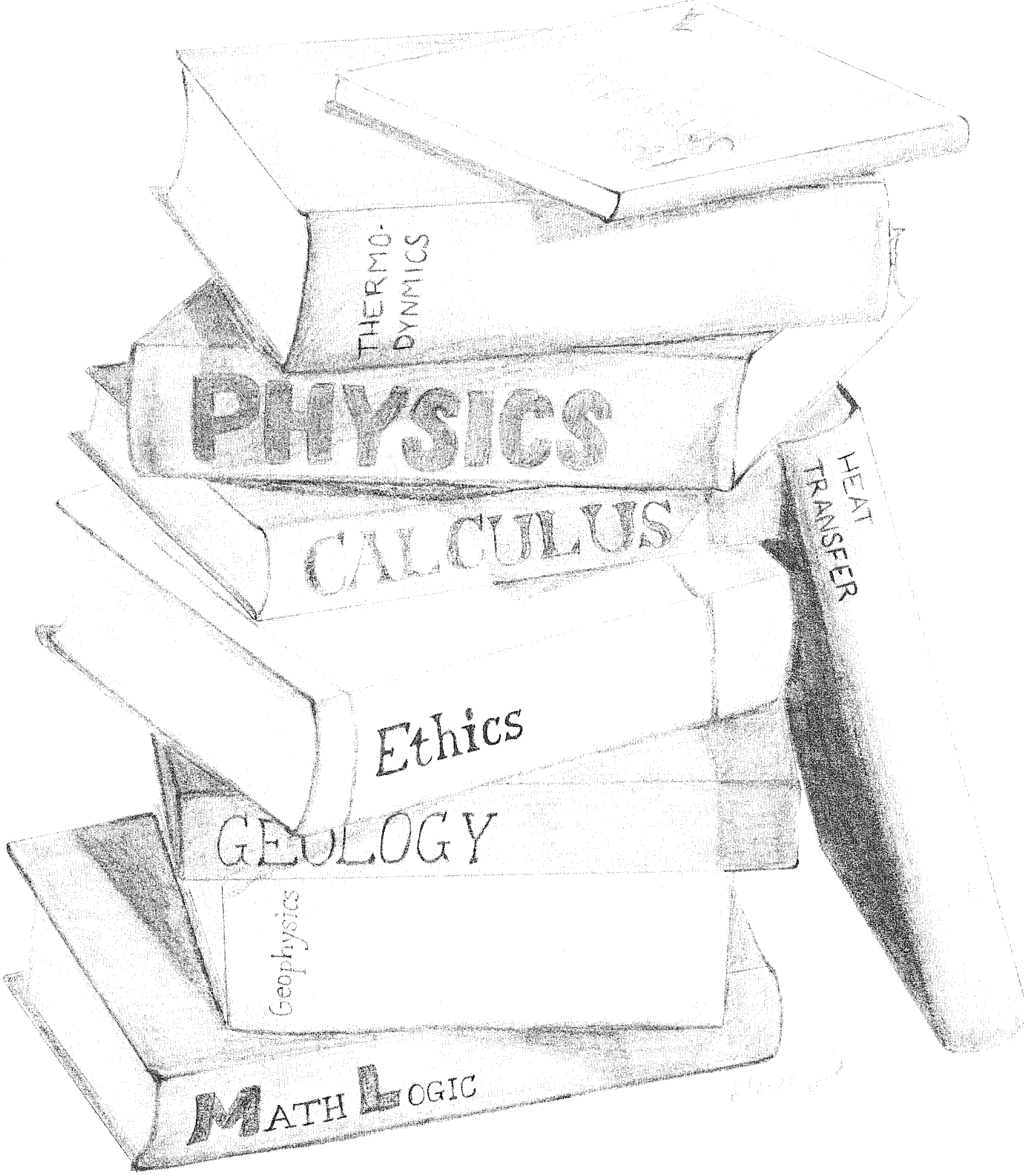


ILLUSTRATION BY JOYCE RAJENDREN

ties that Florman attributes to being a good and conscientious engineer are not the ones that engineering students learn in their calculus or soil mechanics classes. Instead they are formed from your goals, duties, spirituality, and the rights of yourself and others. "By definition, ethical considerations transcend the practice of engineering considerations," he says. "Engineering is embedded in the physical world, and the answers to the ethical problems that arise in that world cannot be handled by engineering thought structures."

Theories of Right Action

In trying to make an ethical decision, Holte believes that one's choices are founded on four general theories of decision-making, the first three of which come from Martin and Shinzinger's *Engineering Ethics*.

Holte believes most engineers subscribe to *goal-based* theories. In this school of thought, "the goals of producing good consequences and avoiding bad ones are ultimately the only morally important considerations." These goals are often translated into the ideas of the "greatest good for the greatest number" and "the end justifies the means."

Duty-based theories state that there are specific duties to perform and types of acts to avoid, even though doing so may not always produce the most good. Engineers making ethical decisions based solely on these obligations can infringe on the rights of others if they feel their *duty* supersedes those rights.

Rights-based theories treat actions as wrong when they violate the ethical and moral rights of individuals. They deny that good consequences are the only, or even the primary, considerations.

Holte has added a fourth category that he believes is responsible for forming many of our initial values and ethical views. He believes that ethical decision-making can be *spiritually-based*, "spiritually" meaning the sum of our life experiences not directly traceable to the senses. This theory is exemplified by the golden rule, which says "do unto others as you would have them do unto you." But Holte also says that it means being selfless, or extending ourselves to others because we must all exist in this imperfect society together.

Ideally, ethical decision-making would draw from all these theories. Rights and duties balance each other quite nicely if each right is assigned corresponding duties, but both can conflict with goal-based thinking. On top of this, maintaining personal beliefs and keeping food on the table weigh heavily against each other.

Holte stated it well when he said:

> The bottom line comes down to ethical engineers making every effort to anticipate misapplication and proper application of their engineering efforts. We must insure that others know the implications of the technology that we are developing. You can't hide behind saying, "I was just working in the lab." The buck stops in the engineer's lap. I contributed the technology. A part of my continuing life is to make sure, insofar as I am able, that I continue to make known the limitations and the positive aspects of the technology that I have created. You stand behind it. You are responsible. Maybe you don't feel that you should be, but the alternative is that nobody is responsible.

And that would get us nowhere fast. ☐

Sources:

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Florman, Samuel. *The Civilized Engineer,* 1987.

Martin, Mike W. and Roland Shinzinger. *Engineering Ethics,* 1983.

Relman, Arnold S. "Fraud in Science: Causes and Remedies," *Scientific American,* April 1989, p. 126.

Loose Lips

You're at a meeting of a local engineering society and talking with a person you formerly worked with at another company. You've both moved to other companies, but you still maintain a casual friendship. As you chat, two other acquaintances of your friend join the conversation.

As the discussion develops, you learn that one of the newcomers works for your competitor and is developing an approach to a manufacturing process problem similar to the one you have recently been assigned to. This person has had a few drinks and is a naturally expansive, free-talking individual. He begins to explain, in some detail, how he successfully overcame a major obstacle in the process and how it resulted in a bonus for him.

What's the right thing to do? Before he gets too far, should you identify yourself as the employee of a competitor? Should you mention that you're working on the same process problem? Should you walk away from the conversation on some invented pretext? Should you do anything?

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Writer Profile: Jim Willenbring

One of these men is Jim Willenbring, second year EE senior and Medtronic technical writer. Since he was once editor of *Technolog*, we pretend to listen to his advice. Jim's only regret is not having been born and raised in Wisconsin, home of a fellow well-respected staff member.

Five Years Long, Two Inches Deep

by Steve Subera

IT students are drowning in the shallow waters of engineering education.

"The best engineers are those who, in addition to technical expertise, have had good training in the liberal arts and understand the world around them."
— Admiral Hyman Rickover

Admiral Rickover's comment, taken from an *Engineering Times* interview in 1984, echoes my own sentiments about engineering education, which I feel lacks both cultural breadth and professionalism. Four-year engineering degree programs are not enough to create a "complete" engineer. Instead, the administration forces students to ingest massive spoonfuls of technical pabulum, leaving the young engineer with little appetite for intellectual diversity. Only with the cooperation of the entire engineering community, including students, can these curriculum defects be remedied.

Our nation's schools produce highly competent engineers capable of great technical wizardry, so why worry about the liberal arts courses they take? Because technical proficiency alone will not elevate engineering to a professional status similar to MBAs, lawyers, and doctors. An engineer tends to assume the position of corporate lackey, satisfied with developing new technology and yielding it to manipulative company executives. Despite generating more public trust than lawyers (and what occupation doesn't?), lawyers run the country, not engineers.

Even engineering students who prefer to shun the public eye or avoid management positions would benefit from a broader curriculum. No one works in a vacuum, and in order to convey ideas properly, speaking and writing skills are essential. An understanding of both history and philosophy will enable an engineer to generate new ideas and see engineering problems from different perspectives.

Purely technical curriculums also fail to produce an abundance of worthy educators. With the exception of a few talented teachers, most professors present technical material for rote memorization only. These researchers have their own narrow interests and are visibly pained when asked to instruct students in introductory engineering classes. Lacking student feedback, the professors leave class wondering why the students are unable to learn.

"An engineer tends to assume the position of corporate lackey, satisfied with yielding new technology to manipulative company executives."

And students leave class wondering why instructors are unable to teach.

Adding liberal arts to a technical education also provides for an enriched personal life. I mention this last, after discussing the tangible benefits of a broad education, because of the inevitable round of snickers I expect. Too many students offer only a "But what's it good for?" response when faced with non-technical electives. Many of these people are beyond persuasion, so I will not engage in a protracted argument, but instead offer a single example. Samuel Florman, civil engineer and author extraordinaire relates a particularly vivid incident from his academic past in the book *The Civilized Engineer*, which should be required reading for all IT students:

> One of my dormitory mates was enrolled in a special course with

ILLUSTRATION BY JOHN TOPIC

> Robert Frost, who was, at the time, poet-in-residence at the college. Several times this friend invited me to join him for an evening of readings and discussion with the noted poet, but I was always too busy writing up my laboratory experiments, or else committed to a party at some local tavern. Today I cannot believe –simply cannot believe–that I never even saw Robert Frost, much less spent an evening with him when I had the chance.

Regrettably, most of today's engineering students would make the same mistake, unable to recognize the rich educational experiences available outside the narrow confines of their own field.

Before suggesting an alternative engineering curriculum, it's necessary to briefly explain the current engineering curriculum structure. All engineering curriculums are regulated by the Accreditation Board for Engineering Technology (ABET), which represents 26 constituent technical and professional engineering societies. ABET has decided that the minimum liberal arts requirement for engineering students is 12.5 %, which translates into one semester of classes. A few universities, such as Stanford, MIT, and those in the Ivy League, require a greater percentage of liberal arts classes, but most remain satisfied with the ABET minimum. There is considerable debate about this liberal arts component with many administrators extolling the values of a liberal education, but failing to produce any change when pressed.

To allow for a larger liberal arts content, the four (which is, in all reality, five) year program must be overhauled. In its place I propose a 4-2 program consisting of four years of pre-professional study resulting in a B.A. in engineering science (or whatever people want to call it), followed by a two-year master's degree in the engineering field of the student's choice.

On the surface this may seem equivalent to our current situation, but it's actually a fundamentally different structure. The first four years of a student's pre-engineering program would consist of a balance of liberal arts and scientific classes, including two years of mathematics, and one year each of physics, chemistry and computer science. Pre-engineering students and liberal arts students would be intermixed in their first two or three years of classes, with both benefitting from the other's viewpoints. The final year would allow a student to emphasize a particular field of engineering, providing the necessary technical background for entering a professional engineering program.

Two factors are crucial to the success of this program: first, the four-year curriculum must be structured so most students are able to actually complete their studies in four years; secondly, and most importantly, the best teachers (not researchers or academicians) must be used in the classroom, especially for the introductory-level courses.

Until I am made king and these changes are implemented, I can only offer a band-aid solution for the engineering student seeking more than a pocket protector and a paycheck. Choose your liberal arts component carefully, resisting the urge to join the masses in multiple-guess, pass/fail classes. Pursue courses that require written assignments and reading classic literature. Maybe add a speech class to your schedule. Outside of school find time for non-technical activities. While pursuing an engineering degree, it's important to rise above the avalanche of technical information and seek answers to questions not posed in your classes. Anything less, and you have cheated yourself out of a complete education. ☐

STEVE SUBERA is a second-year EE senior. Steve started his journalism career as a writer for Hornet Highlights *(published in Colby, Wisconsin), where he once interviewed Senator William Proxmire.*

Up Front
Continued from page 3...

Berube states that "the point of these tactics is to force the whistle-blower to struggle for self-preservation—of career, family, bank account, even sanity—until the dissent is forgotten or put behind weightier survival priorities." Note that the viciousness of the tactics employed by the company will be proportional to the amount of money at stake. Large institutions will not hesitate to ruin a whistle-blower in order to protect their interests.

Given the power and ruthlessness of the adversary, how can a conscientious engineer expect to survive the emotional anguish and financial hardship of whistle-blowing? Fortunately, some simple tactics will lessen the potential damage to your health and career:

- Take action at the first sign of trouble. Begin to carefully document the problem. Develop a strategy.
- Contact an attorney early. Plan how to fund your legal defense, or plan to sue for unlawful termination. Know your legal rights and responsibilities.
- Recognize that a safety net for whistle-blowers is essentially non-existent. Most professional engineering societies, though they pay loud lip service to ethics, will not lift a finger to help you. It will basically boil down to you (and your lawyer) against them (and their lawyers).
- Try to work within your employer's system, but recognize when your situation is hopeless. If your employer has a reputable ombudsman program, use it. However, don't push your employer too far unless you're prepared for charges of insubordination that could lead to termination and blacklisting.
- Look for another job. Quit before they can fire you. Avoid scathing resignations that later undermine your credibility. Don't make empty threats. Instead, get safely to another job, then disclose your information to legal authorities or the news media.

Remember, the whistle-blowing game is hardball. Take action when your conscience is pushed beyond its limits, but don't naively assume that your good intentions will protect you. Roger Boisjoly and other courageous engineers teach us that whistle-blowers pay a high price to protect their fellow citizens from technology driven by greed and incompetence. ☐

LOREN THOMSEN, editor-in-chief of Technolog, *is a seventh-year EE junior. He recently returned to school full-time after working two years as a technician at 3M.*

Saving Lives by Design

by Cathy Bekavac

Safe car design doesn't happen by accident. Auto engineers meet safety challenges head on.

It's 10:00 PM. Two cars lie tangled in a ditch. One driver is dead. The other, a young female, is crying in pain. She can't see because her face was just smashed against the steering column. Her eye socket is crushed, her nose and elbow are broken, her face is bleeding, and her ribs are severely bruised. Though seriously injured, she is alive. Since she was wearing a seat belt, this head-on collision did not kill her.

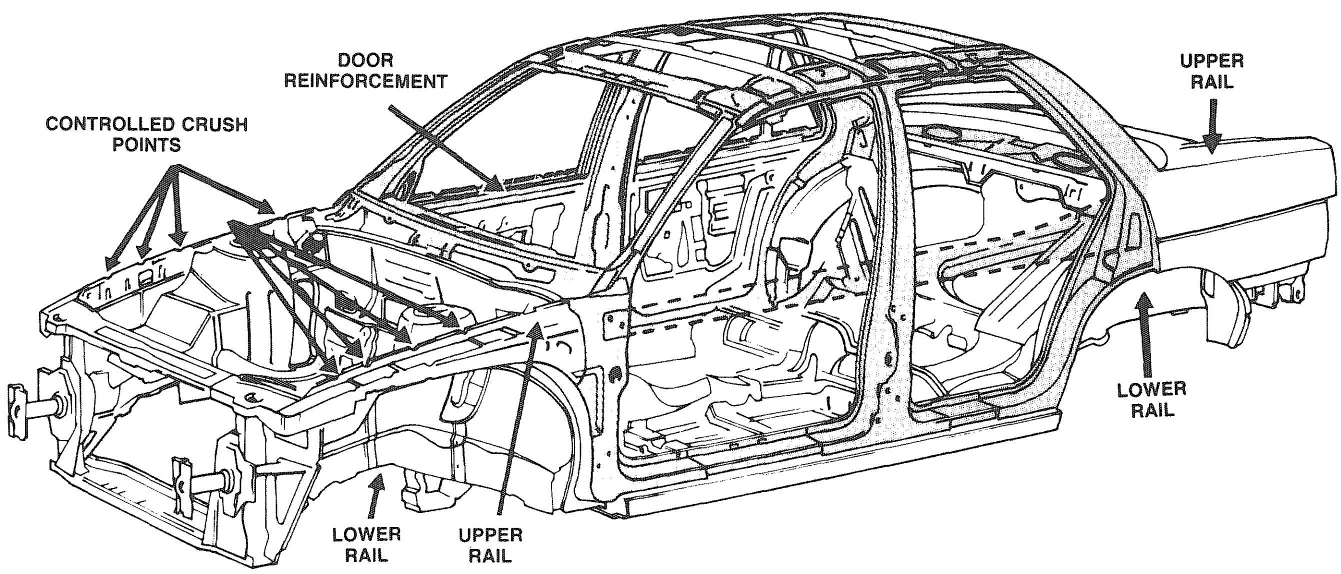
Many of you have known friends or family members that have been in accidents, or perhaps you've been in an accident yourself. Last year 46,000 people died in traffic accidents on U.S. roads, and over one million suffered disabling injuries. Nonetheless, installation of government regulations and consumer demand for safer vehicles have dramatically reduced fatality rates from what they once were. Sixty years ago, there were 15 accident fatalities per 100 million vehicle miles driven in the U.S. Twenty years ago, the rate was down to 5.7. Based on recent statistics from the National Highway Traffic Safety Administration (NHTSA), the rate has declined to 2.4, the lowest in U.S. history and the lowest of any industrialized nation.

Much of the accident rate reduction can be attributed to increased seat belt use, but improvements in car design have been significant also. Engineers have studied data from real-world crashes and developed four basic principles of occupant crash protection.

Principle #1: Maximize occupant stopping distance.
Maximizing occupant stopping distance slows down the occupant as gradually as possible during a crash, preventing injuries caused by abrupt decelerations. Stopping distance is lengthened by using the vehicle structure as it crushes, by using the crush space built into the vehicle's interior components (i.e. instrument panel, steering column, steering wheel), and by using the empty space inside the cockpit. During head-on collisions the occupant continues forward into the dash as the vehicle stops. By designing the dashboard, steering column, and steering wheel to collapse under pressure, the severity of injuries is reduced.

Principle #2: Maintain passenger compartment space.
If interior parts remain fixed during a crash, their crush characteristics are predictable and they leave enough space for the restraint system to work properly. The ability to maintain passenger compartment space is limited by the severity of the crash and the initial amount of interior space.

"Progressive crush" design uses the car's skeletal structure to protect occupants during a collision. Crash energy is absorbed by front- and rear-end structural components, leaving the passenger compartment relatively undamaged. Reinforced doors provide additional protection.



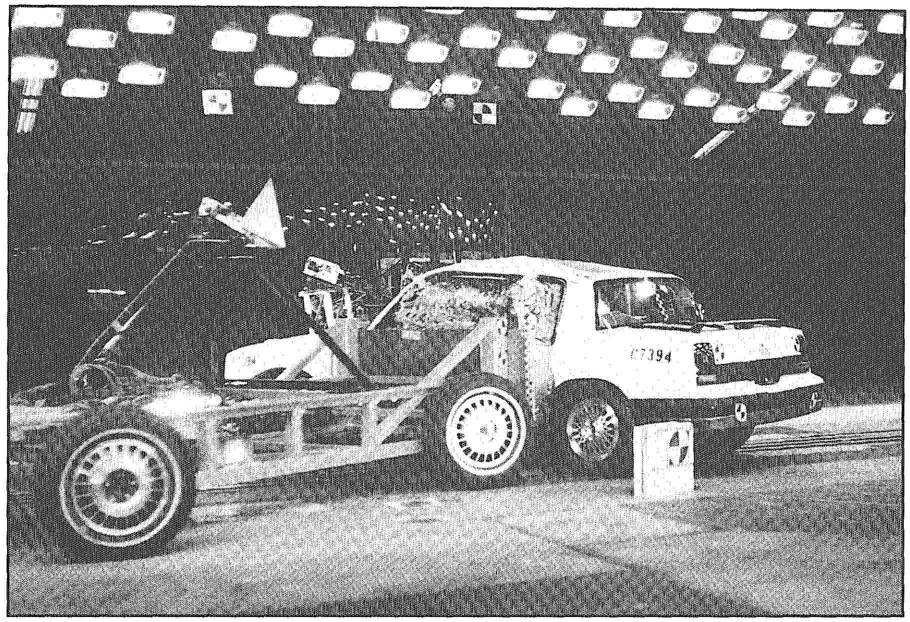
Principle #3: Distribute the forces on the occupant.
Broad distribution of forces on occupants reduces the severity of injuries. Vehicle interior components and restraint systems provide the necessary area to spread impact forces more evenly.

Principle #4: Prevent ejection from the vehicle.
Lastly, preventing complete ejection from the vehicle eliminates the high risk of serious or fatal injuries that an occupant is exposed to outside the vehicle. Occupant ejection is involved in one out of four motor vehicle deaths.

Putting Principles to Work

To protect occupants, today's cars are specifically designed to crush such that most of the energy in a front or rear crash is absorbed by the car's skeleton—the upper and lower metal rails that frame the engine and trunk. The lower rails are designed to crush first at the outer end of the vehicle, with the inner portion of the rails crushing last. The upper rails absorb additional impact energy, and the hood buckles into an inverted "V" rather than sliding backward through the passengers. This entire energy-absorption process is called "progressive crush."

In addition to easing the deceleration of the occupants, a "progressive crush" design also strives to keep the passenger compartment intact, in accordance with the second principle mentioned earlier. For instance, the structure of the doors helps maintain cockpit integrity during the buckling and crushing of the rails. High-strength door locks and hinges, combined with the door's metal reinforcements, make it more likely that the door can be opened after a crash, allowing occupants to exit the vehicle quickly. Furthermore, safety belts secure the occupants inside the cockpit where they can ride out the crash as if part of the vehicle, reducing their chances of ejection or impact with the vehicle interior (or other passengers).

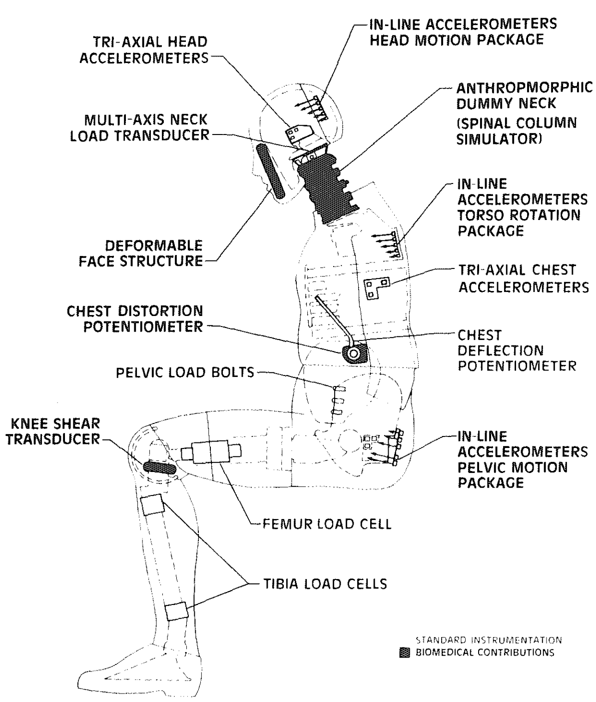


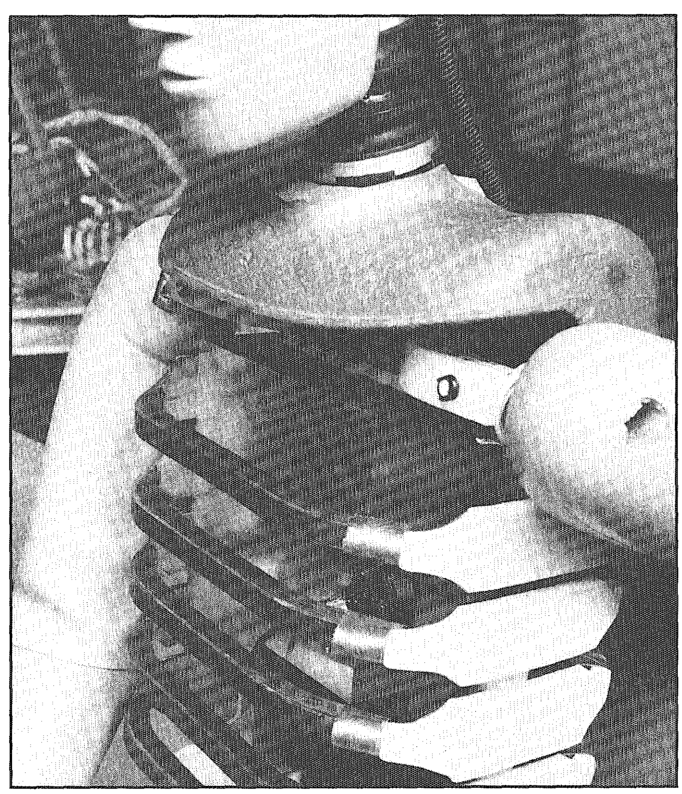
A deformable barrier is crashed into the side of a stationary car at a speed of 33.5 mph.

Though less dramatic, it's important to remember that side-impact crashes can be just as deadly as head-on collisions. Side-guard door beams, introduced in 1969, are a form of side-impact protection required by law. To complement these low-weight, high-strength corrugated steel beams, car engineers are now investigating materials that might improve side-impact protection while being consistent with weight, fuel economy, and styling needs. Energy-absorbing foams as well as formed shapes of metal, plastic, and composite materials are being studied.

To further improve side-impact safety, the NHTSA recently proposed a new side-impact crash standard. The new side-impact standard would involve crashing a deformable barrier into the side of a stationary car at a speed of 33.5 mph. This would simulate an intersection collision where a vehicle crashes at 30 mph into the side of a car moving at 15 mph.

Standard dummies (lower left) contain many sensors used to measure localized crash forces experienced by occupants. BIOSID dummies (lower right), specifically designed for side-impact crash testing, have a special rib-cage design that allows better simulation of chest, abdomen, and shoulder injuries.





The proposed side-impact standard also calls for test dummies to be placed in the front and rear seats next to the impact site to measure crash accelerations of the ribs, spine, and pelvis. Unfortunately, current test dummies do not give accurate test results for side-impact crashes since they were designed to study front and rear collisions only. In anticipation of the new standard, General Motors (GM) has developed a side-impact dummy, named BIOSID, that meets both international safety criteria and NHTSA requirements. GM's new dummy will be adopted industry-wide once it has successfully completed testing by other vehicle manufacturers, the NHTSA, and the Society of Automotive Engineers.

In all types of collisions—front, rear, or side—the steering assembly remains the component most likely to be hit by a driver. Energy-absorbing steering columns reduce driver injury by dissipating impact forces generated in a crash. To further improve safety performance of energy-absorbing steering columns, a self-aligning steering wheel has been developed. The self-aligning steering wheel has a unique energy-absorbing hub that incorporates six deformable metal legs. During a crash, the steering assembly deforms at the hub and aligns the wheel parallel with the driver's chest, thus reducing chest, abdomen, and face injuries. Since its introduction, the energy-absorbing steering column has reduced serious injuries by an estimated 38%, and reduced deaths caused by steering assemblies by 12%. Because of this and similar systems, the Federal government estimates that serious injuries are reduced by 25,000 every year.

The Accident That Never Happened

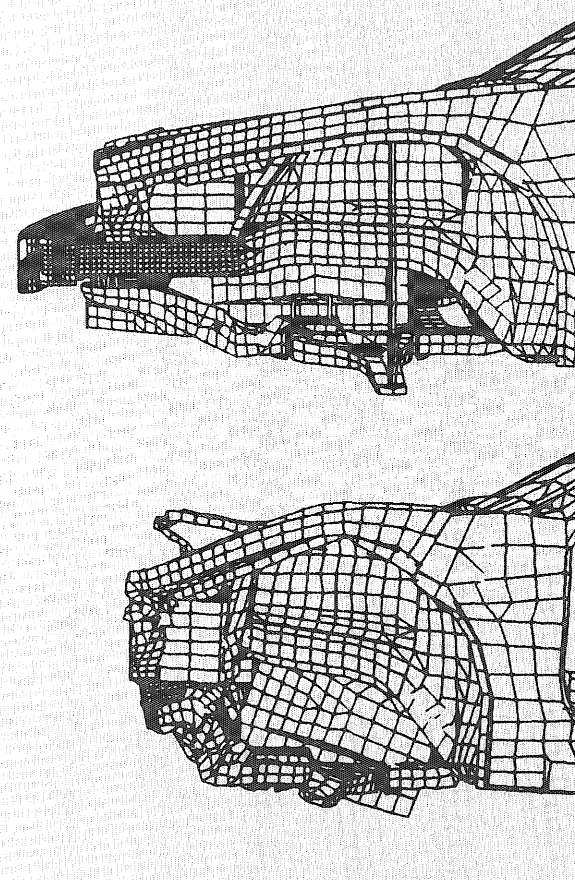
In the past, engineers emphasized protecting occupants after a crash had already occurred. Today's auto engineers, in contrast, are developing new technologies that aim to prevent automobile crashes in the first place.

Auto Engineers Turn to Supercomputers

To test the safety of their designs, auto engineers must use crash simulations. Simulation technologies include barrier tests, impact sleds, computer models, and anthropomorphic crash-test dummies. According to John Kleeves, a Senior Development Engineer for GM, each barrier test, not including the vehicle itself, costs between $10,000 and $15,000. Given that GM's Safety Research and Development Laboratory crash tests as many as 400 full-scale vehicles each year (not to mention 1200 other crash tests on individual components), the total cost is staggering.

The automotive industry, in an effort to reduce the high cost of crash testing, has begun using computer models to simulate how car structures deform during collisions. Computer simulation reduces the cost and effort of testing, and also provides engineers with a better fundamental understanding of crash dynamics.

One computer simulation method employs a technique called "finite element analysis." The results are so comprehensive that designers can check how every body panel, structural member, and component will behave under the forces of an impact. Currently, a full-scale crash simulation using finite elements requires 20 hours on a Cray supercomputer. If this considerable CPU time can be reduced, computer simulation will become a cost-effective and useful tool in the future. Although a comparison of simulated and actual test data shows good agreement, finite element analysis is unlikely to ever replace barrier testing as the sole source of engineering data.



Before and after views of a front-end collision, as modeled with a computer. This finite element simulation required 20 hours on a Cray supercomputer. The model had 100,000 degrees of freedom.

Obviously, the best way to avoid a collision is to slow down, stop completely, or steer around the hazard. In recognition of this basic fact, automakers are equipping many new cars with an Anti-Lock Brake System (ABS). The ABS uses a computer to help keep vehicle wheels from locking during hard braking, thus shortening stopping distance and helping drivers retain steering control on most surfaces instead of skidding out of control. Sensors continuously monitor how fast the wheels are rotating and feed the data to a microprocessor. If the wheel is approaching lock-up, the computer signals a hydraulic modulator to apply and release brake pressure as fast as 15 times per second. This pumping action continues as long as the driver maintains pressure on the brake pedal and the computer senses an impending wheel-lock condition.

Air Bag Technology

Air bags were first introduced in the late 1960s but met limited consumer approval. Today they are being installed as standard items in some cars, and as options in others, at a cost of approximately $850 each.

Air bags supplement seat belt protection by distributing the impact forces more evenly over the driver's head and upper torso, thus reducing pressure concentrations occurring when a driver's head hits the steering wheel. Sensors in the vehicle detect a frontal crash worse than a predetermined threshold of accident severity. A control module then triggers an inflator module, causing the sodium azide sealed inside to undergo a chemical reaction that generates nitrogen gas. The gas expands, filling a cloth bag that's been packed inside the steering wheel or instrument panel. As it fills, the bag pushes open the cover of the steering wheel or panel and expands into the passenger compartment. All of this occurs in a fraction of a second.

Unless drivers see hazards soon enough, even the best braking technology will not prevent an accident. To artificially enhance driver eyesight, several new vision technologies are under development. When a car is in reverse, a "near-obstacle" detection system uses radar to detect objects up to 15 feet from the rear of the vehicle. As a car backs up, the system gives an audible and visual cue that alerts the driver to a potential collision. To help forward vision, a "virtual image" display makes it unnecessary for drivers to refocus their eyes when alternating attention between the road and dashboard displays, thus improving instrument readability and reducing eye fatigue. Infrared technologies are being developed to assist driver vision at night or during poor weather. Adapted from military technology, "heads-up" displays project instrument readouts into the driver's field of view, making it unnecessary to take his or her eyes off the road.

With the application of these new crash-prevention technologies, the accident scenario presented at the beginning of this article could be much different. The young woman scans the road using infrared night-vision enhancement. Suddenly, she sees a car careening towards her. She quickly hits her ABS brakes, steers around the errant car, and rapidly slows to a non-screeching halt. She jumps out of her car and cusses out the other driver. Neither driver stops to wonder what could have happened if their vehicles hadn't been equipped with ABS and the other, now standard, safety features. Let's hope this is the accident of the future. ☐

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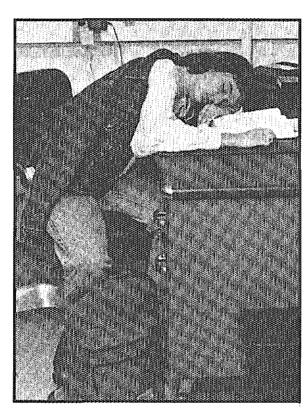
Writer Profile: Cathy Bekavac



Cathy Bekavac, pictured studying in the SWE office, is a fifth-year senior majoring in mechanical engineering. In addition to being co-president of SWE, she is treasurer of the IT Board of Publications. Last summer she was an engineering intern at a GM facility in Detroit.

The Path Not Taken: Women in Engineering

by Paula Zoromski

What is it about science and engineering careers that's engendered the non-interest of women?

The first time I met my three roommates, they asked me the typical college icebreaker: "So, what's your major?" With some hesitation I answered, "chemical engineering." They stared at me dumbfounded. After a rather uncomfortable pause, one woman asked, "Do you have any hobbies?" As soon as I mentioned photography they became interested in me, and a conversation began.

Their reaction to my major has not been uncommon. During a recent vacation I visited the photo studio where I once worked. When I told my boss I was studying chemical engineering he protested, "Paula, you're a creative person. You can't work in technology. You need to work with people in a creative field."

Other responses have ranged from "Oh, you must study a lot" to simply, "Why?" Attitudes of this sort, coupled with the difficult courses in the chemical engineering program, have nearly convinced me to drop out of the field more than once. However, after two difficult, often confusing years, I'm now committed to becoming an engineer. Contrary to the discouraging remarks rained upon me, I believe the field is challenging, competitive, and fascinating.

No Women Welcome?

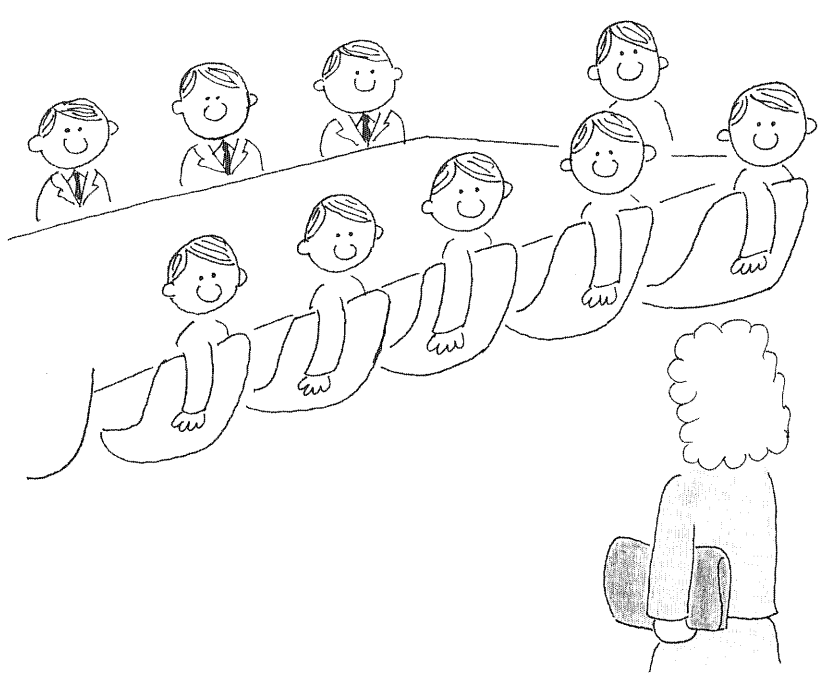
Once I made the decision to stick with engineering, I began to wonder why so few women enter the field. Samuel Florman, in his book *Blaming Technology*, puts the number of practicing female engineers in the U.S. at a mere three percent. The number of bachelor degrees awarded to women is a correspondingly low 16.5 percent.

These figures shocked me; in this age of technology and supposed social enlightenment, I was certain that more women would be involved in the field. I wondered what could possibly be keeping so many women out of engineering. Could it be that the intellect of females is ill-suited to technical problem-solving? Do they fear sexism, discrimination, or harassment? Is there a fear that an engineering career will conflict with their desire to raise a family?

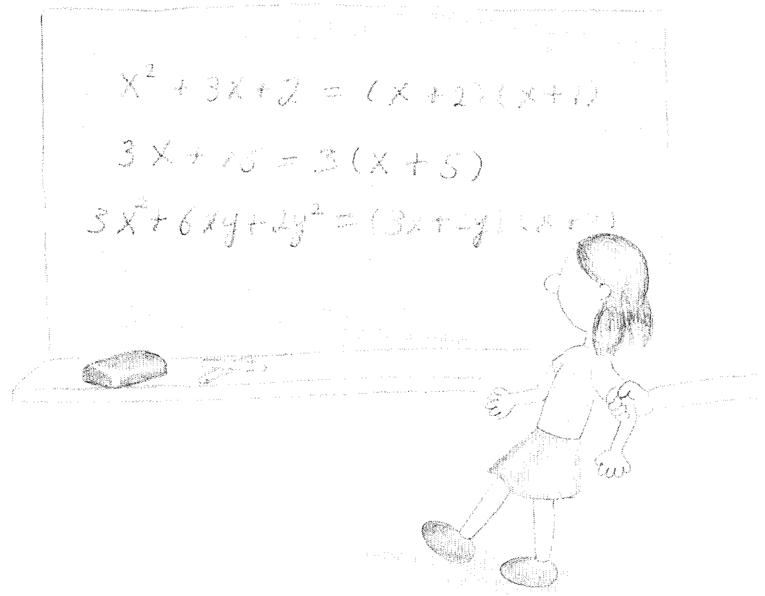
I decided to explore the possibility of gender-related intellectual traits. I found that most experts agree there are differences between men and women in various areas of mental aptitude, but

"Samuel Florman, in his book *Blaming Technology*, puts the number of practicing female engineers in the U.S. at a mere three percent."

they disagree on the significance of these differences. For example, Janet Shibley Hyde, a Denison University psychology professor, researched sex-based aptitude differences that are important to engineering. The differences she found were very small; Hyde reported a 1 percent advantage of men over women in quantitative ability, 4 percent in visual-spatial ability, and 2.5 percent in visual-analysis. Furthermore, the differences between the men and women tested were not universal. Some women scored much better than most men while others scored lower.



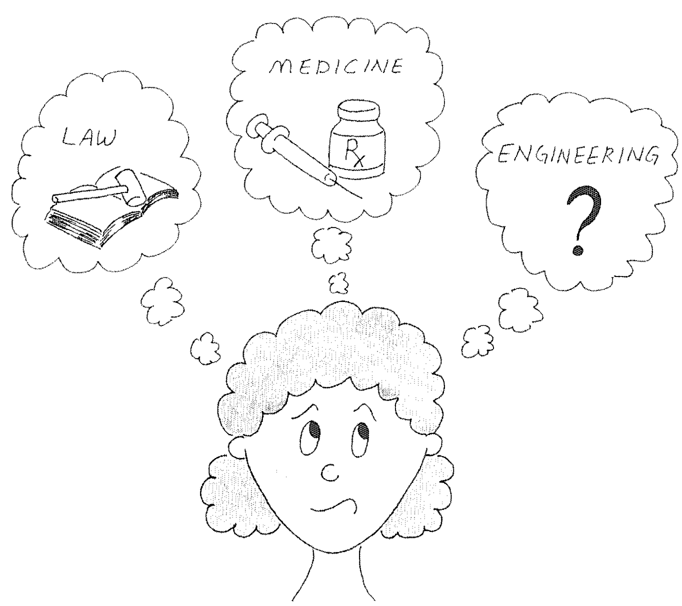
Since gender-related intellectual differences proved insignificant, I looked to sexism. Sexism exists in engineering, but it also exists in such fields as medicine and pharmacy, two fields well-populated with women. Thirty-six percent of the students entering medical



school in 1988 were females. The percentage of women in pharmacy school is over fifty percent. Because sexism is not unique to engineering, it alone cannot explain the shortage of women in the field.

Lack of Role Models, Lack of Understanding

With my original ideas debunked, I was forced to generate new ones. Could it be that women are still specifically discouraged from entering fields that are traditionally male-dominated? Do women overlook the field for lack of role models? Do they perceive that engineering offers no opportunity to help others or serve society?



Personal anecdotes seem to shed as much light on these questions as statistics. I asked IT's new Associate Dean, Dr. Sally Gregory Kohlstedt (a history of science professor), if she had ever wanted to pursue a technical career. She replied that she had never even considered it. In high school Kohlstedt took an interest in a mechanical drawing class, but was discouraged from pursuing it. She was told that the class was for students on the general course, and since she was college prep, her counselor easily convinced her to drop her ideas about mechanical drawing.

"Setting aside the possibility that women are externally discouraged from engineering, it's possible that women simply believe that engineering is personally unfulfilling."

Kohlstedt admits she was explicitly socialized out of the technical field, and one would like to believe this was because she is from a different generation. Unfortunately, many of these attitudes persist. When I was in high school, only two women dared to take a mechanical drawing course, and one dropped out during the first week. This example suggests that socialization may still affect women.

Another example indicates the importance of role models. Because the introductory classes for pharmacists and chemical engineers are very similar, I asked a pharmacist friend if she had considered studying engineering. She said the thought had never crossed her mind because when she was in high school she had no idea what an engineer did or what they studied. She envisioned an engineer as a draftsman. On the other hand, the job of a pharmacist was quite clear to her. I doubt that men have

ILLUSTRATIONS BY BYUNGHO HAN

Advocate For IT Women

Dr. Sally Gregory Kohlstedt, IT's new associate dean, is in charge of faculty development and special projects. I asked her what she hopes to do for women in IT. One of her goals is to make IT's work environment hospitable and encouraging for women. She plans to help women work within the existing system and improve conditions as opportunities arise. Currently, IT has only twenty female faculty members. Kohlstedt is trying to get these women together to discuss any problems they encounter and how they can help each other.

She also plans to work with graduate students, a frequently neglected group. Many of these students have expressed an interest in promoting women in engineering, but are uncertain how they can make a difference. Currently, there are no graduate school women's organizations. Kohlstedt plans to have a reception for these students so they can discuss issues and plan projects. A cohesive group of graduate students could be a tremendous resource for undergraduate students. Simply showing that opportunities exist and that women are taking advantage of them would provide a positive model for undergraduates.

At the undergraduate level, Kohlstedt plans to help students through engineering organizations already in place. One active group is the Society of Women Engineers (SWE). SWE is working to keep female students in the Institute of Technology, and uses a big sister/little sister program. New students are assigned to upper division students, who make themselves available as a resource.

Dr. Sally Gregory Kohlstedt, IT Associate Dean (Faculty Development)

a clearer understanding of an engineer's specific duties, but I do think they receive more exposure to related activities.

Setting aside the possibility that women are externally discouraged from engineering, it's possible that women simply believe that engineering is personally unfulfilling. Women are more likely than men to pursue careers they perceive as helpful to society. Though engineers nearly always work with people, they are generally viewed as professionals who work with machines. Often the significance of these machines is unclear to society. On the other hand, doctors and pharmacists are seen as helping people in a very direct way. Women who are determined to make their lives count in a socially significant way may think medicine is more relevant than engineering. This is a distortion. Like medicine, science and technology can also help society.

I have only considered some of the reasons why so few women pursue careers in engineering. A common set of reasons is elusive because the career choice is an individual one. Each person has different goals, dreams, and expectations. The important thing is that none of the barriers keeping women out of engineering are permanent. Changes are slowly being made.

Women must become more involved in technical areas because, as Kohlstedt stated, "Science and technology are an important part of American culture. We are a technical society. Women need to be in positions to make decisions and define activities. If we are unable to speak in technical terms then, we have no influence." □

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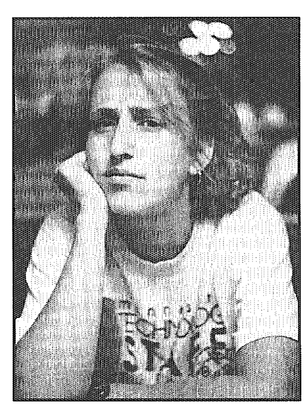
Writer Profile: Paula Zoromski



Paula Zoromski is a senior majoring in chemical engineering. Much to the consternation of her advisor, she does not plan to attend graduate school. Instead, she plans to spend several years after graduation in Latin America. This is Paula's second article for *Technolog*.

It's in the Cards

by Pat Kellogg

University students are being dealt a new high-tech ID card. What are the advantages?

You enjoy registering for class. In fact, you enjoy it so much that you interrupt the movie showing on your three-dimensional holographic television set to select some winter quarter classes. Sliding your student ID into the convenient slot on the side of your personal supercomputer, you are instantly interfaced with the University of Minnesota Computer Network. Your faculty adviser appears on your computer screen and asks what classes you'd like to take. "Ah, something easy," you reply as you download your one-year plan from IT's computer. With your advisor's approval, registration is a snap. An artificial intelligence construct makes sure all your classes fit. The push of a button switches you over to the bookstore's computers where you select your textbooks from the computer shopping program. You complete your winter quarter plans by paying for your tuition *and* books with the simple phrase, "Put it on my card."

Even though it may not look like it, the new student identification cards are a step towards this future. With these new cards, the University hopes to combine the many current student files into a single database that can be used campus-wide. Wouldn't it be nice to handle registration and fees without standing in lines at offices scattered across campus? Why carry around fee statements and transcripts when all student information could be retrieved from a computer? Mary Amundson, Assistant Director for Student Services, hopes that in the future the new ID cards will solve a variety of problems. "We're trying to set the standard for four years down the line," she explains.

Why New Cards?

There are many possible uses for the new card. Residence halls could shorten cafeteria lines by using a high-speed scanner to check each student's meal privileges. Coffman Union and Cooke Hall could make it easier to check out sporting equipment. A bar-code reader in Bierman could ensure that non-students did not get discounts on tickets and events. Another possibility would be to use the student ID as a "debit card" to keep track of parking

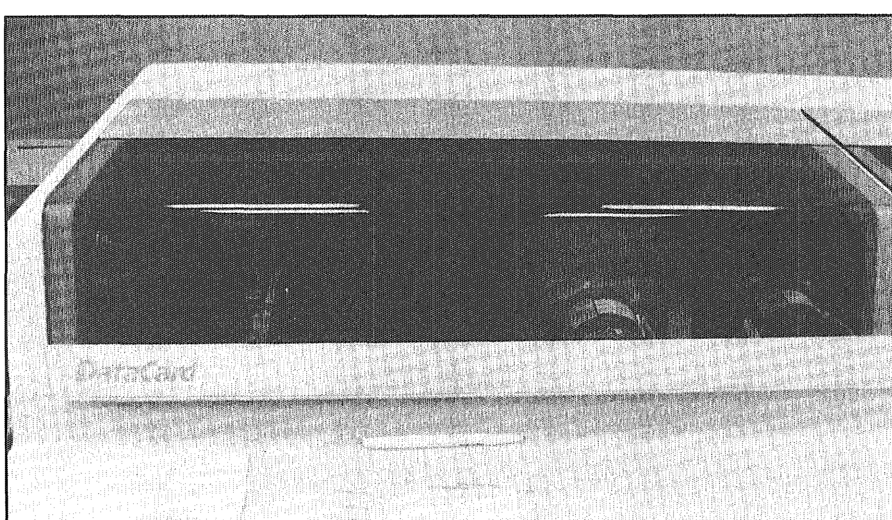
"Sliding your ID into the convenient slot on the side of your personal supercomputer, you are instantly interfaced with the U of M Computer Network."

expenses, with each lot subtracting its fee from a pre-purchased amount. The bar code might also be used with STARS, the new Student Accounts Receivable system that the Bursar's office will use next year. This system will centralize student fees, thus making it easier to pay bills and budget for financial aid and tuition.

However, the main reason for issuing the new cards is the bar code on the front. The University library check-out system will become fully automated this year, using the bar code to speed inventory and book returns. Whenever a person wants to check out a book, their bar code will be read by a laser scanner. Immediately, the library computers can check to see if the person is still registered as a University student, verifying eligibility to borrow University materials. In the past, students had to provide a current fee statement and a student ID to check out books. A fee statement, though, does not guarantee that classes have not been dropped, or that its owner is currently a University student. The new ID cards eliminate the need for a fee statement at the library, and will reduce theft and illegal library use. However, all University offices are not yet connected to the new database. "You'll still need to carry around your fee statement," Amundson warns. "A lot of University departments still rely on hard copy for storage."

ID Logistics

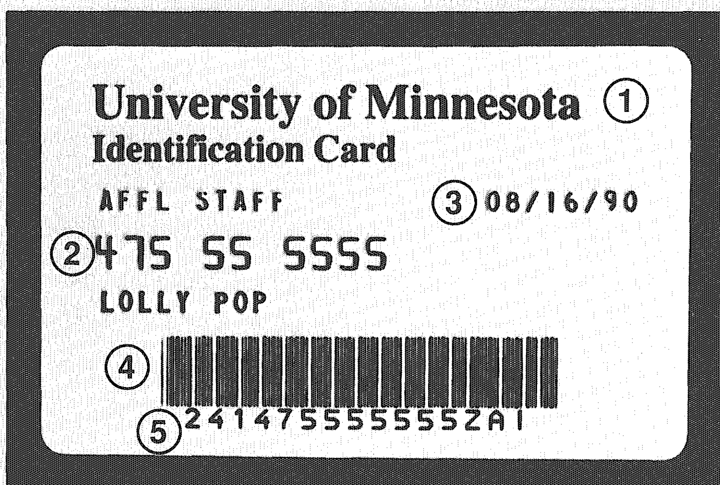
Not only will it take time to set up the computer storage, but it will require the entire month of November just to distribute all the new ID cards. About twenty thousand cards have been distributed thus far to new students, transfer students and assorted University personnel. This month,



Above is the Datacard 15000 machine owned by the University. The cards are embossed by the stepper wheels on the right, then sent to the "topper" at left to blacken the raised letters. This machine can produce up to 10,000 cards per hour. Theoretically, it could make enough IDs in four hours to supply the entire student population.

Anatomy of a Card

1. Student identification cards start as "blanks" made by DataCard's plastics division. The red U of M logo, the signature bar, and the text on the back are all added as the card is made. The cards must meet strict manufacturing standards, or they won't print properly in the 15000 machine.



2. The ID operator enters the social security or file number of a student, and the information is sent to the 15000. The card is embossed with raised letters, then a "topper" heats a black foil that highlights the letters. The embossing is important for those University departments without a bar code reader. The ID's raised letters can create a carbon copy of the ID on University documents.

3. The student ID number on the card is much smaller than the social security number. In the future, the University would like to stop relying on a specialized ID number. Many University employees need ID cards, but because they aren't students, they have never been assigned a number. Also, even though a student's name or status may change, their social security number won't. It also provides a clear index number for computer identification.

4. The bar code is printed on the ID using thermal heat transfer, much like a thermal printer on some personal computers. The 15000 doesn't distinguish between the bar code and the numbers beneath it, printing everything in a 512 by 810 pixel dot matrix. The resolution must be precise because the lines on the bar code have to be distinct in order to be read properly. In fact, early in the cards' production run, the first two lines of the code ran together whenever the print head became too hot. Now, a special processor and a temperature sensor monitor the energy per dot.

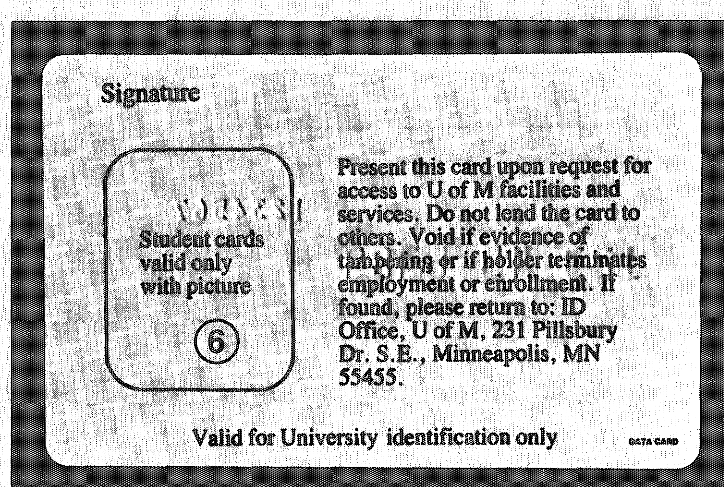
5. The bar code is written in "three-of-nine" code, meaning that each number of the code is made up of nine alternating black and white bands. In three-of-nine code, three bands are thicker than the rest, which allows for error-checking to ensure the card was made properly.

The first digit of the code is always a two, signifying an ID card, in contrast to a three for library books. The next two digits indicate whether the owner is a student, faculty member or non-faculty employee. After that comes the social security number with a "Z" at the end as a filler character in case the number is expanded someday. The second to last letter represents the version of the card. If a card is lost and a new one is made, the library computer is told to recognize the new card and ignore the missing one. The last character is an error-check for the parity of the entire code, to make sure that the card is made properly.

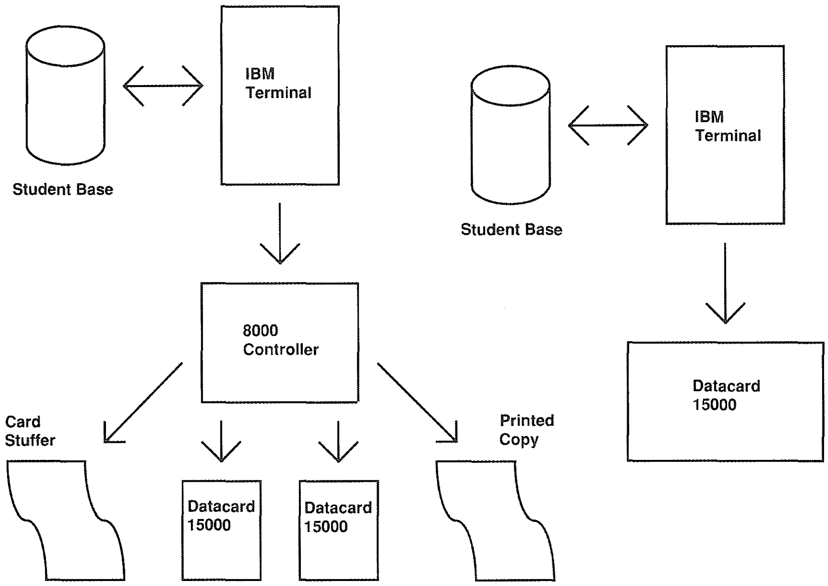
6. Say cheese! The new photos will be in color, and a small "M" in the bottom right hand corner will discourage dishonest people from substituting a different picture on the ID. The entire back side of the ID card is laminated with clear plastic, and the finished product is given to the student.

Card Care

Your new identification card is not indestructible. Constant rubbing or chafing can wear away the bar code. Carrying it loose in a pocket can cause scratches by keys, coins and other hard objects. It's best to keep your ID in a wallet or purse away from other cards. Above all, don't use your new ID card for scraping icy automobile windshields or jimmying a lock. If you treat your ID carefully, it should last your entire college career.



PHOTOS BY STEVE HONG



Datacard's usual configuration for printing cards (left) allows for many peripherals to be driven from one controller. The University's set-up (right) is unique because an IBM terminal controls the Datacard 15000 machine directly, bypassing the expensive controller.

Student Support Services has rented the Armory gymnasium to distribute another forty thousand cards to remaining students. Despite the number of students needing new cards, long lines shouldn't be too much of a problem. Amundson explains, "The cards are pre-printed, and we purchased five new cameras." The date and time for picking up new IDs will be printed in the *Minnesota Daily* and on fliers distributed around campus. All students must do is show up and flash a smile for the camera.

"The idea of student information shared by all campus computers may seem a bit Orwellian."

A student's first ID will be free, but lost, stolen, or mutilated cards will cost ten dollars to replace. However, if the bar code becomes faded or unreadable on its own, the card can be exchanged for another. Students may wonder why replacement costs rose from last year's five dollars. Amundson explains, "I think the price is justified. There's the high cost of upkeep on the (card printing) machine, and the color photo on the back, which is new."

The machine used to make the new ID cards was purchased from DataCard International, located in Minnetonka, Minnesota. The total cost of system hardware and software was about one half million dollars. The printing machine, the DataCard 15000, is the same type used to print Discover and American Express cards. However, large credit card companies usually own several 15000 machines and use a special controller to divide up tasks. The University, on the other hand, wanted to print a relatively small number of cards directly from one IBM terminal. To accomplish this, DataCard developed software to "fool" the IBM into thinking that the 15000 was just another peripheral and to transmit data using the normal IBM 327X protocol, without the need for a controller to "multi-task" several machines.

Is 'Big Brother' Watching?

The idea of student information shared by all campus computers may seem a bit Orwellian. Would a "hold" on a student's record mean they couldn't buy football tickets? Would an overdue library book cause suspension of dormitory food service? Would your academic record be open to scrutiny every time you used your card? However, this is not quite the case. Amundson explains, "There is only a certain amount of information sent back to the terminal." The student's name, birth date, home address, and student status are the only things shared among all terminals. Also, the student database is kept separate from the validation database used by the library.

Someday, perhaps, all University information will be stored in one computer open to all departments. On that day the dream of registration by phone, or tuition payment using a student ID, may become reality. Unfortunately, it will be a long time before the University is fully connected by a computer network. Until then, it is encouraging to know that the new ID cards are the first step toward the campus of the future. □

Sources:

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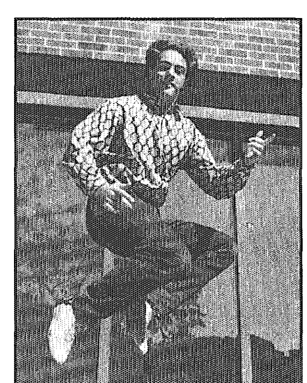
"Author Slays Myths of I.D. Cards," *Automatic I.D. News*, April 1989.

"Money Clip Can Damage Credit Card," *Minneapolis Star Tribune*, August 17, 1989.

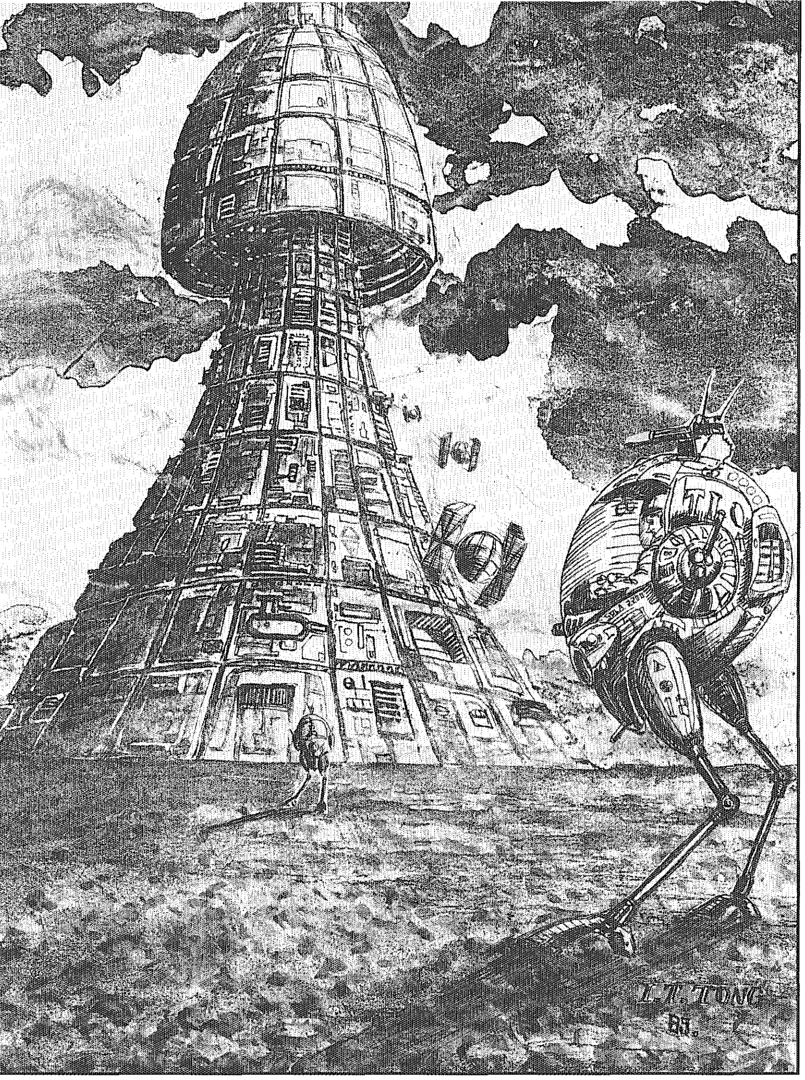
Palmer, Roger C. *The Bar Code Book*, 1989.

minnesota TECHNOLOG

Writer Profile: Pat Kellog



Pat Kellog, *Technolog* neophyte, is an EE junior who participates in the co-op program. He submitted his article at the urging of a well-respected staff member. A self-admitted geek, Pat enjoys juggling and is a member of the "Society for Creative Anarchism." Whoops, we mean "Anachronism."



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If you're too embarassed to drop it off in person, slip it under our door (Room 2, Mech. Engr.) in the dead of night. We don't mind. Many of our staff writers do the same thing.

Self-Help Seminars:

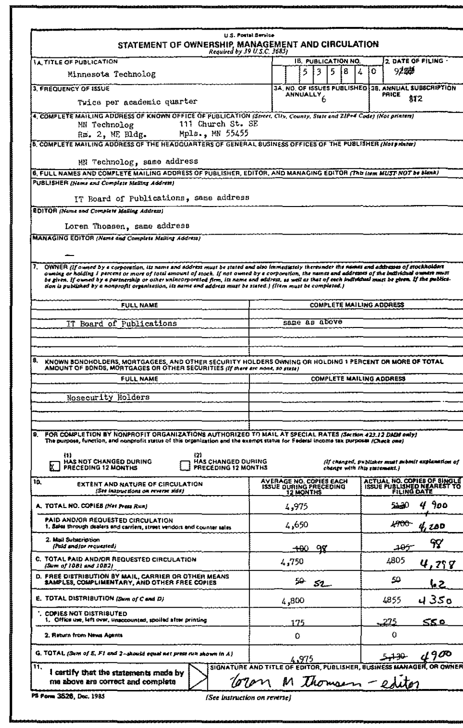
"How to Overcome Self-Doubt Through Pretense and Ostentation" — Honors students: attendance required; Annual Elitist Ball will follow. Dr. David Frank, speaker. 7 p.m., Nov. 4, 5-267 Feld Hall. (IT Honors Department)

"How I Made $100.00 in Real Estate" — Success story by a 15-yr. veteran of the real-estate field. Bill Walshowitz, speaker. 5:15 p.m., Nov. 9, 13 Burton Hall. (School of Business)

"Money Can Make You Rich" — Success story by brother of world-famous multi-billionaire. Dan Trump, speaker. 2:30 p.m., Nov. 31, 423 Bilk Hall. (School of Business)

"Do-It-Yourself Home Restoration" — A look at period house restoration by the man slated to replace Bob Vila as the host of "This Old House." Dr. Kenneth Keller, speaker. 8:45 a.m., Dec. 9, 5 Elan Hall. (School of Architecture)

"How to Convert Your Family Room into a Two-Car Garage" — A practical guide to home additions. Zack Miller, speaker. 10:00 a.m., Dec. 9, 5 Oppelheimer Hall. (School of Journalism)



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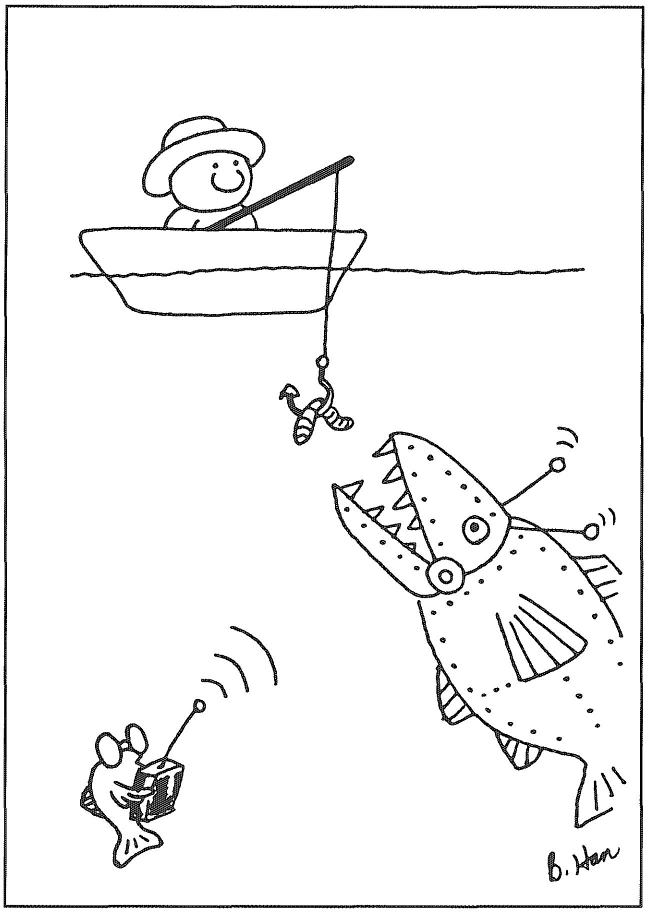
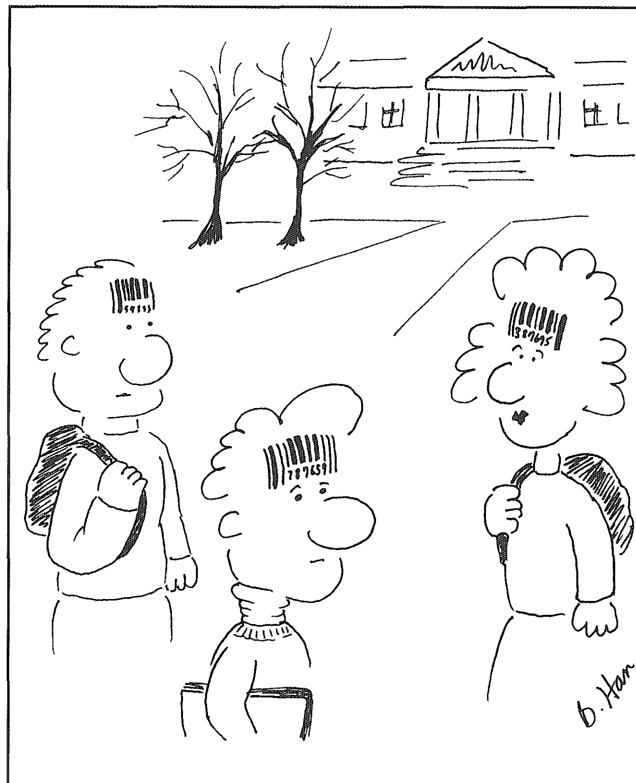
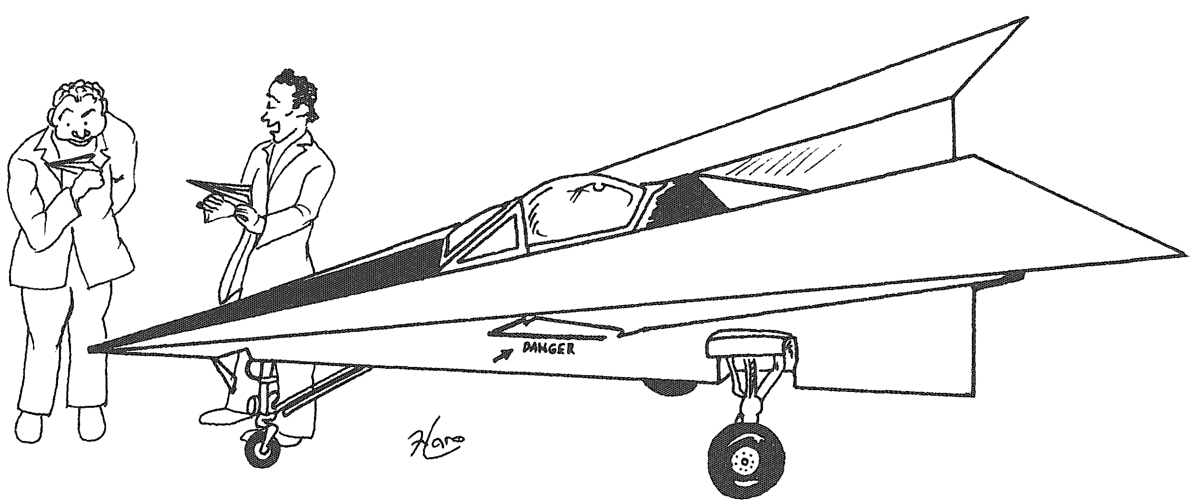




By 1997, University students will no longer have a problem with losing their ID cards.



"What really struck us was its simple design."

January 1990

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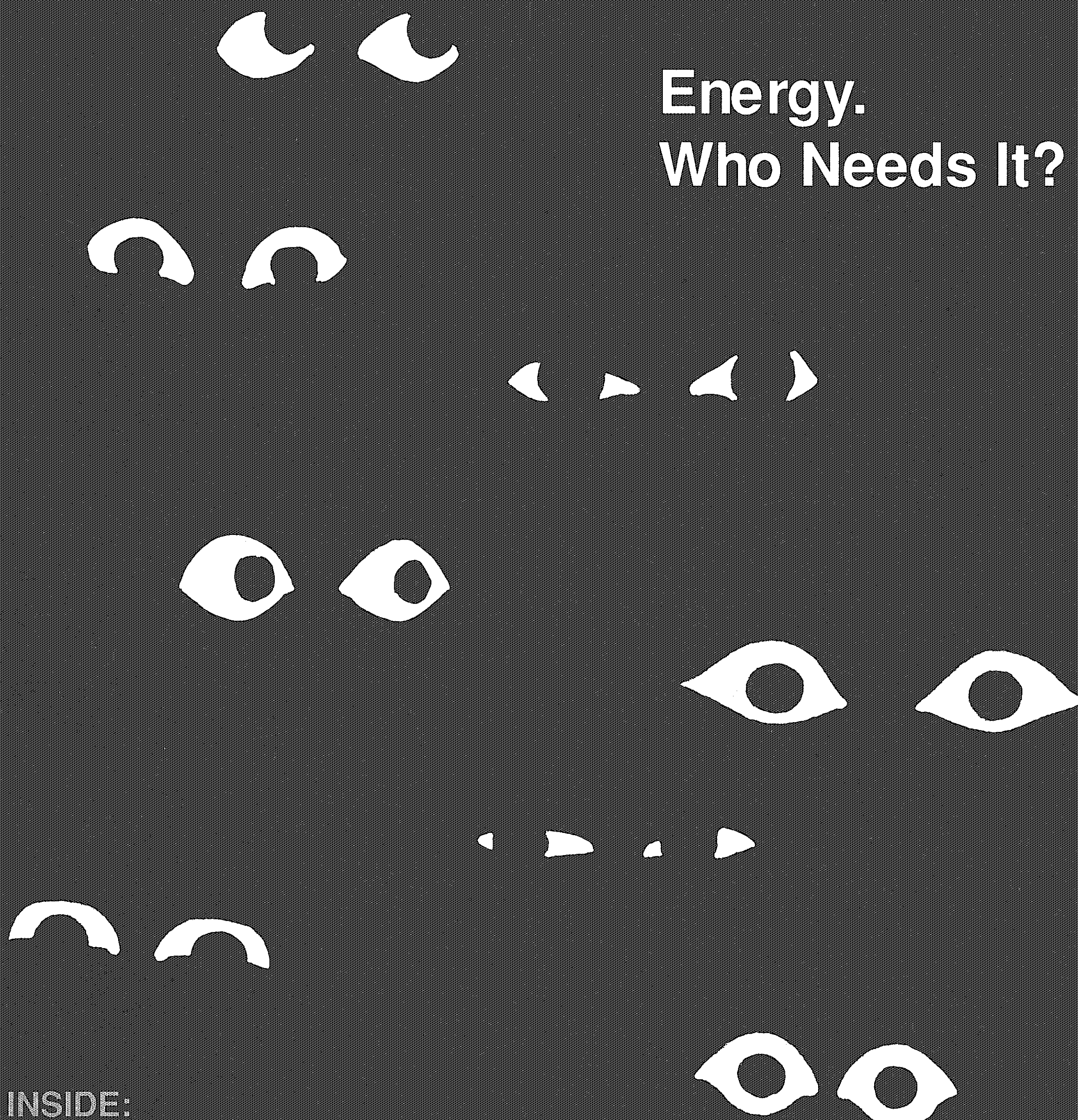
The Official Undergraduate Publication of the Institute of Technology

Energy. Who Needs It?



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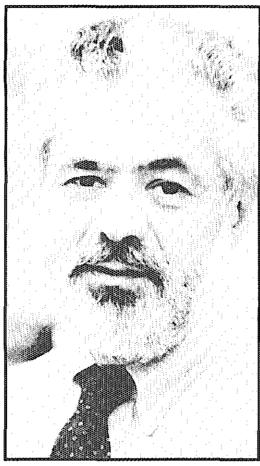

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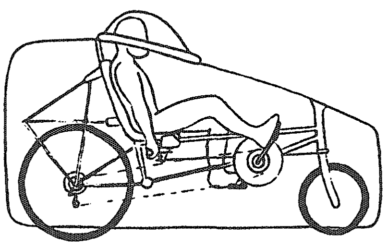

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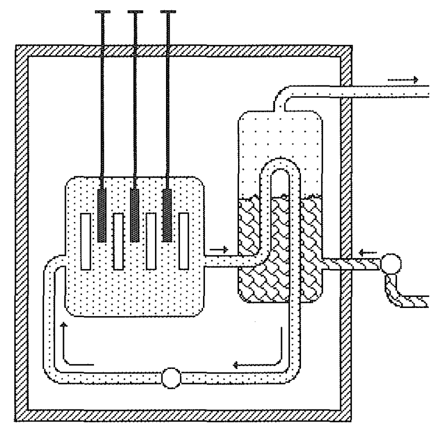

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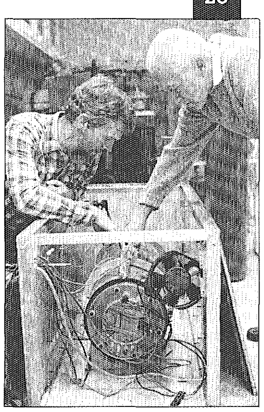

DEPARTMENTS

On the cover: In the dark about power production's state-of-the-art? *Minnesota Technolog* has devoted this entire issue to shedding light on the subject, covering three hot topics: nuclear power, fusion, and human power.

COVER ILLUSTRATION BY JOYCE RAJENDREN

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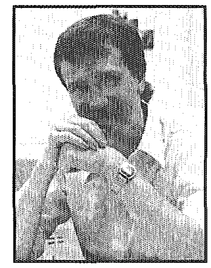


by Loren Thomsen

Don't go to engineering school to learn about design. In academia, analysis reigns supreme.

This past October I had a disturbing experience during an electrical engineering midterm. The exam was going tolerably well until it came time to solve a second-order differential equation that described the motion of a rolling car. Call me crazy, but I had prepared for the exam by studying electrical systems and ignoring the seemingly irrelevant (i.e. rolling car) material. Voltages, currents, and impedances were familiar to me. Forces, velocities, and friction coefficients were not.

I suspect the professor would argue that any differential equation was relevant since he was only testing my ability to use Laplace transforms. Perhaps. But why didn't he confine the exam to electrical systems, which already offer an abundant supply of differential equations? As the course wore on, the answer became clear. Though supposedly about electrical system design, the course only had a weak connection with electrical engineering, and an even weaker connection with design. Seldom were resistors, capacitors, or inductors mentioned, and variables were almost never referred to as currents or voltages. We went the entire quarter without ever analyzing, much less designing, an op amp circuit. The course was primarily about using abstract mathematical methods to analyze abstract mathematical models.

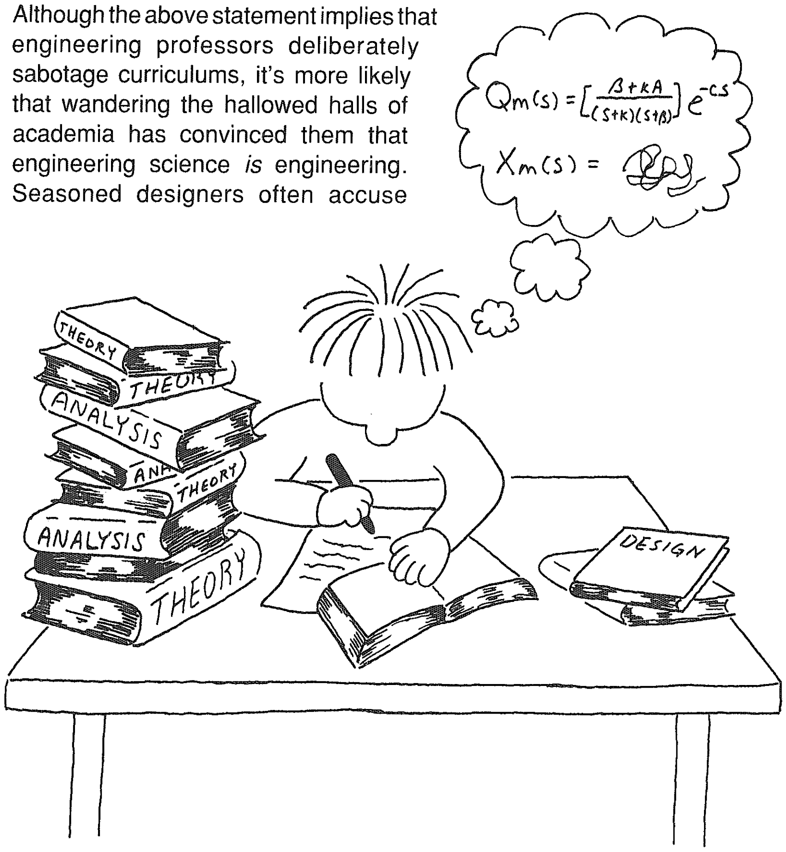
> **"Seasoned designers often accuse graduates of not having a clue about the actual practice of engineering, but it's also clear that our professors are equally ignorant."**

Some might claim that I was the victim of an isolated incident or that I expected too much from the course. However, many in industry (and even some in academia) would point out my experience as a good example of engineering science running amok in engineering curriculums. As Arnold Kerr and R. Byron Pipes point out in the October 1987 *Technology Review*, the design content in America's engineering coursework has been steadily diminishing since World War II, displaced by an emphasis on math and science.

Though regrettable for those students who are interested in design, the ascendance of math and science has also had more serious consequences. Today's engineering graduates, though competent analysts, are unqualified to design profitable products or processes, leaving America at a disadvantage in the world marketplace. A good example of this is the video-cassette recorder; Americans possessed the research skill necessary to invent the VCR, but lacked the design and manufacturing expertise necessary to bring it to market (unlike the Japanese). According to Kerr and Pipes, Japanese schools have curriculums similar to those in America, but Japanese employers compensate by providing most entry-level engineers with comprehensive design training. Entry-level engineers in the U.S. don't stay with one company long enough to merit similar training, even if their short-sighted employers are willing (or able) to provide it. The Germans outdo both the Japanese and Americans by providing their students with rigorous design training, which has likely contributed to the excellent reputation of German engineering.

Although it's not fair to blame engineering educators alone for America's declining global competitiveness, it is reasonable to insist that our engineers receive adequate training in the fundamentals of design. At first glance, the solution seems obvious: Re-emphasize design in America's engineering curriculum. The Accreditation Board for Engineering and Technology (ABET) stepped in to protect design coursework during the 1970s, but currently seems satisfied with letting the minimum percentage of design credits remain at 12.5% (the same as the liberal arts requirement). However, even if ABET did mandate an increase in design coursework, realistic observers know that it wouldn't do much good. The legion of engineering scientists populating faculties would sidestep new design requirements the way they sidestep current design requirements—by claiming design credits exist in courses that are primarily dedicated to analysis.

Although the above statement implies that engineering professors deliberately sabotage curriculums, it's more likely that wandering the hallowed halls of academia has convinced them that engineering science *is* engineering. Seasoned designers often accuse graduates of not having a clue about the actual practice of engineering, but it's also clear that engineering professors are equally ignorant. Dr. Eric Walker, former president of Pennsylvania State University, asserted in a Spring 1989 *Bent* article that, "Many, if not most, of our country's undergraduate students are taught by people who have never practiced engineering, never designed anything that has been manufactured, who cannot be called real engineers...." Kerr and Pipes offer a longer and more damning indictment of engineering professors and the curriculums they perpetrate:



> Incoming engineering faculty typically have little or no experience in design, yet are the ones frequently expected to teach design courses. Often considering the classes a burden, these professors usually adhere to a standard design text and are unable to enrich courses

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ILLUSTRATION BY BYUNGHO HAN

through personal knowledge. To secure tenure, they generally do research in the engineering sciences, for which grants are available and results can readily be published.... The situation is growing worse as design professors with actual experience retire. Should the number and quality of design courses continue to drop, the engineering programs at U.S. universities will become, in our view, pre-engineering programs at best, insufficient to prepare students for the effective practice of engineering.

A Radical Idea: Have Engineers Teach Engineering

Although there is broad agreement in industry and academic circles that training in analytical techniques is necessary, it's time to recognize that the de-emphasis of design coursework has gone too far. Granted, sophisticated technology requires sophisticated analytical techniques, and even hardcore designers do a significant amount of analysis. But a balance between engineering science and design is needed for the sake of America's technological survival.

A necessary first step toward balance is a faculty shake-up. Engineering scientists play an important role in technological progress, but that role does not include masquerading as design instructors. To ensure that graduates are genuine engineers, school administrators must begin hiring experienced designers to teach design courses. Many administrators pooh-pooh the likelihood of luring experienced designers out of industry. However, now that academic salaries have become comparable to those in industry, industry professionals are mainly discouraged from becoming instructors by the knowledge that their kind will not be welcomed or respected by the pseudo-engineers who now rule academia. To recruit industry professionals, administrators must implement a tenure system that does not discriminate against a professor whose skill is design (or, God forbid, teaching). Furthermore, do away with the requirement that instructors have a Ph.D. As Kerr and Pipes point out, prior to WWII few engineering professors had a Ph.D., evidence that instructors were valued for their mastery of engineering, not their research credentials.

Once qualified instructors have been hired, mending America's ailing engineering curriculum will become feasible. Rather than overthrow engineering science altogether, engineering schools should implement a two-track curriculum, with engineering-science students on one track, and design students on the other. Design-track students could actually learn almost as much analysis as their engineering-science counterparts, but they would learn about analysis within the context of design rather than analysis for the sake of analysis. Under a two-track system, one group of graduates could enter industry ready to work as designers, and the other group could supply large corporations and graduate schools hungry for engineering scientists.

The obstacles to improvement are formidable. In fact, nothing short of turning the whole faculty system inside out will suffice. Nonetheless, engineering school administrators cannot afford to let engineering science further engulf engineering curriculums, ultimately making possession of an engineering degree completely unrelated to one's ability to engineer. Unfortunately, until the situation is corrected, undergrads must stay alert for cars careening through EE exams, and must never skip class. They might miss that rare lecture when the professor actually discusses design, or at least what he or she has read about it. □

LOREN THOMSEN, Technolog's *editor-in-chief is an EE junior. He's a bitter, bitter young man. He intends to earn his Ph.D., become an accomplished designer and instructor, and return to IT to irritate the geezers in the EE faculty with his flamboyant teaching style.*

LETTER

"Perspectives" Contributer Resents Bio

Dear Editor:

I protest the biographical statement next to my picture [November/December 1989, p. 7] that read in part "with these credentials we feel she should be working in industry, earning some real money, instead of working for Student Pugwash USA." I realize that whoever wrote this sentence and put it next to my picture thought they were making a joke, but I don't think it was funny. It assumes that anyone reading the article already knows that Student Pugwash is a non-profit educational organization. Although the previous issue of *Technolog* carried an explanation of SPUSA on the back cover, can you be sure that everyone read it? As a young organization, we cannot afford to have jokes made at our expense. Ordinarily, we would send something like this to our board members as an example of the staff's myriad efforts to promote Student Pugwash. This insulting editorial comment effectively prohibits me from sending the article to anyone connected with our organization.

You invited a Student Pugwash staff member to write an article for your magazine, and I was happy to respond to the invitation. I enjoy reading *Technolog* and appreciate the issues it covers. However, I feel my efforts to contribute to the topic of technology and society were treated unprofessionally. In the future, I hope you will keep in closer contact with your writers so as not to repeat the same offense.

Sincerely,
Kathryn B. Janda
Conference Coordinator
Student Pugwash USA

[Your bio was not meant as an insult, and we apologize for our mistake. Author bios have traditionally been tongue-in-cheek and even mildly insulting, but they are never meant to be malicious. In any case, they are not meant to be taken seriously, nor are they generally taken as such by our readers. In the future we will check with outside contibutors before running a bio; we regret not doing so earlier. — Ed. Staff]

So What Would *You* Do With $1.6 Trillion?

by Gary Cook

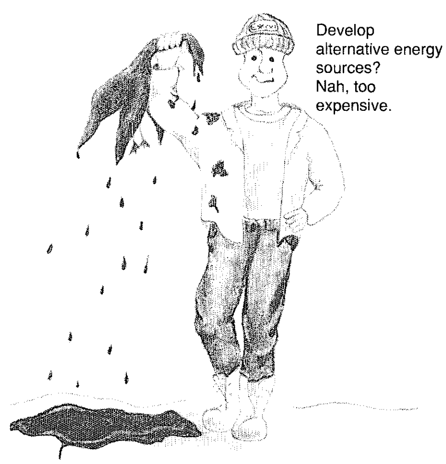
What would you do if you had an extra $1.6 trillion? Buy a new car? Take a cruise around the world? Pay off the national debt? Clean up the environment?

If you chose to clean up the environment your $1.6 trillion would just barely scratch the surface. According to the International Journal of Energy, this was the environmental cost the world incurred in 1986 for its consumption of fossil fuels, above and beyond the price paid for the energy itself.

We've been told we're living in an era of cheap energy, and we can see this "truth" reflected at the gas pump and in our monthly heating bill. However, the real bill may come due in the form of gasoline storage tanks that leach petroleum into our drinking water, acid rain that destroys our forests and lakes, smog that chokes our cities, and a rapidly changing biosphere that could forever alter the way we live.

"What's the real cost of energy? This question no longer interests only environmentalists—even the energy producers themselves are putting the question high on their list of priorities."

So then, what's the real cost of energy? This question no longer interests only environmentalists—even the energy producers themselves are putting the question high on their list of priorities. Witness the recent World Energy Conference in Montreal where 3400 energy experts from 91 countries pushed the usual concerns of energy supply and demand off their agenda and focused on the environment instead. This conference demonstrated the dawning of an era where environmental policy will begin to drive energy policy.



Seven state regulatory commissions are already mandating that public utilities take external social costs into consideration, and another 36 states may soon follow suit. However, since no single best method has been found for determining the least-cost method of producing power while minimizing external costs, and because no satisfactory way has been found for computing the exact price of external costs, the California Energy Commission proposed a procedure in which three types of costs would be considered: government subsidies; externalities such as environmental impact, health and safety costs, economic impact, supply reliability and security; and private costs.

Whether they gave equal consideration to each cost or weighted private costs five times greater than the others, the Commission found that conservation and renewable energy technologies (RETs) such as wind, photovoltaics, biomass, solar, geothermal, and hydroelectric were society's least-cost options. Conventional technologies like oil, coal, nuclear power, and natural gas were the most expensive.

We shouldn't be surprised that conservation is a good energy buy. After all, it was primarily conservation that kept America's energy consumption stable from 1973 through 1986 while our economy grew by more than 40%. But renewable energy?

"Conventional wisdom asserts that renewable energy is too expensive to compete with fossil fuels..., but other analyses imply otherwise..."

Conventional wisdom asserts that the emerging RETs are too expensive to compete with fossil fuels in most markets; other analyses imply otherwise, but these should not infuse us with unreasonable expectations for renewable energy, nor should we forsake conventional energy because of them, since many aspects of energy analysis are still unclear. How, for example, do we affix a price tag to climate change caused by global warming or determine the lost value of land leached of nutrients, especially when we cannot precisely determine the entire cause of the damage?

Furthermore, the emerging RETs themselves are still in relative infancy. Many of the systems, such as photovoltaics, are not yet efficient enough to be cost-effective and are only able to provide intermittent power. Others, such as the creation of fuel from biomass, are still in the re-

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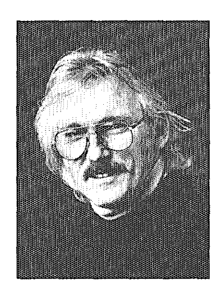


ILLUSTRATION BY JOYCE RAJENDREN

search phase. Because of this, we cannot expect them to provide us with substantial amounts of energy in the next few years. The manufacturing and distribution bases for these technologies are extremely small and it will take decades of growth before they can satisfy our huge energy appetite.

Although they aren't ready for immediate use, this doesn't mean that RETs don't have a place in the world's energy picture. Today, because of more than a decade of rapid technological advances, they have many niche applications and have even begun to crack conventional energy markets. Tens of thousands of supplemental photovoltaic systems have been installed across the globe, wind machines provide California with billions of kilowatt-hours of electricity each year, and we use nearly one billion gallons of ethanol fuel annually.

However, the real excitement still lies in the future. Economies of scale will bring down renewable energy costs substantially in the next few years and will make RETs competitive with conventional energy sources. More research will cut costs even further and make renewable energy sources more efficient and reliable, promising to turn intermittent systems into constant-supply sources. And in the far distant future, we'll witness the advent of RETs that are completely harmless to both humankind and the environment.

Such would be the case for hydrogen fuel produced with photovoltaic power. In a simplified sense, all that's needed is a photovoltaic cell, some sunshine, and a little water. The energy produced by the system would electrolyze the water and break it down into oxygen and hydrogen; burning this mixture would produce little but pure energy and water vapor.

This is just one of the many marvels looming on the horizon, and when these systems finally realize their full potential, we may no longer have to ask, "So what's the real cost of our energy?" Once RETs are cost-effective, supplies would be inexhaustible, technology readily available, and environmental damage minimal.

The next century may see the world go from a "low-cost" energy era to a "no-cost" energy era. Unfortunately, the road is likely to remain bumpy for many years to come. □

BRC: The New Alchemy?

by Michael Lee

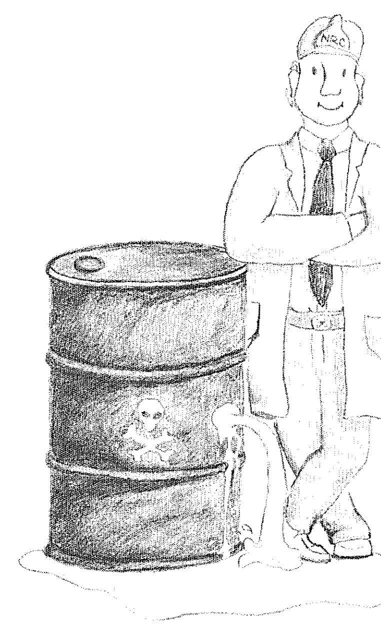
The medieval "science" of alchemy sought not only the transmogrification of base metals into gold, but a universal cure for disease and a means of indefinitely prolonging life.

A new modern-day form of alchemy seeks to transform dangerous radioactive waste into harmless garbage that can be poured down the drain, dumped at the local landfill, or incinerated in a garbage burner. As in medieval times, the procedures are shrouded in secrecy. Preparations for the new alchemy (a.k.a. BRC—Below Regulatory Concern) have been in progress since 1985 and yet there has been virtually no press coverage. The new alchemy has also been called "linguistic detoxification," and it involves transforming dangerous radioactive waste into everyday garbage—a sort of reverse mutation from a special regulated category to a common, unregulated one.

"The new alchemy has been called 'linguistic detoxification,' and it involves the transformation of dangerous radioactive waste into everyday garbage..."

The term "low-level" nuclear waste is a catch-all category for approximately 50,000 cubic meters of hazardous materials dumped annually at the three licensed low-level disposal sites across the country. Low-level waste is defined by the number of years it must be separated from the rest of the environment—between 100 and 500 years—and these hazardous materials range from waste oil and resins to protective clothing and tools. Nuclear power plants account for about 70% of this waste, industry about 29%, and medical facilities the remaining 1%, but by the year 2020 the decommissioning of nuclear power plants will make the nuclear industry responsible for about 99% of all low-level waste. Hence, the industry that stands to benefit most from this new alchemy—the nuclear power industry—would save money by avoiding the high cost of disposal. Instead of paying for proper storage, they could dump it down the proverbial drain.

With the passage of the Low-Level Radioactive Waste Policy Amendments Act of 1985, the Nuclear Regulatory Commission (NRC) was ordered to develop procedures for deregulating some portion of the low-level waste stream and declare it Below Regulatory Concern. However, because there is general agreement within the scientific community that no "safe" level of exposure to radiation exists, the determination is being made based on the "acceptable risk" to the U.S. population.



Determining an acceptable level of risk is a highly subjective undertaking. NRC

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policy stated in 1986 that "studies of comparative risks experienced by the population in various activities appear to indicate that an annual probability of death of the order of one in one million per year or less is not taken into account by individuals in their decisions as to actions that could influence their risks."

The convenient subjectivity of these assumptions is demonstrated when the same policy, just two years later, reads: "The Commission believes that annual individual fatality risks below approximately one in 100,000 are of little concern to most members of society. Providing for some margin below this level, the Commission proposes 10 mrem as the level of individual exposure."

In the United States, a risk of one in one million equals 250 fatal cancers per year, while one in 100,000 equals 2,500 fatal cancers. Which level it is that members of society are not concerned about is not made clear by the Commission.

This kind of change in policy seems to be more a justification for a 10 mrem exposure level than an unbiased scientific determination. The 10 mrem level is twice that allowed by the United Kingdom's National Radiological Protection Board, which allows a total exposure of 5 mrem but limits the exposure from each waste source to only 0.5 mrem. Meanwhile, the NRC believes that multiple waste streams in the U.S. "probably" would not accumulate in such a way as to expose any individual to more than 10 mrems per year. However, the NRC policy document goes on to explain that "some individuals may receive doses near the 100 mrem per year limit when doses from other practices are taken into consideration." A typical chest x-ray, for example, emits approximately 20-30 mrems by itself and the latest analysis of the data from the Radiation Effects Research Foundation's Life Span Study of Hiroshima and Nagasaki Survivors indicates that low-level radiation may be 10 or even 20 times more dangerous than previously thought.

"The entire BRC regulatory...process, has involved bad science, bad policy, and a flagrant disregard for public health."

As might be expected, these kinds of proposed risk levels are causing much consternation at the Environmental Protection Agency (EPA). The EPA is charged with "protecting human health and the environment" by evaluating all risks from environmental hazards and setting appropriate standards for safety. Now, the EPA is required to establish a "regulatory cutoff practice" for BRC radioactive waste dumping.

In October of 1988 the EPA proposed regulating BRC radioactive waste exposure to less than one mrem per year, while the NRC wanted to allow exposures as great as 100 mrems. These standards are orders of magnitude apart and cannot both be correct.

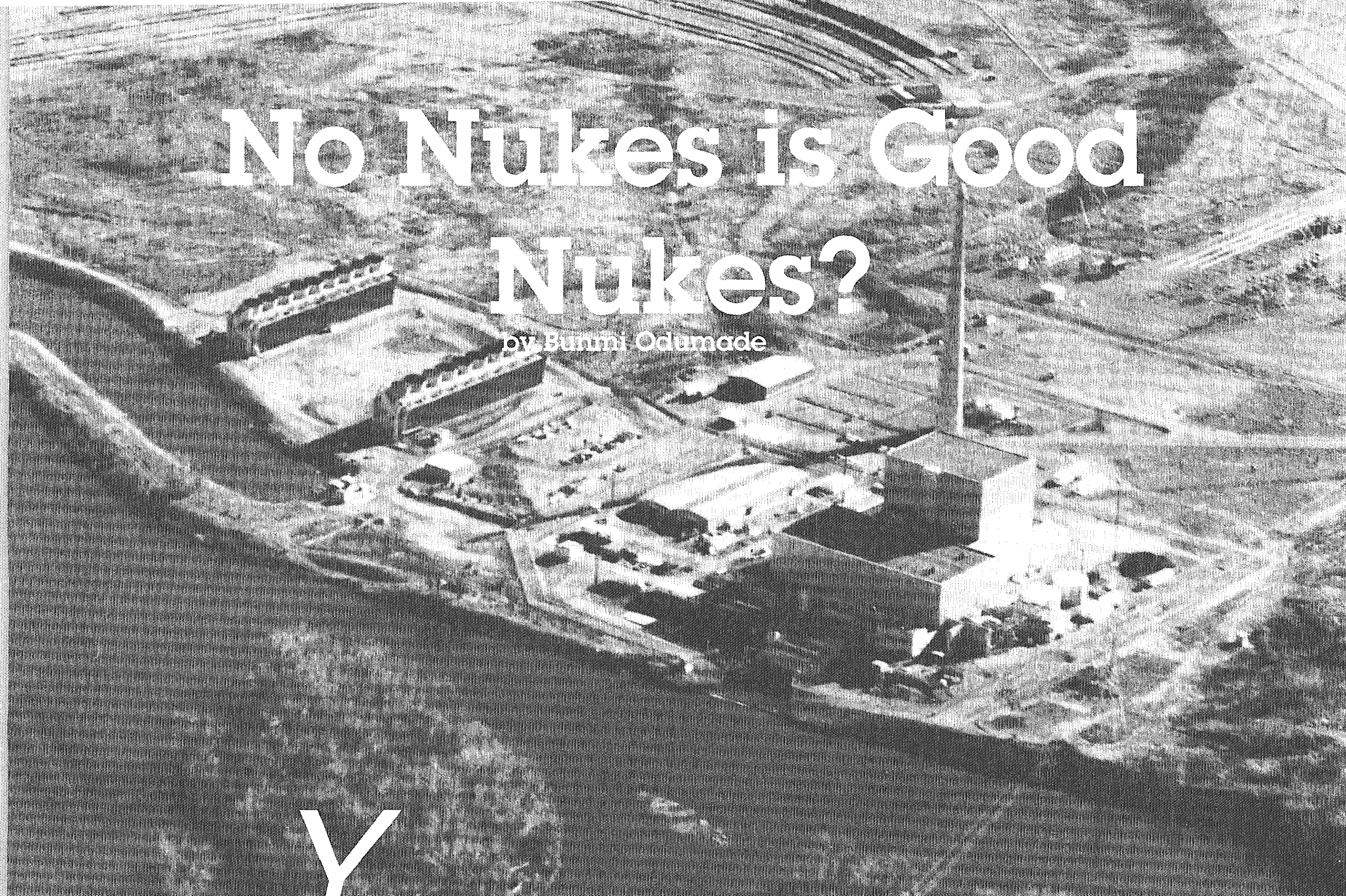
By March 7, 1989, the EPA was able to propose a policy aimed at solving the regulation dilemma. In an official policy statement the EPA proposed four separate methods of calculating acceptable risk. The traditional approach, in line with the limits the EPA allows for other toxic materials allowed one fatal cancer per million people per lifetime; another method allowed one fatal cancer per 100,000—a standard ten times less stringent than usual EPA standards. Perhaps it was no coincidence that the less stringent standard allowed the desired 10 mrem exposure the NRC wants.

There exists much uncertainty regarding the long-term health risks of low-level radiation, and until we know more, all radioactive waste should be properly stored separate from the rest of the environment and monitored just as we have done since 1970. The entire BRC regulatory (or rather deregulatory) process has involved bad science, bad policy, and a flagrant disregard for public health. The BRC policy should be abandoned, but if we as individuals do nothing to stop this process, radioactive waste will soon be dumped into the environment. The time to act is now. ☐

MICHAEL LEE graduated from the U in1968 with a degree in psychology and later earned a sociology Ph.D. at American University. He is currently MPIRG's Research Director and is specifically interested in environmental sociology and risk assessment.

No Nukes is Good Nukes?

by Bunmi Odumade



Yes!" "No!" "We need it now!" "It's expensive!" "It's efficient!" "It's dangerous!" "Develop it!" "Ban it!"

Wonder what all the commotion is about? That's right...another nuclear energy debate. Nearly every speaker, article, or book on the topic is strongly for or against it. What's needed is an unbiased discussion about nuclear energy as a source of electricity.

The Nuclear Family

In humankind's endless search for new and more powerful forms of energy, it was inevitable that we would eventually turn to nuclear power. By breaking the strongest force known—the force binding neutrons and protons in atomic nuclei—we are able to harness tremendous amounts of energy. During nuclear fission (Figure 2), atomic nuclei are split by neutron bombardment, releasing the binding energy as heat and radiation. In addition to energy and fragmented nuclei, a fission reaction also generates neutrons that can split other nuclei. If an adequate supply of fissionable material is present, neutrons are continually released and reused, resulting in a self-sustaining chain reaction. It is important to note, however, that a speeding neutron must be slowed before it can react with a nucleus. A fission reaction cannot occur without the presence of some material to sufficiently retard the movement of free neutrons.

Given the basic nature of fission reactions, every nuclear reactor has several essential parts. The "core" consists of the uranium fuel that undergoes fission. A "moderator" (usually water or graphite)

ABOVE: NUCLEAR POWER PLANT AT MONTICELLO, MN

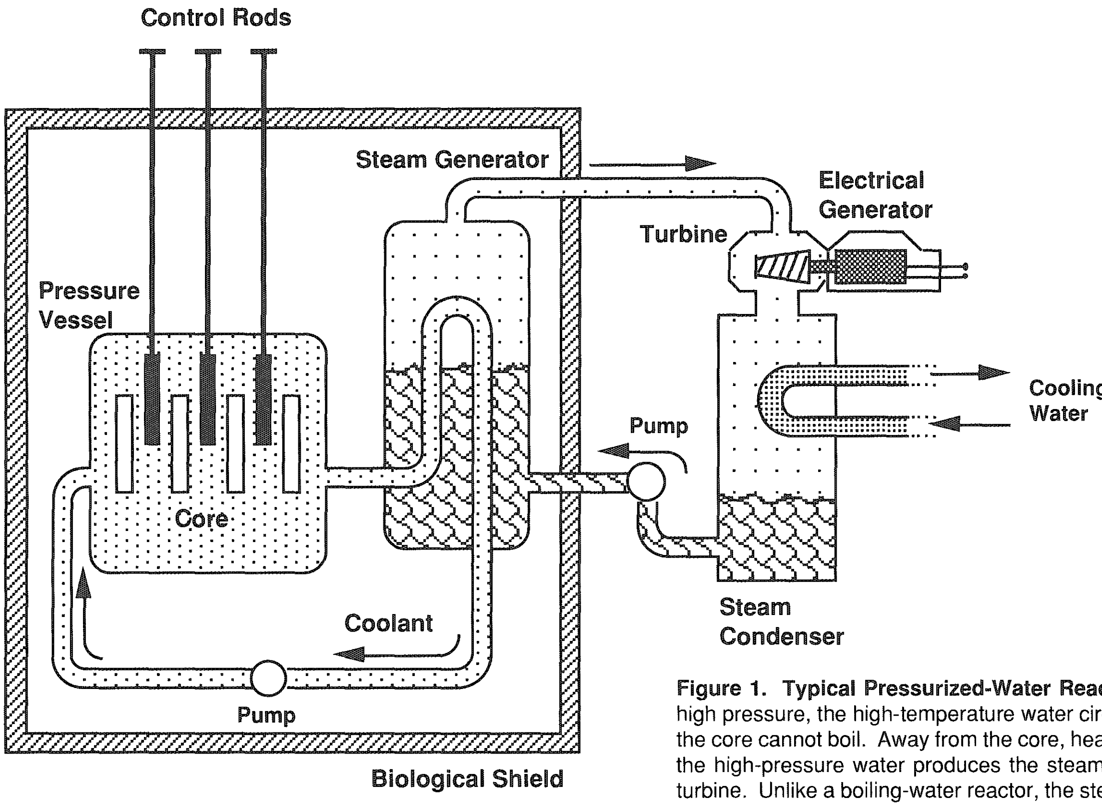


Figure 1. Typical Pressurized-Water Reactor. Due to its high pressure, the high-temperature water circulating through the core cannot boil. Away from the core, heat extracted from the high-pressure water produces the steam needed by the turbine. Unlike a boiling-water reactor, the steam that powers the turbine is not radioactive.

serves to promote a chain reaction by slowing neutrons as they pass through it. "Control rods" are present to give reactor operators a means of regulating the core's chain reaction rate. Control rods, which can absorb neutrons entirely (rather than just slow them), can be inserted into the core when it's necessary to slow or stop the fission reaction.

Once a chain reaction is underway, a "coolant" carries away the heat produced so that it can be used to power a turbine and generate electricity. The coolant can be liquid, gas, or liquid metal, and reactors are classified according to their coolant type. Pumps constantly circulate the coolant, ensuring that the core doesn't overheat. A "pressure vessel" surrounds the core of most reactors and contains the circulation channels for the high-pressure coolant. Furthermore, the pressure vessel's walls are lined with thick steel in order to control the radiation emitted from the core. Workers are further protected from radiation exposure by a concrete "biological shield" surrounding the pressure vessel.

There are many different types of reactors, but the two types most commonly used in the United States are pressurized-water reactors and boiling-water reactors.

A pressurized-water reactor (PWR) uses ordinary water as both its moderator and coolant (Figure 1). Its cylindrical core contains thousands of long, thin vertical rods packed with uranium fuel pellets. Pressure in the pressure vessel is kept so high that the coolant can become extremely hot and still not boil.

"A nuclear plant requires far less fuel than a fossil fuel plant to produce an equivalent amount of energy."

Heated by the fission reaction, the high-pressure coolant exits the pressure vessel and enters a heat exchanger where steam is produced. The heat exchanger, usually referred to as a steam generator, is very long and contains thousands of tubes through which the cooling water circulates. Heat passes through the walls of the tubes from the hot, pressurized coolant to the surrounding water. Although the surrounding water is at the same temperature as the liquid coolant, it actually boils because it's at a lower pressure. The resultant steam is piped from the steam generator to a turbine that drives an electrical generator. This path to the turbine never passes through the core, so the steam is not radioactive. In essence, the heat exchanger isolates the steam from the radioactive coolant and core.

Boiling-water reactors (BWR) have cores similar to those in PWRs, and they also use ordinary water as their moderator and coolant (Figure 3). Unlike PWRs, however, the pressure inside the reactor vessel is low enough for the coolant to boil. Thus, the steam used to power the turbine is generated within the core itself, making it radioactive. Compared to a PWR, a BWR has an advantage in that no separate steam generator is required.

Good Nuke, Bad Nuke

When compared to their coal or oil counterparts, the nuclear reactors described have some clear-cut advantages. For one thing,

ILLUSTRATIONS BY BRIAN NEURAUTER

a nuclear plant requires far less fuel than a fossil fuel plant to produce an equivalent amount of electricity. Consider: fissioning one pound of uranium produces as much energy as 3,000,000 pounds of coal. Granted, naturally occurring nuclear fuel is in short supply, but if nuclear power was fully exploited, it could replace coal and oil as a source of the world's electricity for thousands of years. Furthermore, nuclear power does not pollute the air, an important consideration given the environmental problems caused by acid rain and global warming.

Despite the seemingly attractive alternative nuclear power offers to the continued consumption of fossil fuels, nuclear opponents assert that the disadvantages far outweigh any advantages. At every step in the life cycle of a nuclear power plant, including construction, operation, and decommissioning, observers claim that nuclear power presents serious economic, technical, and environmental problems.

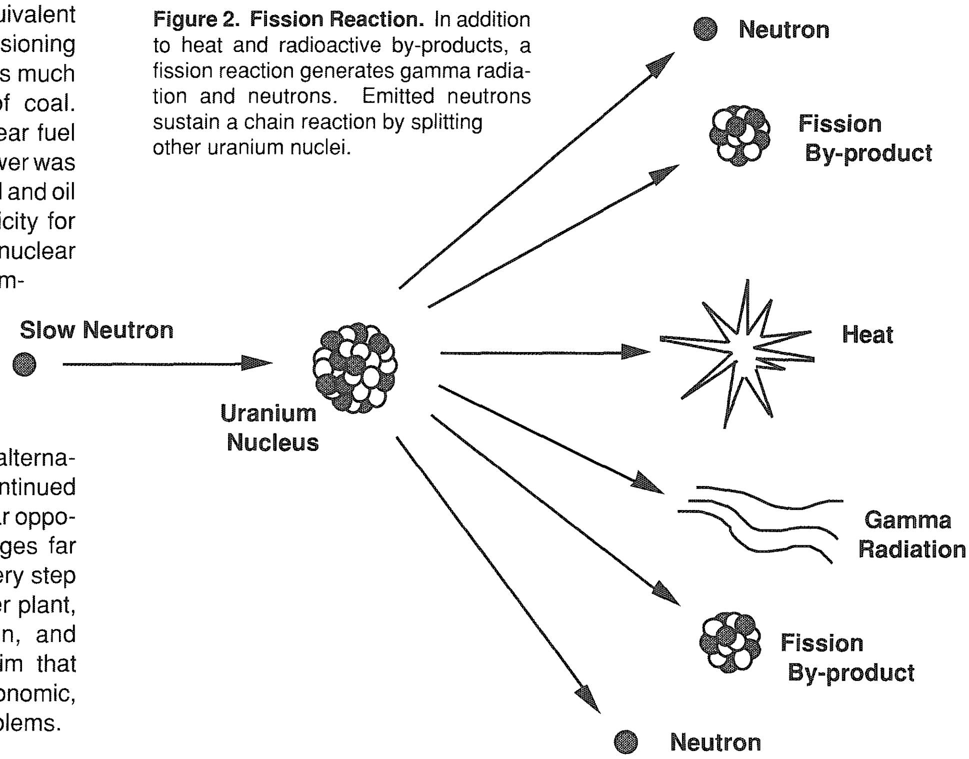


Figure 2. Fission Reaction. In addition to heat and radioactive by-products, a fission reaction generates gamma radiation and neutrons. Emitted neutrons sustain a chain reaction by splitting other uranium nuclei.

One of the largest problems cited by critics is the enormous cost of constructing a nuclear power plant. Although the plant may later generate cheap electricity (due to low fuel consumption), equipment failures and other unexpected problems can prevent the up-front cost from ever being recovered.

Also, once constructed, operating a nuclear plant undoubtedly poses more potential hazards than a comparable fossil fuel plant. To minimize the risk of an accident (see sidebars), nuclear power plants are heavily regulated. There's considerable debate, however, whether regu-

Incident at Three Mile Island

This infamous accident happened in the PWR at the Three Mile Island Station, Unit 2 (near Harrisburg, Pennsylvania) on March 28, 1979.

"With normal cooling interrupted, the core became fiercely hot, melted, and collapsed."

The accident began when the main water supply to the plant's two steam generators was lost. Since no water could enter the steam generators, the pressure and temperature in the core rose because its heat was not being dissipated by the steam generator. In response to the rising temperature and pressure, a motor-operated pressure relief valve opened to reduce pressure in the core. Unfortunately, when pressure dropped to a safe level, the valve failed to automatically close. Consequently, core pressure continued to fall, triggering the emergency core-cooling system. Subsequently, a worker incorrectly interpreted pressure readings to mean that there was a high level of water in the core, and decided to shut down pumps that supplied the steam generators. As a result, the generators were losing water when they desperately needed it.

The problem was compounded when two coolant pumps supplying the core were shut down to protect them from excessive vibration. With normal cooling interrupted, the core became fiercely hot. Much of the upper part of the core melted, collapsed, and plugged the gaps between fuel rods. This partially blocked steam and water flow, further inhibiting core cooling. Heavily radioactive water now gushed through the open pressure relief valve. In spite of the accident's seriousness, a total core meltdown did not occur.

The accident resulted from a combination of design deficiencies, inadequate procedures, and operator error. Because of design changes and new regulations, a similar type of accident is unlikely to recur.

"The accident resulted from a combination of design deficiencies, inadequate procedures, and operator error."

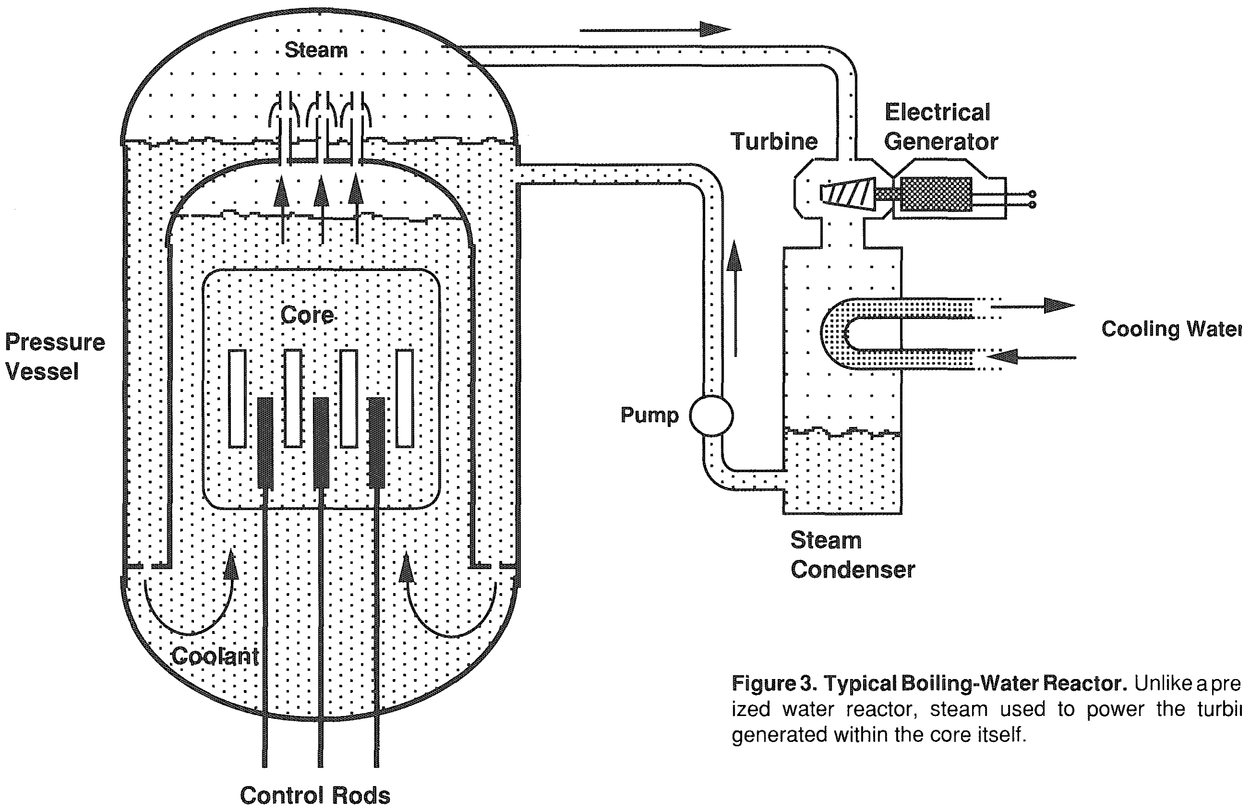


Figure 3. Typical Boiling-Water Reactor. Unlike a pressurized water reactor, steam used to power the turbine is generated within the core itself.

lations, standard inspections, and licensing ensure sufficient safety. Author and Registered Professional Engineer Petr Beckmann says "There is no such thing as safe energy conversion on a large scale. Energy is the capacity to do work and as long as man is fallible, there is always the possibility that it will do the wrong kind of work." Though this is undoubtedly accurate, Michael Lee, Research Director for the Minnesota Public Interest Research Group (MPIRG), points out that, "If you take the worst-case scenario between coal, nuclear, and solar, none would be as dangerous as a nuclear accident."

A further operating hazard arises from the waste generated by a nuclear plant. When uranium undergoes fission, the resulting by-products are radioactive; some remain dangerous for 600 years, others for thousands. Highly toxic "high-level" waste constitutes four percent of the total waste generated within the reactor's core.

Nuclear power proponents claim that banning nuclear power won't significantly reduce waste generation since the defense industry produces considerably more high-level waste than the commercial power industry. Furthermore, the United Nations Scientific Committee on the Effects of Atomic Radiation has figures to show only 0.01 percent of the radiation exposure experienced by average Americans comes from nuclear power.

"'The nuclear power industry did not consider the cost of decommissioning. What they did was hope that technology in 30-35 years would provide some solution to the problem.'"

Despite these assurances that commercially-generated waste is low volume and well isolated, nuclear opponents believe that disposing of high-level waste is a problem that has yet to be satisfactorily solved. Currently, underground storage sites for spent fuel rods and other radioactive waste are being built under the assumption they'll remain isolated from future generations. Michael Lee disagrees, claiming, "I have not heard one expert yet say that they can isolate high-level waste...Geologists say that if you bury it deep in a depository it will be up on the surface before the 'safe level' is reached....I think the waste problem is unsolvable."

Aside from problems concerning construction costs, accidents, and waste, aging nuclear plants now present another costly and hazardous dilemma—decommissioning. Once the useable lifetime of a plant has expired, it must be dismantled and the site left for other uses. To date the decommissioning process has only been initiated on one plant, and this is on a facility smaller than most plants operating today. In this case, the decommissioning is slated to last five years (ending in 1990) at an expected cost of nearly 100 million federal dollars. Cost estimates for decommissioning a current commercial plant range from $100 million to $3 billion.

In addition to the costs, decommissioning also raises the question of how to dispose of the radioactive reactor remains. There's debate whether to remove the large pres-

Russian Roulette

The most deadly accident in the history of nuclear power occurred at Chernobyl Station Unit 4 in the Soviet Union on April 26, 1986. Prior to this accident it was widely assumed that nuclear power plants could not explode like atomic bombs. Chernobyl changed that.

"Prior to this accident it was widely assumed that nuclear power plants could not explode like atomic bombs."

Like many other reactors in the Soviet Union, Chernobyl Unit 4 used graphite as its moderator and water as its coolant, unlike most U.S. reactors, which use water for both. Additionally, Unit 4 had a slow-insertion control rod system, and no containment structure surrounded its reactor.

Refueling a reactor of a Chernobyl-type design is a risky process because the graphite moderator is unable to fully suppress a chain reaction in new fuel. According to a Nuclear Regulatory Commission (NRC) report, "...the large, enriched uranium fuel load creates many critical masses in the core. The control rod system alone is not sufficient to hold the core subcritical for the initial loading." To make matters worse, workers in charge of refueling took many reckless shortcuts (such as removing the control rods) that disabled safety systems. When part of the core went out of control, the lid over the pressure vessel lifted, rupturing the water tubes and touching off a steam explosion. According to nuclear power commentator William Sweet, the first explosion "...set the stage for a second explosion, which was much more violent than the first and almost certainly was a full-fledged nuclear explosion." Overall, the accident killed 31 people, and another 170 suffered radiation injuries.

Such an accident is not likely to occur in the U.S. because our reactors do not use graphite as a moderator. Unlike Chernobyl Unit 4, the nuclear reaction in U.S. plants slows down when water is lost, since water is the moderator facilitating the reaction. According to William Sweet,

"Workers in charge of refueling took many reckless shortcuts that disabled safety systems."

"A fizzling steam explosion could occur in a U.S. reactor if a molten core dropped into a pool of water, but the possibility is remote and the result would not be the enormously violent nuclear explosion that destroyed Unit 4."

sure vessels intact, or carve them into small pieces. The latter choice, besides being costly, exposes workers to radiation. Martin Pasqualetti, decommissioning expert at Arizona State University, says that while "it's a lot cheaper and safer to take the vessel out whole, it does not seem feasible for larger reactors." Michael Lee believes that "the entire nuclear power industry did not consider the cost of decommissioning and I think this is the biggest fault they had. . . .They, as far as I can tell, preferred not to know. What they did was hope that technology in 30-35 years would provide some solution to the problem." Unfortunately, it has not.

As long as no viable alternatives to traditional, fossil-fuel-based energy sources exist, the nuclear debate will rage on. However, the options at this time seem fairly cut and dry: Abandon nuclear power as too costly and hazardous, or develop it, despite its inherent risks, as an environmentally sound alternative to traditional fuels. □

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minnesota TECHNOLOG

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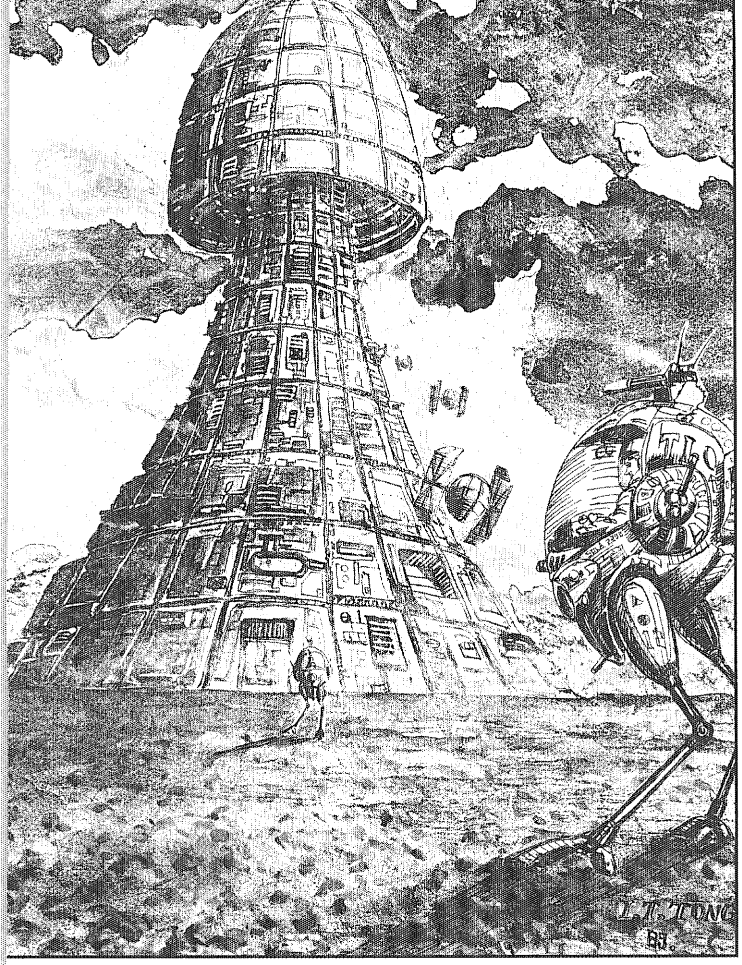
Bunmi Odumade is a second-year ME major who plans to attend grad school. Claiming to lead an exceptionally boring life, she's also active in SWE and works as an undergraduate tutor.



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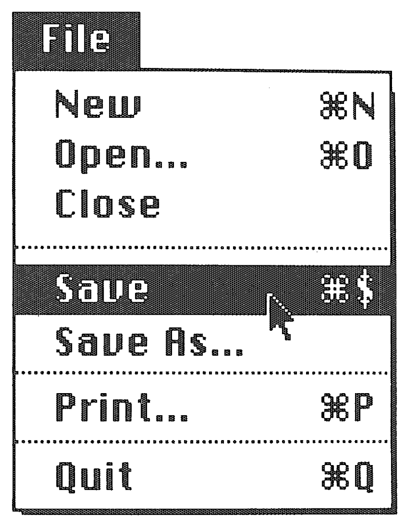
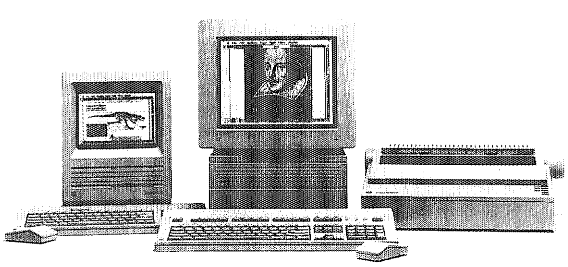
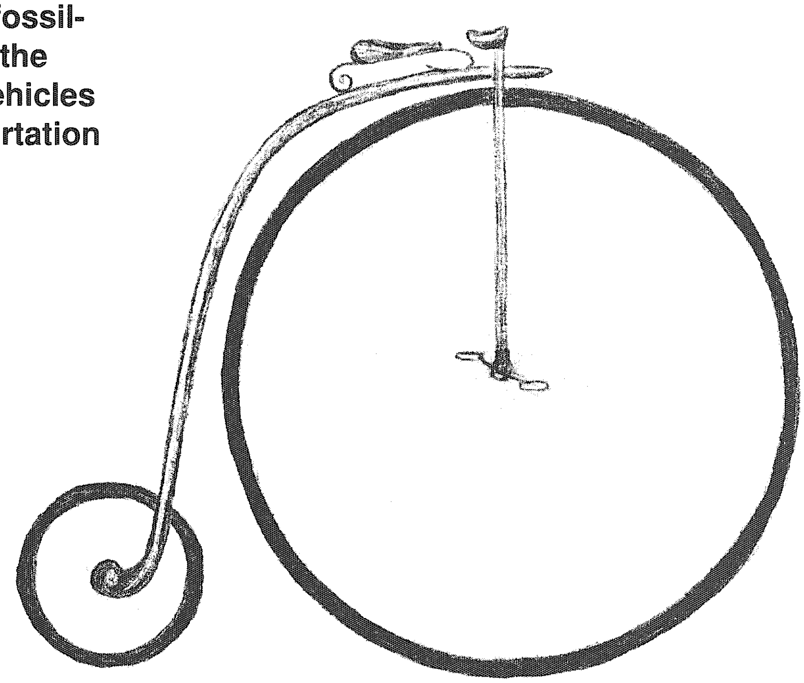




Wild Thing, You Move Me

by Darin Warling

A human engine. Can it propel us away from the filth-ridden, fossil-fuel oblivion awaiting us in the future? Human-powered vehicles may be tomorrow's transportation of choice.

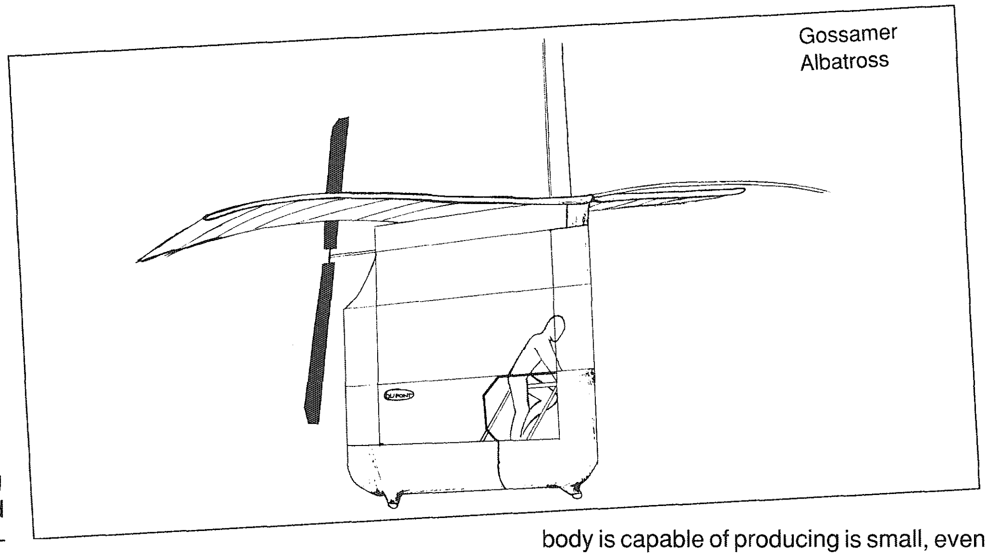


People, as a source of power, have largely been ignored during the 20th century due to the exploitation of cheap, non-renewable resources. However, since civilization obviously didn't begin with the advent of the internal combustion engine, our technological evolution has its roots in human power. Indeed, *homo erectus* hoofed about as a self-contained unit. Every bit of usable energy was stored in his or her own body, and the supply constantly needed replenishing, which was no mean feat; remember, *homo erectus* existed before the Age of the Big Mac. Food was not purchased at the supermarket. Rather, it was stalked, bashed with a large rock, dragged back to the cave, gutted, and, if the diner was lucky, cooked.

Okay, now let's skip ahead a couple of years to, say, a few thousand years B.C. Finally—a life of relaxation, thanks to the miracle of modern agriculture. Granted, tending the crops and herds demanded physical labor, but food no longer had to be hunted. It just sat there, complacently waiting to be harvested.

The final stop on this whirlwind tour of human-power history is the late 20th century. We awake to cacophonous digital alarms at 7:00 AM, shower under the delightful Select-O-Temp WaterJet, nuke our breakfast in the microwave, and zip off to our air-conditioned high-rise offices in petrol-powered autos, spending the rest of the day crunching numbers on battery-powered calcula-

ILLUSTRATIONS BY JOYCE RAJENDREN



Gossamer Albatross

tors, shuffling paper, and making telephone calls. Note how little of our time is spent chasing down mammoth for dinner. The brain does most of the work these days, leaving the body as little more than a collection of vestigial organs and flaccid muscle that exists only as a life-support system for the cerebrum.

Rather than relying on human muscle, the modern world has been converted to run on another source of energy: fossil fuels. They are cheap, plentiful (at least for now), rich in energy, and easily converted into useful work. Unfortunately, they won't last forever and the pollution they generate is toxic to both humans and the planet alike, threatening to turn the Earth into a barren wasteland unfit for habitation.

Obviously energy consumption can't go on forever the way it is now. Alternate energy sources will have to be exploited, especially those that are both renewable and clean such as the sun, wind, and water. In other words, we'll probably revert back to the same energy sources our ancestors used for hundreds of thousands of years, including human power. This is not as radical as it sounds—human power has received a lot of lip service, especially during the energy crunches of the 1970s. Unfortunately, just like other alternate energy supplies, not much has come of it, except in one area—human-powered transportation. This may be the one technology that's ready to help us exploit the power of human muscle rather than continue our fatal love affair with fossil fuels.

The Human Machine

The biggest problem with human power is that people just can't put out the same amount of power as fossil fuels, nor can they do it as steadily. The human body is basically a fuel cell whose sole purpose in life is to convert chemical energy into mechanical work so the brain can carry out its whims. It's a fairly small, inefficient power plant that needs to constantly burn fuel to keep running, even if no useful work is being done. The only time it stops using fuel is when it shuts down for good.

The amount of power the human body is capable of producing is small, even when compared with the modern econo-box auto. An average healthy adult male is able to generate a peak output of 950 W (1.3 h.p. or thereabouts), but only for a burst of about 5 seconds or so. Power output drops off sharply after that, to an average of 200 or 300 W over the course of an hour, and finally slopes downward to an average of 75 W (0.1 h.p.), which can be maintained for an indefinite length of time without significant fatigue. The Hyundai Excel GLS, on the other hand, is able to generate a constant 60,400 W (81 h.p.) as long as its gas tank holds out, and even then it can be refilled immediately, whereas a human needs a hearty meal and a good night's sleep before doing it all over again.

"The brain does most of the work these days, leaving the body as little more than a collection of vestigial organs and flaccid muscle that exists only as a life-support system for the cerebrum."

A meal and a good night's sleep are two problems that crop up in human-generated power, but not in other sources. The meal is needed to provide a fresh supply of energy, since the body is unable to store any appreciable amount of energy except in the form of body fat (which cannot be quickly converted to energy). Although one kilogram of body fat contains the equivalent of 32.3 megajoules (MJ) of energy, this is relatively small considering that one kilogram of gasoline holds about 46.4 MJ of energy, nearly 50% more than body fat. The need for a good night's sleep is merely the symptom of what is actually a two-part problem: 1) the body is running low on energy and needs time to replenish its depleted reservoirs, and 2) the body is able to use energy faster than it can dispose of the waste, leading to what is commonly called fatigue.

So, you might ask, if people are such poor generators, why should we bother developing human-power technology in the first place? Why not keep using our fossil fuel supplies until they dry up? These are good questions, and they are easily answered: The human body is able to convert stored chemical energy into usable power in a cleaner manner than fossil fuels and it uses energy more efficiently. The only fuel we need is food and water, both of which are adequate across most of the world. We eat food, break it down, store it for later use, and then call it up anytime we please with a little oxygen and a minimum of fuss. The only by-products of the process are carbon dioxide, heat, and organic waste, all which can be quickly reabsorbed by the environment.

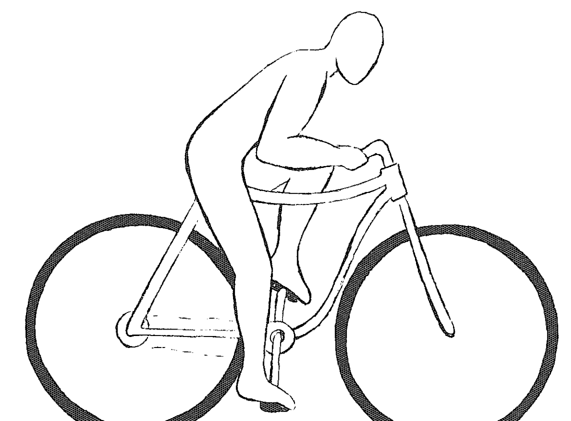
The Evolution of Pedal Power

Even though output is small and delivery uneven, human muscle is still able to generate enough power to replace fossil fuels in many instances, transportation being a good example. Human muscle has been used to power canoes, rowing shells, recreational paddle boats, high-performance hydrofoils, and even airplanes, as demonstrated by Paul MacCready's 27 kg (60 lb) *Gossamer Albatross*, which crossed the English Channel in 1979 at an average speed of 16 km/h (10 mph). More recently, the human-powered *Daedalus* flew from Crete to the Greek mainland during the summer of 1988.

> **"In 1984 two students from Northrup University broke the 55 mph speed limit in an HPV and were subsequently issued an honorary speeding ticket from the California Highway Patrol."**

Overcoming Air Resistance—It's a Drag

In 1973, Bill Abbott, a California physician, took to the Bonneville Salt Flats on his bike. Pedalling briskly, he achieved a top speed of 223.1 km/h (138.7 mph).



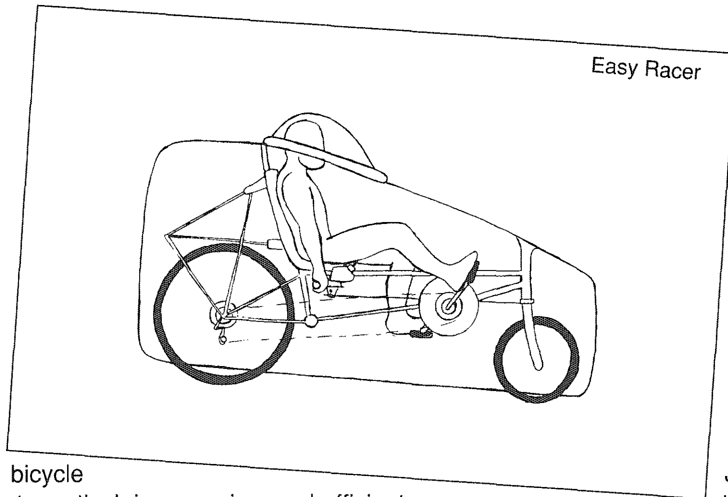
Rover Safety Cycle

In contrast, you may have noticed that you haven't been able to manage much over 40 km/h (25 mph) on your trusty Huffy. Although in better shape than ordinary bicyclists, speedster Bill Abbott had another, more significant advantage—a pace car drove directly in front of his bike, cutting the wind for him. Even at a mere 30 km/h (19 mph), air drag accounts for over 80% of the force against a bike and rider. Because drag force is proportional to the square of velocity, exceptional aerodynamics are the key to high speeds.

The bulk of air resistance is generated in two ways: pressure drag and skin drag. Pressure drag occurs when the airflow around an object fails to follow the surface contours smoothly, resulting in turbulence. Skin drag, on the other hand, is the result of air's viscosity, which creates shear forces along the object's surface that oppose its motion. Both of these are rolled into a single number called the drag coefficient, and because shape generally has a bigger influence on drag than surface finish, this is the biggest design consideration of a high-speed vehicle. For example, a perfect sphere is an inefficient shape because its rear is not tapered (unlike a teardrop's), resulting in a turbulent wake. This is reflected in the sphere's drag coefficient of 1.3, while a teardrop has a drag coefficient of less than 0.1. The drag coefficient for an average car is between 0.3 and 0.4, while the coefficient for a standard bike and rider is about 0.8.

Another way to improve aerodynamic performance is to reduce the vehicle's frontal surface area. Since motion generates dynamic pressure, which is measured in force per unit area, a frontal area must be specified before a drag force can be calculated. Reducing frontal area reduces drag force, thus lessening the power needed from the rider. This explains why recumbents are so much faster than standard bikes: When a rider is horizontal, his or her surface area is much smaller than when vertical, by as much as a factor of ten.

Air density also influences aerodynamic performance of a bicycle. For example, on the Mexico City velodrome, which is at an elevation of 2260 m (7400 ft), track records are routinely 3 to 5% faster than those of other tracks because of the difference in air density. On the moon, which has basically no atmosphere and only one-sixth the earth's gravity, you could theoretically cycle all day at 380 km/h (238 mph) using only 75 W (0.1 hp) of power; furthermore, you could achieve a top speed of around 4000 km/h (2500 mph) for a short period of time. Even show-offs like Dr. Bill Abbott would be impressed.



Despite its flashy air and water counterparts, the bicycle has proven to be the most practical, inexpensive, and efficient human-power technology yet developed. The lowly bicycle has historically been an efficient and enjoyable mode of travel, beginning with the advent of the first recognizable "modern" bicycle, the Rover Safety Cycle. It was designed and built in 1884 by John Starley and William Sutton in response to the unwieldy and dangerous monstrosity known as the "ordinary" high-wheeler, which basically consisted of a tiny rear wheel and a seat mounted over an enormous 152 cm (60 in) driving wheel.

After the arrival of the safety bike, technological development continued at a steady pace. The next major step was the invention of the pneumatic tire in 1887 by a Scottish veterinarian named John Boyd Dunlop (who created it to soften the ride of his son's tricycle). These not only provided more comfort but were also faster, and within a few years solid tires had virtually disappeared from the market, making Mr. Dunlop a millionaire in the process. Following the advent of the pneumatic tire was a long period of transmission development, mostly in Europe, which ended in the 1920s with the modern derailleur system.

One of the last major steps taken during this period was the development of the first recumbent bicycles, in which the rider reclines in a seat rather than perching high atop one, allowing the pedal/force reaction to be countered by the backrest rather than the body's weight. The first semi-recumbent appeared in the United States around 1895, followed by the first full recumbent in 1901, but they never really caught on stateside. They were somewhat more successful in Europe, and France introduced the first fully-developed racing recumbents in the 1930s. Using a streamlined, supine bike built by Charles Mochet, an obscure French cyclist named Francis Faure defeated the world champion in a 4 km (2.5 mile) pursuit race and broke a large number of track records, prompting the world cycling governing body to ban recumbents and all aerodynamic devices beginning in 1938. This effectively halted the evolution of the bicycle for the next four decades.

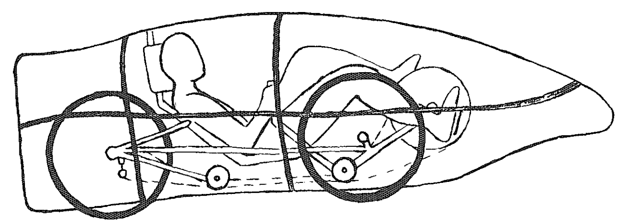
The bicycle once again became a machine of interest following the 1972 oil embargo and the rise of the environmental movement. In 1973, Chester Kyle and Jack Lambie began quantitatively testing streamlined bikes and concluded that the force necessary to power the bike could be reduced by 60% using a wing-shaped enclosure over both the bike and rider. This set off a storm of development. In 1975 the first human-powered vehicle (HPV) race was held. Fourteen teams entered and the winner attained a top speed of 72.2 km/h (44.9 mph). In 1984 two students from Northrup University broke the U.S. national speed limit in a recumbent tricycle called *White Lightning* and were subsequently issued an honorary speeding ticket from the California Highway Patrol. In 1988, *Easy Racer*, a Kevlar-skinned recumbent managed 105 km/h (66 mph).

"Current HPVs lack basic creature comforts such as upholstered seats, AM/FM stereos, air-conditioning, and power windows."

Future of Human-Powered Locomotion

Though capable of remarkable speeds, will any of these bicycles ever be of practical use? As it stands, a human-powered highway-speed vehicle is completely impractical. First of all, when a record is set, it's done by a world-class athlete. Secondly, the bikes (or planes or boats or whatever) are highly specialized. They have no room for a sack of groceries or a couple of small children. They are not meant to bounce over potholes or go from Minneapolis to Duluth. They lack basic creature comforts such as upholstered seats, AM/FM stereos, air-conditioning, and power windows. They lack basic safety features such as seat belts, rearview mirrors, windshield wipers, and headlights. Finally, you sweat an awful lot when you're putting out 500 W (0.67 hp), because only about 25% of it is actually transferred to the pedals. The rest comes out as heat.

In short, HPVs haven't been engineered for the real world, as demonstrated by the *Vector Single*, which weighs in at a hefty 36



Vector Single

kg (80 lb), eight times heavier than a standard racing bike. Using 750 W (1 hp), it's possible to climb a 6% grade at 18 km/h (11 mph). However, it is also possible to descend that same 6% grade at 161 km/h (100 mph) or more. Unfortunately, the *Vector Single* has no brakes.

A more reasonable objective for human-powered transportation might be a small commuter cycle that's as comfortable as the average mountain bike, yet engineered for an urban asphalt assault. It would be a streamlined, covered recumbent tricycle, built of carbon fiber, aluminum, and thin plastic. It would weigh around 25 kg (55 lbs) and have a cruising speed of 32-40 km/h (20-25 mph). This is quite a bit faster than your average mountain bike, plus it would have a few amenities to boot—a comfortable seat, a small storage area, windshield wipers, mirrors, and a tiny rechargeable battery to power headlights and turn signals and such. And finally, as an extra bonus option, it would probably come equipped with a lightweight fossil-fuel engine to aid in climbing those nasty hills, thus converting your vehicle into a true moped, unlike the motorized scooters of a few years ago that were little more than glorified, underpowered motorcycles. The total cost of this dream vehicle would be about $1000.

Given the state of the art in human-power technology, what does the future hold? Human power, especially human-powered transportation, is an energy source that has yet to realize its full potential, and the situation will probably remain this way for a good number of years—at least until fossil fuels become more scarce. In many third-world nations bicycles are already the standard for both personal transportation and light hauling, but bike designs will continue to evolve toward maximum efficiency and usefulness. The mountain bike, which gained widespread popularity only a few years ago, is already a step in this direction. As far as general bicycle design goes, the standard non-recumbent bike is likely to remain the norm due to its simple, inexpensive, and sensible design, although recumbents will continue to become more and more common.

As it stands, we are currently using about 0.005% of the sun's incident energy, but if energy consumption continues to double every decade, within 150 years we will consume energy at the same rate the sun delivers it. Obviously, serious environmental problems will have cropped up by then, and although the lowly bicycle is at a loss to halt, or even much slow, our headlong rush towards oblivion, it's at least a token gesture of resistance. ☐

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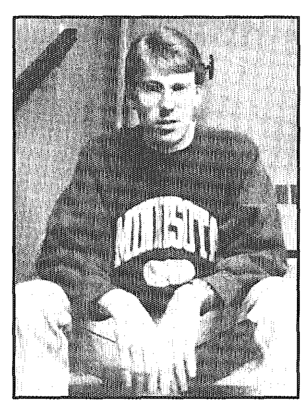
Writer Profile: Darin Warling

Darin, pictured here during the middle of finals week, is a junior majoring in CSci and ME. He believes life is an improper triple integral in polar coordinates that requires obscure trigonometric identities to solve. Do *not* be alarmed by the valve sticking out of his head.



Hot and Cold Running Fusion

By Nathan Malby

Though far removed from the limelight, many researchers continue to search for clues to the cold-fusion mystery. Meanwhile, government and industry leaders place their bets on the future of fusion technology, hot and cold.

So whatever happened with that cold fusion thing anyway?

Last spring, *Minnesota Technolog* ran an article (Spring Two, 1989) explaining what was then a hot controversy. Now cold fusion seems to have cooled off and fallen from the headlines and into the backs of people's minds. Was it an idea that just didn't pan out? Or will it someday revolutionize energy production around the world?

The Rise and Fall of Cold Fusion

Following the March announcement of the discovery of cold fusion by Utah experimenters Pons and Fleischmann, hundreds of scientists around the world rushed to confirm the discovery by recreating the experiment in their own labs. Excitement quickly faded, however, when no one could duplicate the exact results reported in the original experiment. Some experimenters detected heat, others found neutrons or other fusion by-products, but none reported both heat and neutrons in the same experiment. Without verification of heat production with fusion by-products, the theory that fusion was occurring could not be supported.

The claims made by the Utah experiment were simply too fantastic to be accepted without outright proof. Pons and Fleischmann were declared deluded, incompetent, even outright frauds. They were severely criticized for their failure to perform simple tasks dictated by the scientific method such as control experiments with ordinary water. Experts also questioned whether their calorimeters (heat measuring devices) were properly calibrated. Eventually, due to inexact measurements, Pons and Fleischmann retracted their claims, and their data was dismissed by the scientific community.

Theoretical evidence against cold fusion mounted as well. According to two scientists at the University of Illinois, fusion could not occur on a significant scale in an electrochemical cell. They showed that in order to explain the observed excess heat, fusion must occur at a rate about 3×10^{23} times greater than is theoretically possible. The Illinois scientists concluded that the excess heat measured by Pons and Fleischmann must have been caused by a chemical reaction, not a nuclear reaction.

"Pons and Fleischmann were declared deluded, incompetent, even outright frauds."

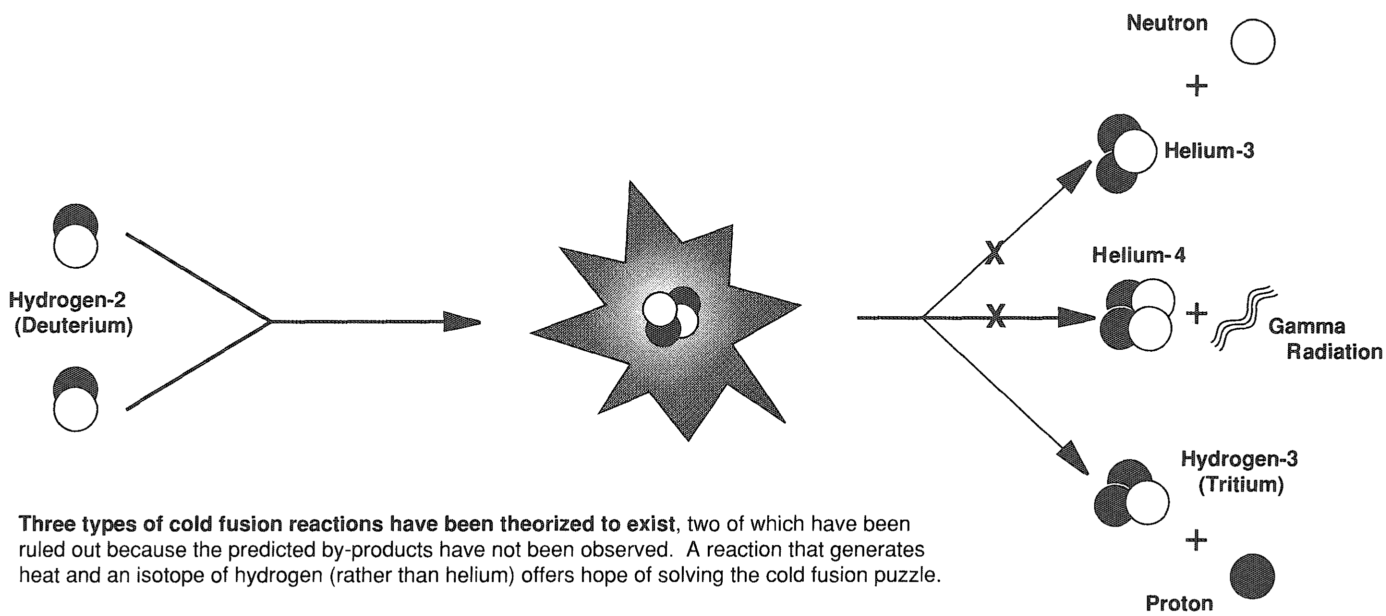
Finally, the U.S. Department of Energy (DOE) asked its Energy Research Advisory Board to assess cold fusion research. The board issued its preliminary report in July, stating that no results were "sufficiently free of ambiguities to make us confident that the steady production of excess heat has been observed." Concluding their assessment, the board said, "experiments reported to date present no convincing evidence that useful sources of energy will result from the phenomenon attributed to cold fusion." It became evident that although something might have been going on that no one fully understood, few were willing to believe that it was actual fusion.

If at First You Don't Succeed...

Undaunted, some researchers continue to study the phenomenon, including those at Stanford University, the University of Minnesota, and Texas A&M.

The research team at the U of M is lead by Richard A. Oriani, a professor in chemical engineering. He and his colleagues, physics professors John Broadhurst and J. Woods Halley, were as skeptical as most scientists last spring. The first experiment run at the U of M with cold fusion (or "cathodic charging of deuterium and palladium" as Oriani calls it) produced no excess energy. Oriani then added heavy sulfuric acid to the electrolyte solution of lithium hydroxide and heavy water, lowering the pH of the solution to about two. Following this change in experiment design, a second run produced excess heat of 200 kilojoules (kJ). According to Oriani, if you assigned the excess heat production to a chemical reaction, it would mean an energy output of 5 million electron-volts per atom of palladium. "That's out of sight

"Cold fusion experimenters are confronted with a body of baffling data and unpredictable results."



Three types of cold fusion reactions have been theorized to exist, two of which have been ruled out because the predicted by-products have not been observed. A reaction that generates heat and an isotope of hydrogen (rather than helium) offers hope of solving the cold fusion puzzle.

for a chemical reaction," says Oriani. "I'm inclined to think that nuclear reactions are involved."

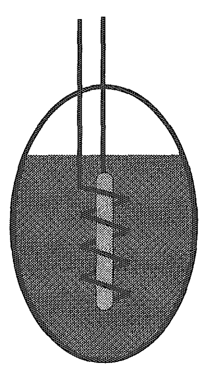
The third run was conducted using a palladium rod borrowed from chemists at Texas A & M University. Results similar to the second run were produced. Unfortunately, the experiment was "prematurely terminated" by a July 27th explosion that wrecked the lab equipment. Nevertheless, Oriani has obtained enough data to substantiate his observation of excess heat. He plans to publish his calorimetric results in a *Nature* article as he rebuilds the lab.

"The DOE has decided that the negative evidence against cold fusion outweighs the few positive findings, and that no funding can be justified."

In theory, three types of fusion reactions exist, but scientists have ruled out two because no nuclear by-products have yet been found. One reaction results in helium-3 and a free neutron, but observation of both excess heat and neutron emission have never been verified in the same experiment. This is the reaction Pons and Fleischmann originally claimed to have produced. Another reaction would result in helium-4 and gamma radiation, but no scientist has detected either helium-4 or gamma radiation in a palladium electrolysis experiment. The last possible reaction results in tritium (a hydrogen isotope) and a proton. John Bockris, a Texas A & M chemist, has observed tritium during a cold fusion experiment, but he's the only scientist who's observed excess heat and tritium in the same experiment.

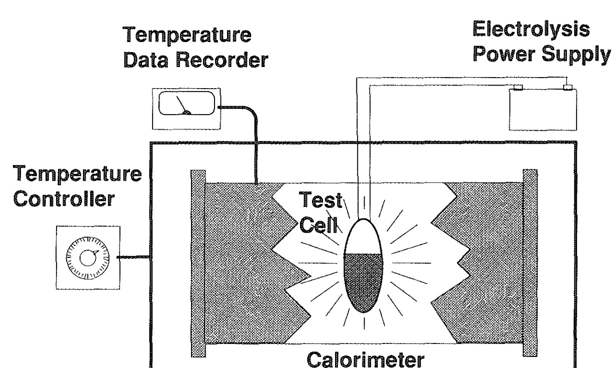
Some scientists have tried to discount Bockris' detection of tritium as resulting from contamination. This is not a reasonable explanation, asserts Oriani, because Bockris measured a tritium count about 200 times above normal contamination levels. However, it remains to be shown that the tritium formation is directly correlated with the observed bursts of heat. Bockris admits that the observation of both heat and tritium occurred in only one out of many test cells. Kevin Wolf, also of Texas A & M, has measured tritium counts 2 million times greater than contamination levels, and yet these experiments have produced no excess heat.

The cold fusion experimenters are confronted with a body of baffling data and unpredictable results. Despite recent advances, Oriani and the U of M team remain aware of the theoretical reasoning that opposes the notion of cold fusion. "We are all still skeptical, but there are data and thermal effects that cannot be dismissed. We need to do much more work to discover what are the necessary conditions to produce this excess heat."



Above, the diagram shows the primary components of the test cell within the calorimeter. The electrolyte solution that the platinum and palladium electrodes are submerged in consists of heavy water, heavy lithium hydroxide, and heavy sulfuric acid.

Below, a test cell is contained within a calorimeter that measures the cell's heat output. The calorimeter is lined with 200 thermocouple junctions connected in series. The voltage from these thermocouples is recorded by the data recorder and used to calculate temperature changes. To insulate it from ambient temperature changes, the calorimeter is contained in a temperature-controlled chamber.



ILLUSTRATIONS BY VINCE GREEN

Cold Fusion and the Utah Experiment

Fusion is the nuclear reaction that keeps the sun burning. The sun's gravity fuses hydrogen atoms together to form helium, releasing vast amounts of energy in the process. This is the opposite of the fission reaction that occurs in nuclear power plants. In fission, a neutron strikes a uranium nucleus, causing it to split into fragments and release energy. However, fusion releases about four times more energy for a given amount of fuel than fission. More importantly, fusion's byproducts are inert and harmless compared to the radioactive waste produced by fission. For years, scientists have been working to develop methods to sustain controlled fusion reactions and harness the energy for productive use. In order for fusion to occur here on earth, a hydrogen mixture (plasma) must be heated to a temperature exceeding 100 million degrees Celsius. At such a high temperature, the hydrogen nuclei possess enough energy to overcome their mutual electromagnetic repulsion known as the "Coulomb barrier." The problem scientists face today in developing a practical fusion reactor is sustaining a sufficiently dense plasma at a sufficiently high temperature for a sufficiently long time.

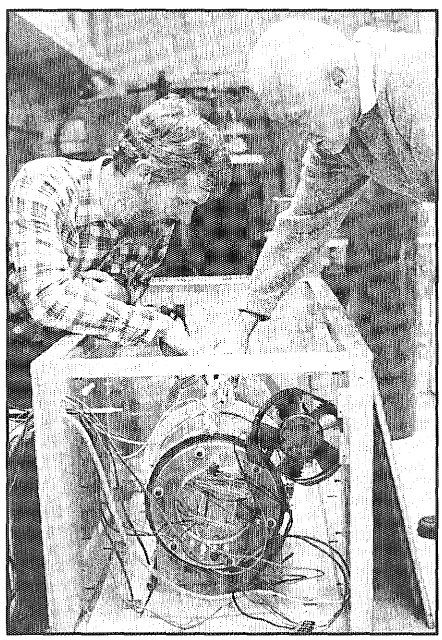
But on March 23, 1989, Dr. B. Stanley Pons, chairman of the University of Utah Chemistry Department, and Dr. Martin Fleischmann of Southampton University in England, announced that they had found

The Business of Cold Fusion

Amidst the ups and downs of cold fusion research are questions of money. The DOE has decided that the negative evidence against cold fusion outweighs the few positive findings, and that no funding can be justified. In spite of this, the University of Utah, with some state aid, has founded the National Cold Fusion Institute, a non-profit corporation. Currently, 30 scientists are working there to find what causes the bizarre and unpredictable effects produced by cathodic charging of deuterium and palladium.

"Many experts feel that heavy-ion fusion represents the only fusion technology that is efficient enough to be used to generate commercial power."

DOE pessimism has not kept some companies from pursuing their interest in cold fusion. General Electric, for one, has signed an agreement with the University of Utah to cooperate on cold fusion research. Though many companies quickly lost interest in cold fusion when the scientific community grew skeptical, GE believes that the potential of cold fusion as an energy source is too great to ignore. Johnson Matthey, the British metallurgical company that supplied the palladium rods Pons and Fleischmann used in their experiments, has also signed a collaboration agreement with the University of Utah. In total, 60 companies have signed confidential disclosure agreements with the University and received permission to examine the nine cold fusion patent applications filed by the University.



Richard Oriani and John Nelson, researchers here at the University, inspect a cold-fusion apparatus in their labarotory.

Hot Fusion

Although cold fusion has stolen most of the headlines in past months, hot fusion is still progressing. While the DOE has decided not to fund cold fusion research, it is dividing a reduced fusion fund between magnetic confinement fusion research and inertial confinement fusion (ICF) research. Magnetic confinement uses huge electromagnets to suspend the hydrogen fuel as it is heated to 100 million degrees Celsius. A common magnetic configuration is the "tokamak," which holds the plasma in a toroidal (doughnut-shaped) chamber during the fusion reaction.

A typical ICF reactor uses a laser array to compress tiny hydrogen spheres, causing deuterium and tritium to fuse. The intense heat and pressure caused by focusing high energy beams on the hydrogen forces the pellet to implode while being heated to temperatures high enough for fusion to occur.

Last June, Robert O. Hunter, director of the DOE's Office of Energy Research, announced plans to withdraw some support from the magnetic confinement program in order to further fund the ICF program. In the mid-1990s, the DOE plans to proceed with separate ignition experiments for magnetic fusion and ICF, and, by the year 2000, choose which technology would be best for a multibillion-dollar test reactor. So far, neither method has been able to produce more energy than it consumes.

A relative newcomer to the fusion race is heavy-ion fusion, a form of ICF. Instead of using lasers to implode the hydrogen targets, it uses charged-particle beams of lead or other massive elements. This offers several advantages over lasers. The accelerators used to create the heavy-ion beams are much more efficient in converting electricity into energy beams and can fire several times a second without breaking down. Most laser confine-

PHOTO BY PAULA ZOROMSKI

an easier way. They claimed to have created a fusion reaction at room temperature, "cold" fusion, through a simple electrolysis-of-water experiment using platinum and palladium. Palladium can absorb about 900 times its own volume of hydrogen gas and, in the presence of an electric field, the nuclei of the hydrogen isotope deuterium (a hydrogen atom with one proton and one neutron in its nucleus) moves unusually freely within palladium's atomic structure. It was these unusual characteristics of palladium that gave Pons and Fleischmann their idea for cold fusion.

They encircled a thin rod of palladium metal with a wire coil of platinum and placed both electrodes into a solution of "heavy" water (water that has deuterium in place of ordinary hydrogen, i.e. D_2O instead of H_2O) and heavy lithium hydroxide. When a current was passed through the electrodes, the water broke up, oxygen molecules collected at the platinum electrode and deuterium collected at the palladium electrode. But that wasn't all. Pons and Fleischmann also measured unusually large amounts of heat being produced by the test cell. The heat energy, if combined with the energy consumed by the dissociation of water molecules, represented more energy coming out of the cell than electrical energy going in. In addition to this "excess" heat they also observed neutron emissions. Based on these observations, they theorized that the palladium rod had not only absorbed the deuterium but that the palladium lattice had lowered the Coulomb barrier between deuterium nuclei (deuterons) and allowed them close enough together to induce fusion.

ment systems can only be fired a few times per day at best. The advantages of heavy ions over light ions are that fewer heavy ions are needed to produce the same impact and the heavy-ion beam is easier to aim. Many experts feel that heavy-ion fusion represents the only fusion technology that is efficient enough to be used to generate commercial power.

Hot or cold, a common goal drives these fusion researchers relentlessly onward: to solve the fusion puzzle and possibly create a safe, seemingly inexhaustible energy source. And for Pons and Fleischmann, who continue to seek answers late into the night, the objective is more personal—vindication. □

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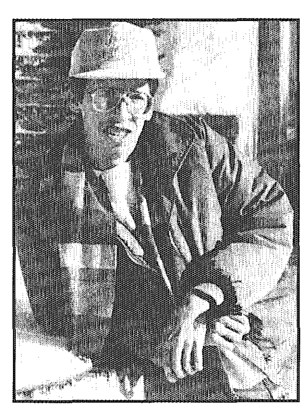
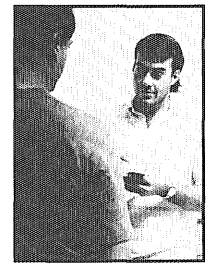
Writer Profile: Nathan Malby



Nathan Malby is a fifth year ME major and hopes to graduate by the turn of the century. When asked what he does for fun, Nathan replied with pride, "All I do is study and work. I have no leisure time." Nathan is a welcome addition to the *Technolog* staff.

Losing Teachers to Tenure

by Steve Subera, Staff Columnist



Is tenure in the best interest of the IT undergrad? Is it hurting the quality of your education?

So you think the majority of your professors couldn't teach their way out of a wet paper sack? Well, the U's tenure system may be to blame (tenure is the guarantee given to professors after a specified number of years that they'll always have a job). Although the primary criteria for obtaining tenure listed in the official tenure handbook is "effectiveness in teaching and professional distinction in research," I've found that all too often in the Institute of Technology a professor's teaching ability is given little weight when evaluation for tenure comes up because it's difficult to accurately judge and departments often fail to rely on student evaluations. The result of this is little or no punishment for poor instruction, and just as importantly, no incentive for developing better teaching skills.

Of course, tenure ensures academic freedom for the faculty, which is good. It was established to protect those professors from termination who hold views contrary to both the administration and popular opinion, and once granted, a professor may not be fired except for the most heinous of activities. Unfortunately, the tenure procedure is unduly shaped by politics and personality clashes, leaving the system less than perfect. Because each department's tenured faculty votes on whether or not to grant tenure to a particular professor, they are responsible for shaping the department's future; this may be detrimental if the tenured faculty are elderly or out of touch with the current needs of the undergraduate. For example, if the electrical engineering department of a certain school is full of theoretical physicists, they may only be in the mood to grant tenure to others of their breed rather than bringing in people talented in electrical design.

At large institutions such as ours, where research is emphasized, the publication of technical papers is foremost in attaining tenure. This pressure to "publish or perish" has often led to an attitude where the number, and not necessarily the quality, of research papers (or the quality of teaching) is the ultimate factor in deciding whether or not to grant tenure.

"...this may be detrimental if the tenured faculty are elderly or out of touch with the current needs of the undergraduate."

But despite much criticism, tenure, or some suitable variation, must be maintained in order to grant faculty members the freedom to conduct their research without fear of reprisal. One suggestion is rather than granting tenure within six years (and subsequently letting the professor coast for the rest of his or her career), a longer and more gradual process could be developed.

Obviously, the tenure system is not perfect and whether it should (or could, or would) ever be changed, especially for engineering and science professors, is a question needing serious discussion. Its emphasis on research does not necessarily harm teaching skills, but it should not be used as an excuse for poor instruction. The administration and the faculty must not forget the reason why the University exists and why we all came here in the first place—we wanted to be taught. □

STEVE SUBERA is sick of these blurbs, having been on our staff too damn long. Fact: He's a fifth year EE senior with no known direction and a gift for irritating his editors.

Help Wanted: *In-Depth Issues* Columnist

Technolog is currently looking for a well-organized, above-average writer who's on time, comfortable with deadlines, and takes pride in his or her work. We need an activist, someone who's willing to champion the interests of the undergrad and act as a positive force for change within IT and the business community at large—a personable maverick who can do research and is eager to make contact with the movers and shakers of the science and engineering world.

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Trivial Grains of Knowledge...

by Darin Warling and Loren Thomsen

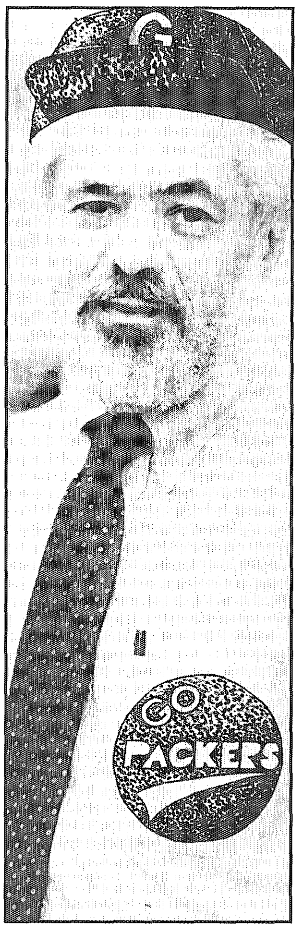
1. How many student-designed buildings exist on campus?

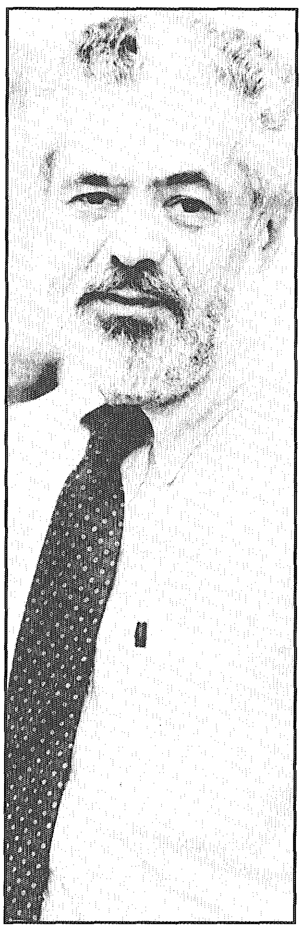
2. How long does it take the average IT student to graduate?

3. What's the largest academic building on campus?

4. What does the word "comstock" mean?

5. Of the total number of degrees held by the faculty of the EE department, what percentage are not in electrical engineering (within 5%)?





Separated at birth???
Pictured on the left is Lindy Infante, head coach of the resurgent Green Bay Packers, watching his quarterback's head get ripped from his shoulders by Keith Millard, defensive lineman for the Minnesota Vikings. Pictured at right is Ettore Infante, head dean of the resurgent Institute of Technology, watching the PSO set fire to his secretary. Note the similar postures and expressions. Are these two men related? You make the call.

Answers:

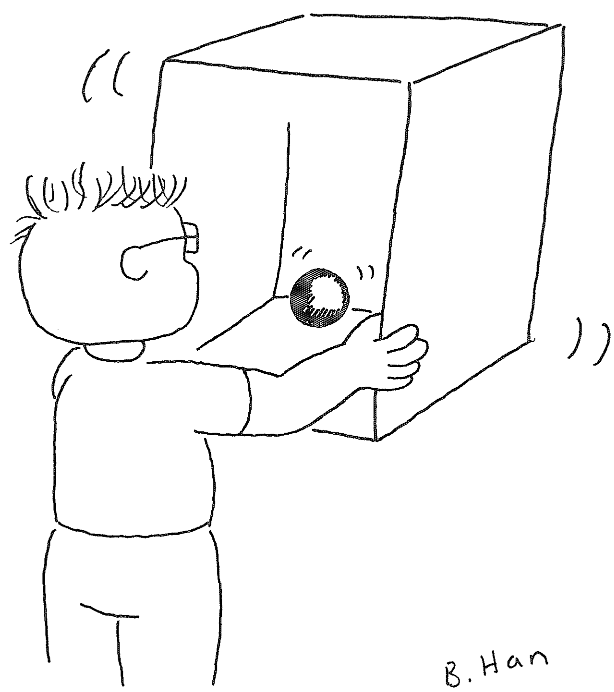
1. Sorry—the answer is zero. Not even the Architecture Building, contrary to what you may have been told by your orientation guides.

2. According to Associate Dean Russell K. Hobbie, it takes the average IT student five years plus one quarter to graduate. Don't worry—you really aren't as far behind as you thought....

3. The EE/CSci building, with 158,000 square feet of floor space.

4. The word "comstock," according to our dictionary, means "a ludicrous prude, especially in matters concerning sex and art."

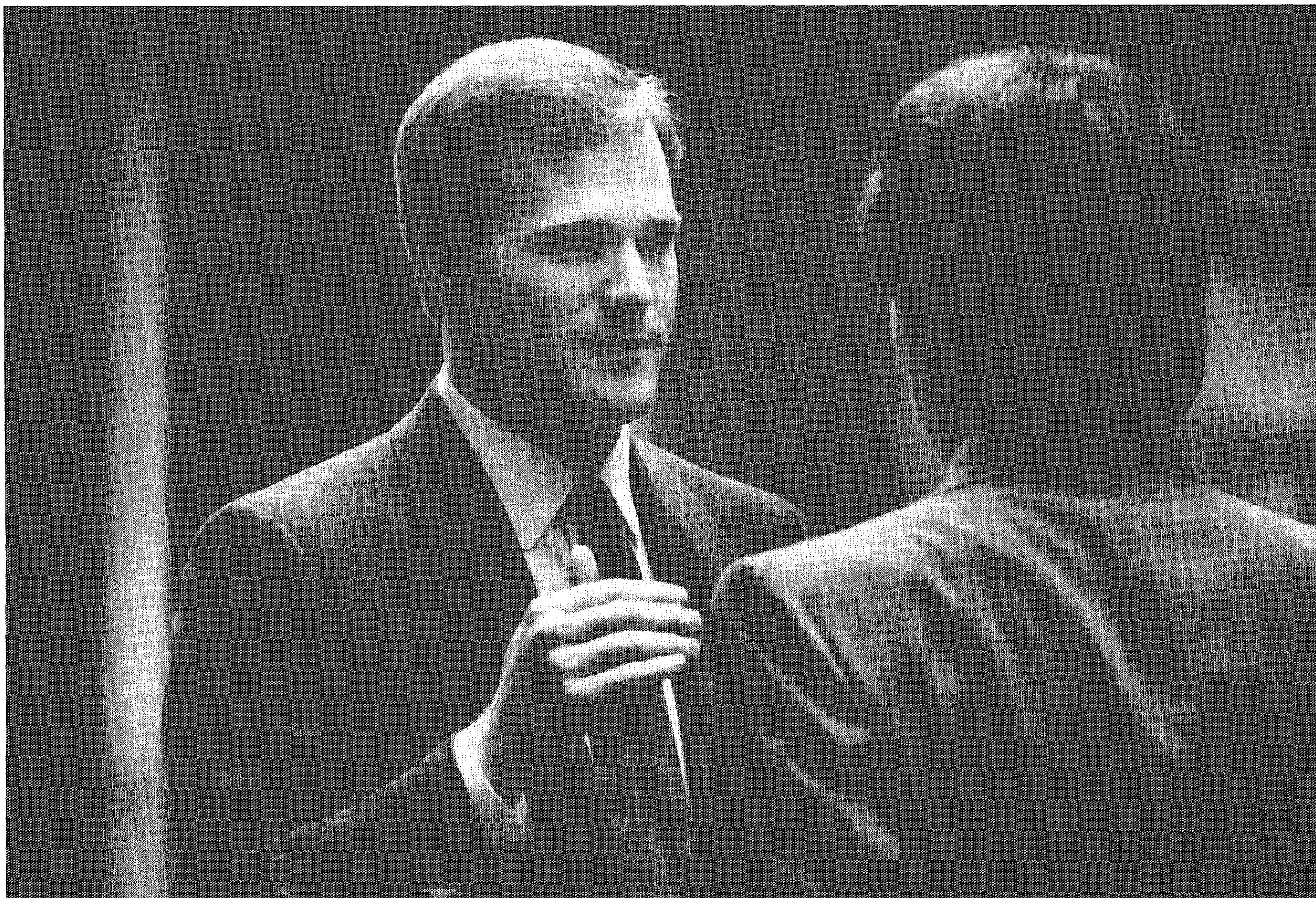
5. Nearly 50%. Staggering. (Out of the 119 degrees listed for 40 profs, only 63 of them were actually in the field of electrical engineering—the rest were in physics, math, and mechanical engineering, among others.)



Erwin Schrödinger at five years of age.

PHOTOS BY PATRICK O'LEARY

Jeff Lime never turns down a challenge.



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The Official Undergraduate Publication of the Institute of Technology

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INSIDE:

Doctors Do It. Lawyers Do It. Why Not Engineers?

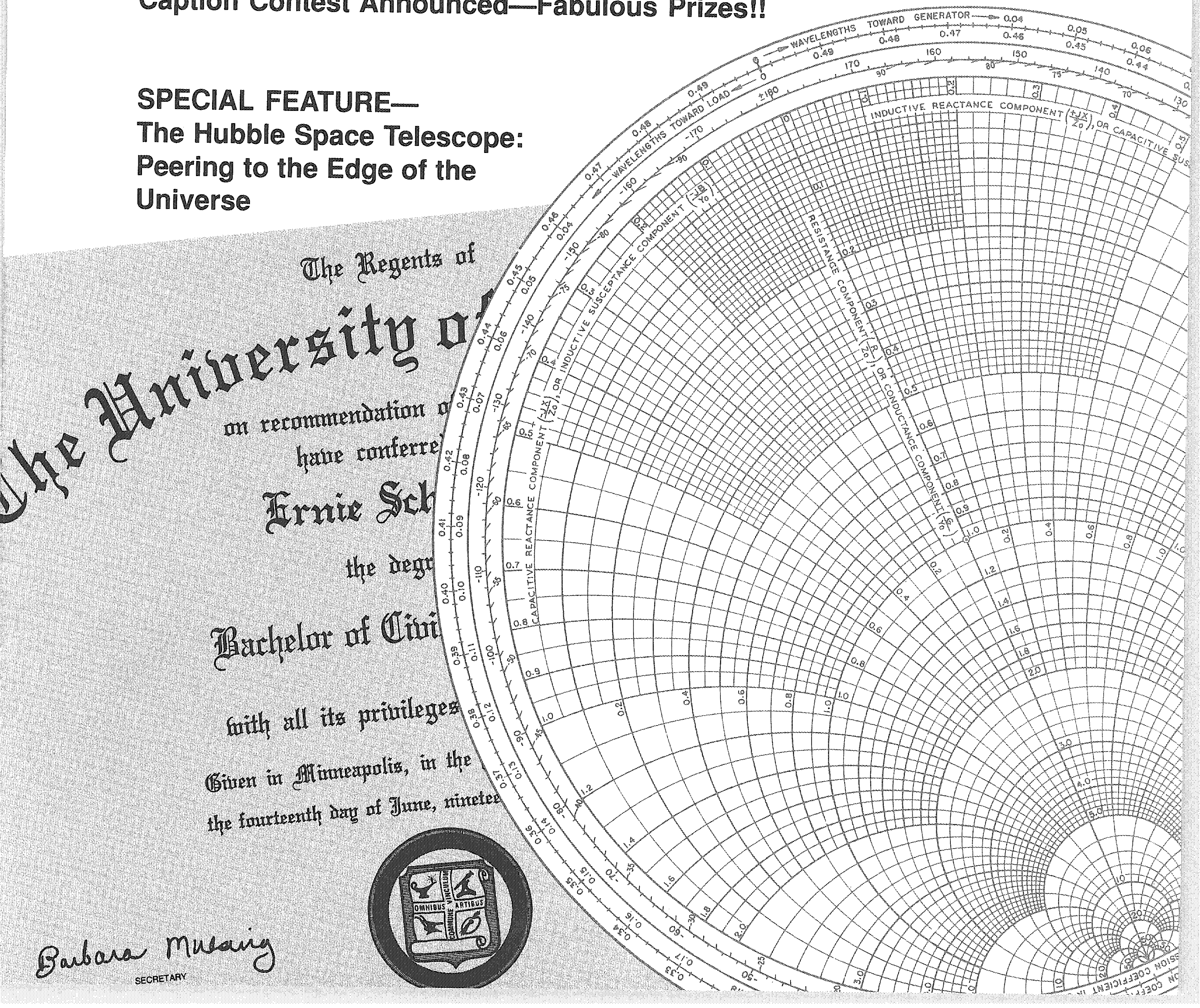
Taking Your American Know-How Abroad

Tales From Engineering's Dark Side

Caption Contest Announced—Fabulous Prizes!!

SPECIAL FEATURE—

The Hubble Space Telescope: Peering to the Edge of the Universe



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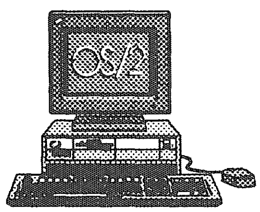

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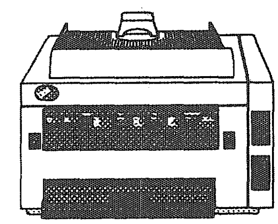

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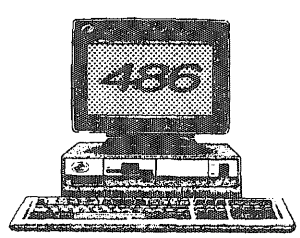

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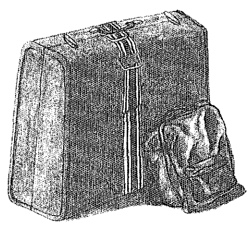

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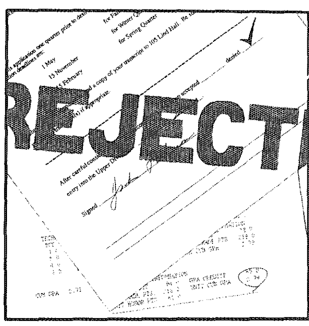

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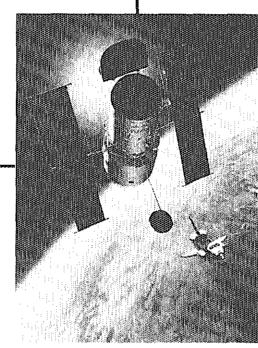

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Departments

On the cover: A University of Minnesota diploma and a Smith Chart (© 1966, Kay Electric Company), used in electrical engineering to avoid tedious transmission line calculations.

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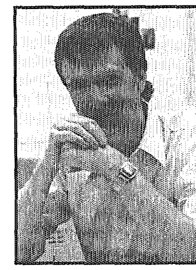
Minnesota Technolog, the official undergraduate publication of the University of Minnesota's Institute of Technology, is published six times yearly, twice during each academic quarter.

A Matter of Degrees

by Loren Thomsen



Burnt out, craving cash, and tired of texts, IT graduates flee campus. Their destination? Anywhere but graduate school, thank you.

Sooner or later, nearly every IT student faces an important question: Should I go to graduate school, or not? A few fortunate students can quickly answer yes or no, but most go through a period of indecision when weighing graduate school against immediate employment. In fact, many students postpone the decision until their senior year. By then, graduate school is often considered an option only if a well-paying job in industry fails to materialize.

However, despite lucrative job offers, some graduating seniors still find good reasons to choose graduate school over industry. Motivated by an idealistic hunger for more knowledge, some simply want to learn more about their undergraduate field, perhaps planning to someday teach or do research. Other students use graduate school to change fields, both within engineering and science itself, or to switch to something completely outside the technical domain such as law or medicine. Many purely career-minded students believe an advanced degree will lead to a better entry-level job, a larger starting salary, and rapid promotions. Such students expect increased long-term income will more than offset the cost of obtaining an advanced degree.

"Most graduating seniors refuse to inflict several more years of torture upon themselves by staying in academia. Furthermore, graduates are weary of being poor and want to begin earning a good income."

In spite of the many idealistic and pragmatic reasons to attend graduate school, most students prefer taking jobs in industry. Why? Among the many reasons, two are paramount. First, most graduating seniors are deathly sick of school and refuse to inflict several more years of torture upon themselves by staying in academia. Secondly, graduates are weary of being poor and want to begin earning a good income. Indeed, according to a study published in the July/August 1989 issue of *Engineering Education* magazine, the foremost career aspiration of engineering seniors is "to earn a comfortable income." "To make significant, practical, useful technical contributions in my field" ranks a distant second.

Nonetheless, it's worth noting that many graduating seniors who spurn graduate school leave the option open, claiming they might pick up an advanced degree (at employer expense, of course) after a few years of experience. Unfortunately, juggling career, family, and advanced schooling is too difficult for most people to handle successfully. Most engineers and scientists who forsake graduate-level education when they're young will end up basing their 40-year career solely on a bachelor degree.

Recruiting Reluctant Undergraduates: Why It Matters

Though students don't realize it when pondering the graduate school option, America's technical health has a stake in their decision. If war is used as a metaphor for global economic competition, then countries with the best-educated technical talent wage a winning battle, and those with less-educated engineers and scientists find themselves outgunned. Currently, most of America's best and brightest technical graduates are lured directly into industry and do not develop their talents to full potential. Furthermore, given the large number of professors expected to retire during the coming decade, America's graduate students will form the pool of future engineering and science educators.

Fortunately, foreigners have filled the void left by the American students who shun graduate school. Although large numbers of foreign students prop up our technical graduate programs and ultimately become assets in our workforce, America cannot expect this to continue indefinitely. Indeed, Mac Van Valkenburg, dean emeritus at the University of Illinois, points out that Japan has also recognized the value of recruiting foreign talent and plans to

attract more Asians to its own schools, students who otherwise might have attended American universities. On the European front, competitors such as France and Germany attract students by providing free tuition. Moreover, assuming foreign students continue to come here at all, John Armstrong, vice-president for science and technology at IBM, claims it will become harder and harder to get European and Asian students to stay in America due to improving job opportunities in their home countries.

Given the importance of having an adequate supply of American-born, graduate-educated scientists and engineers, what can graduate school administrators do to successfully recruit reluctant American undergraduates?

For starters, they need to take a fresh look at the factors discouraging undergraduates from pursuing graduate-level education. For instance, one informal study by NASA found that undergraduates are uninformed about the nature of graduate school, and mistakenly think that it's just a slightly

UP FRONT Continued on page 11...

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The Dark Side of Engineering

by Pat Kellogg

So, you want to be an engineer? If you're a freshman, perhaps you were lured into IT by a colorful brochure showing students studying outside, playing volleyball, and generally having a good time. College looked like fun, and engineering seemed like a good idea. However, there are many things your colorful brochure neglected to tell you.

First, there's the common myth that if you're an engineer, you're guaranteed a job; however, not all engineering graduates do find a job in their field. According to Kathleen Clinton, assistant director of the IT Placement Office, "Twenty to twenty-five percent of our students never get a job offer." Finding a job is especially difficult for aerospace engineers. About one-third of last year's graduating class failed to find work, and 75% of those that *did* find jobs had to move out-of-state.

Many graduates must leave Minnesota to find work because there simply aren't enough jobs here; recent cutbacks at Control Data and Honeywell, for example, have left many engineers unemployed. And when a company falls into financial trouble, it's often the engineers that shoulder the burden by way of longer hours, reduced staff, and sharply reduced budgets. Steve Tibbets, who was a programmer at Control Data's now-defunct ETA Systems, explained: "First they cut my department in half. With fewer people and a smaller budget, of course we lost more money. Finally, they fired me, as if it was all my fault."

> **"About one-third of last year's aerospace graduates failed to find work, and 75% of those that *did* find jobs had to move out-of-state."**

So engineering may not provide a secure job, but at least it pays well, right? Last year the average starting salary for a chemical engineer from the U of M was $31,200 and a lucky few earned over $34,000 their first year out of college. However, starting salaries don't tell the whole story. A beginning engineer may start at a high salary but could still be working for roughly the same salary a decade later. And even if you do make it into management, many professional engineers claim there is a "glass ceiling" that prevents technical managers from reaching higher-paying, non-technical managerial jobs. According to *Who's Who in Industry,* less than 15 percent of the chief executive officers of the country's 100 largest companies had engineering backgrounds. Lester Thurow, MIT's Dean of Management, explains, "There are certain second-level jobs that never lead you to first-level jobs. People regard engineers to be too specialized to actually run a company."

Women engineers especially have problems getting promoted to positions they deserve, and often they're stuck in little more than glorified secretarial jobs that don't allow them to use their engineering skills. Furthermore, female graduates end up earning only 65 to 85 cents for every dollar a man in the same position would make. With statistics like these, it's a wonder that there are any women engineers at all.

And as for having a job *and* a family, you can forget it. The amount of overtime required from engineers makes it difficult

PAT KELLOGG is an EE junior. Pat talks tough and walks tough, but he's actually very personable, malleable, and puppy-like. Nonetheless, he enjoys hanging out in the Technolog *office spreading discontent among the other writers, bemoaning the dark side of magazine engineering.*

ILLUSTRATION BY JOHN TOPIC

to have a personal life. In a poll in *Engineering Design News,* 75% of the engineers who responded said that excess overtime adversely affected their marriage. Over one-fourth of the engineers polled said they were working 13 to 20 hours of overtime each week, and since most engineers are not paid by the hour, any extra time is gratis. George Buick, head programmer for Highland Superstores, says, "You must be able to make a commitment to solve a problem, even if it means you work until 11 PM. This is something your spouse might not understand or feel good about."

It appears that these long hours and lack of recognition may be affecting enrollment in engineering programs, IT's included. The number of freshmen entering IT this year was 706, down from the 979 freshmen who started in 1985. And in the past four years, approximately one-third of those 979 students have dropped out. It's difficult to pinpoint why fewer students are choosing engineering, but one reason may be that the classes are simply "too hard," even for students who were considered well above average in high school. Mistreatment of undergraduates and a research-oriented faculty are also often cited as problems.

Freshmen may be drawn to engineering by a pretty brochure with lots of nice pictures, but they often don't know what they're getting into. Avoid an unpleasant collision with the "real world" by reading essays and articles about your major, or better yet, get an internship or summer job related to your major to find out what it's really like firsthand. The Society of Women Engineers sponsors many excellent speakers from industry each year, and the IT Placement Office will also provide information. Please, consider the pros *and* the cons of engineering; make an informed decision before making a career commitment that you may end up regretting for the next four or five decades. □

Making It Big

by Grant Ovsak

Engineering students today are faced with many pressures, including the expectation that we must "make it big."

The phrase usually brings to mind visions of big companies and big salaries. The glamour of working for a large, well-known company may boost your ego and make your parents proud, but making it big may best be achieved by starting with a relatively small company. It's one case where bigger is not necessarily better.

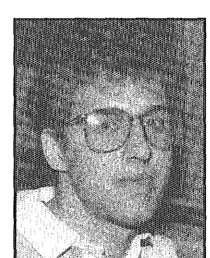
Small companies, despite being small in size, are large in opportunity, including the opportunity to excel—a rarity for most journeymen engineers in large, bloated megacorporations. Compared to large corporations, jobs in small companies are often characterized by expanded responsibilities, increased flexibility, and greater freedom, offering engineers the chance to excel on a daily basis.

"Small companies, despite being small in size, are large in opportunity, including the opportunity to excel—a rarity for most journeymen engineers in large, bloated megacorporations."

Small companies, because they generally have fewer levels of management and closely-knit R & D teams, are able to offer opportunities that larger companies either can't or won't. Unfortunately, many engineers employed by large companies and involved in large research groups are limited to small areas of research. Engineers and researchers in smaller firms, however, can participate in each and every stage of a project, from its formation, through research and testing, to its completion and delivery to the customer. This broad experience will benefit both the engineer as an individual and the company as a whole, perhaps providing the entry-level engineer with the confidence and broad skills necessary to become outstanding later in his or her career.

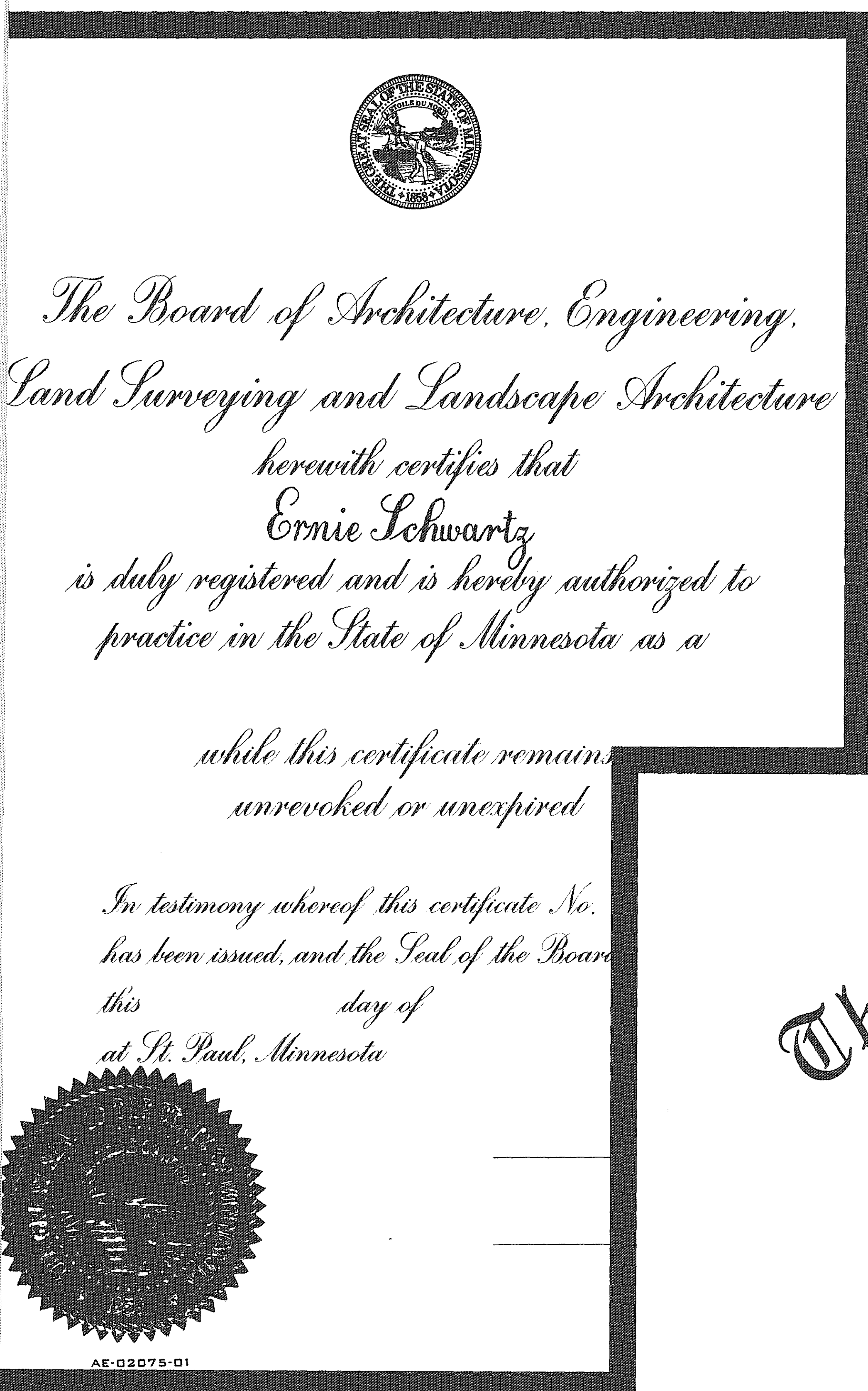
The choice between working for a large company or a small company often comes down to this: Would you rather be a small fish in a big pond, or a big fish in a small pond? Given the benefits of working for a small firm, "making it big" may actually mean "starting small." □

GRANT OVSAK is a senior in EE and member of Tau Beta Pi and the IT Board of Publications. Upon graduation he's spurning large companies, small companies, money, and the real world in general, preferring graduate school instead.



To Be a Professional

by Tom Halvorsen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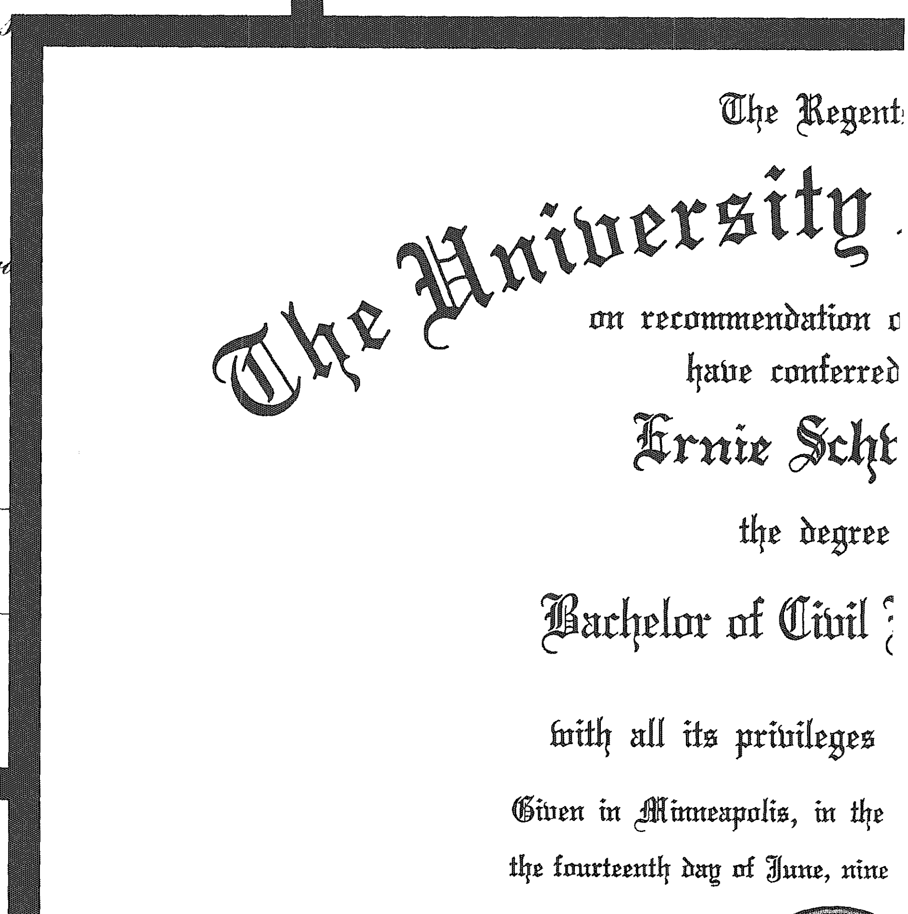
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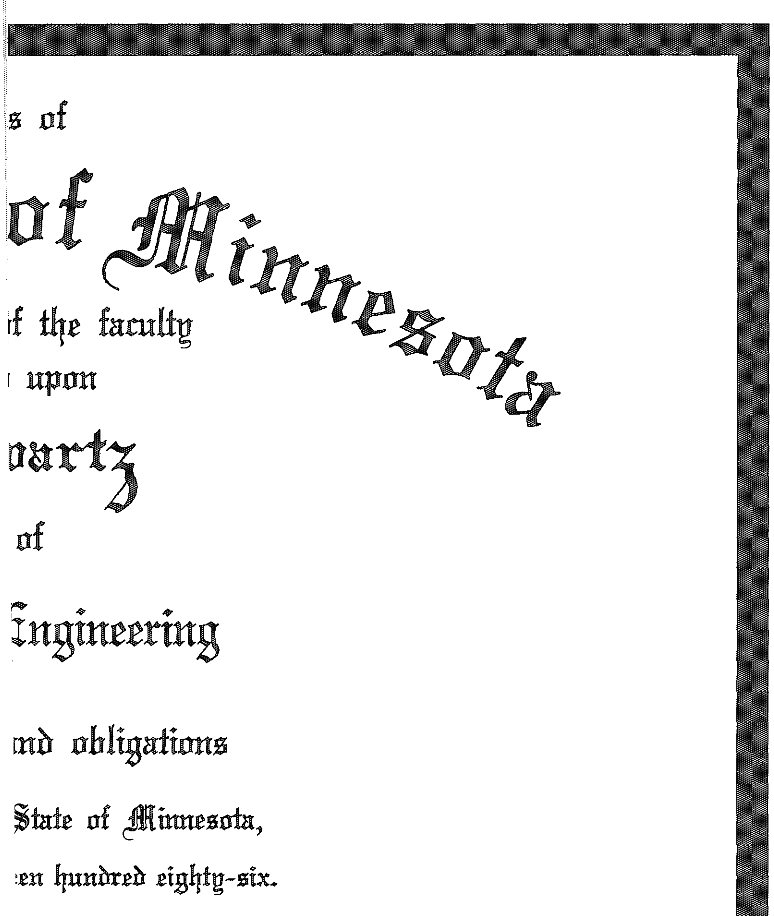
Your doctor, lawyer, dentist, even your hair stylist, is a registered professional. Should you be one, too?

pro-fes'sion (-fesh'un), n. [fr., from L. pro-fessio (-onis), a declaration.] ... 3. a vocation or occupation requiring advanced training in some liberal art or science, and usually involving mental rather than manual work, as teaching, engineering, writing...

What does it mean to be a professional? Webster's definition focuses on the intellectual aspect of the term, and the rigorous academic preparation required of an engineer certainly emphasizes that focus. However, John Constance, in his book *How to Become a Professional Engineer*, reminds us that "technical competence is a necessary but not the sufficient condition for becoming a professional engineer; ...of equal or greater importance, he (she) must possess altruistic characteristics and must conform rigidly to a code of ethics of a high order."

A uniform code of behavior for professional engineers is a relatively recent development. Wyoming, in 1907, was the first state to come to terms with professional regulation. The idea was slow to catch on, however, and a half century passed before all fifty states had minimal statutory regulation of engineers. Constance blames this slow development on a lack of a cohesive identity within the profession. Initial emphasis was on the registration of civil engineers because their designs were deemed particularly critical to public safety. Only recently have states adopted a uniform standard for testing and certifying all engineering disciplines.



In the 1970s, several professional engineering and scientific societies began to push for a broader definition of professional behavior. This led to the adoption of the *Guidelines to Professional Employment for Engineers and Scientists*, a document currently endorsed by well over 30 societies, including IEEE and ASME. Its four sections deal with the professional behavior of employer and employee in the areas of recruitment, employment, professional development, and termination or transfer. This document reflects what is clearly the trend of the future: increased emphasis on the professional character of engineering.

Does Taking a Test Make Someone a Professional?

A review of professional occupations reveals a wide range of requirements for professional employment. Practitioners of some vocations are required to pass both a qualifying exam and participate in continuing education (nurses, pharmacists). Some professionals need only pass a single exam (lawyers); others are only required to take continuing education courses. However, none of these restrictive requirements apply to engineering.

"Although most engineering societies strongly endorse professional registration and continuing education for all engineers, they reject that either requirement be officially mandated."

The statutes governing professional registration allow an organization to employ a single registered engineer. This one individual is deemed adequate to supervise the work of several other engineers. Would our society condone such a minimal standard within the health-care industry? Would you feel comfortable in a hospital where one doctor in 50 had taken and passed the state boards? What's unique about the engineering profession that exempts its members from either mandatory certification or continuing education?

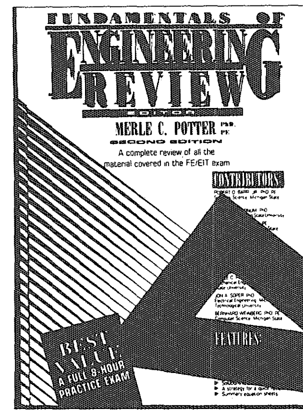
Granted, it's certainly possible to behave in a professional manner without taking a certification examination. The behavior and work of thousands of unregistered engineers clearly attest to this fact. It's also true that successful completion of an exam in no way guarantees that an individual will perform in a professional or ethical manner. To date, most engineering societies have chosen to resolve this dilemma by sitting squarely on the fence. Although they strongly endorse professional registration and continuing education for all engineers, they reject that either requirement be officially mandated.

Decisions, Decisions

For civil and consulting engineers the pursuit of professional registration is an occupational necessity. For everyone else, the decision remains highly personal. Most engineers that I have spoken to claim that registration seldom has quantifiable advantages such as increased salary or accelerated promotion. One's self-concept as an engineer and vision for the future are perhaps the only guiding forces in making this decision. The path to professional registration requires deliberate effort and planning. It won't happen by default.

For whatever reason, most students won't pursue professional registration. In fact, a significant number will not even seriously consider it. This may not be surprising, since the reasons recommending registration seem slight. Yet, for engineering students with a clear vision of their professional goals and a commitment to their chosen field, professional registration becomes a natural choice.

Unfortunately, academic life affords few opportunities for exposure to professional engineering role models, which perhaps explains why so few students see professional registration as a natural part of their engineering education. However, it's abundantly clear that unless the decision to seek professional status is made while in college, it probably will never be pursued. If you decide to "work a few years first," the likelihood of ever taking the exam required for professional registration is slight. This is a clear case of "to not decide is to decide not."



To begin the process of professional registration, a student must first take the engineer-in-training (EIT) examination (see sidebars). The same test is given to students in all engineering disciplines, and covers a wide range of engineering and science topics. The exam lasts eight hours and can be taken prior to graduation, or anytime thereafter. The second step on the road to professional registration is work experience. A minimum of four years of "qualifying engineering experience" is required. One year of this requirement may be waived for graduates of a Masters or Ph.D. program.

The final registration requirement is the successful completion of the Practices and Principles examination. This exam is also eight hours long, but, unlike the broad-scope EIT exam, is geared toward individual disciplines. Minnesota currently offers examinations and professional registration in 16 engineering fields: aeronautical/aerospace, agricultural, ceramic, chemical, civil, electrical, geological, industrial, manufacturing, mechanical, metallurgical, mining/minerals, nuclear, petroleum, sanitary, and structural.

The EIT Exam: The Inside Story

Gary Wolf graduated from the University of Minnesota with a B.S.M.E. in the spring of 1989. He is currently employed in the Military Avionics division of Honeywell. In April of last year, he took and successfully passed the EIT exam. In this interview synopsis, Wolf shares his thoughts on professional registration.

Why He Did It

Wolf considered the EIT exam an opportunity he could not afford to neglect. Taking the EIT exam while still a student would keep all of his options open, including the possibility of working as a consultant or owning his own job shop. He also believed that taking the test would demonstrate a desire for professional advancement to his employer.

Test Preparation

To prepare for the EIT exam, Wolf first purchased a review manual (like those available from ASME). He counted back 13 weeks from the date of the exam (one for each exam section), and then devoted a block of time each week to studying one particular subject. He started his review with the material with which he was most familiar, and saved his weakest subject areas for the few weeks just before the exam.

Exam Logistics

The exam's four-hour morning session consists of 140 questions, each worth a half point. All questions should be answered, and there is no penalty for guessing. Time passed very quickly for Wolf during this portion of the exam, and he was unable to finish all sections. The afternoon session allows some choice of subject matter. There are 100 questions, again worth a half-point each, and the student is not required to answer them all. Wolf found this session more difficult than he had expected.

"While conceding that the exam was an intimidating experience, he says that, ultimately, it was just 'one more test.'"

Wolf felt that only two of the many books he brought with him to the exam were helpful as references. He relied most heavily on a physics book and the EIT review manual. Prior to the exam, Wolf placed tabs in the various sections of the EIT manual to facilitate quick reference. He suggests this as a quick way to access necessary formulas and information.

Wolf recalls the economics portion of the exam as the most difficult for him. In general, Wolf felt that his ME coursework, because of its breadth and diversity, had given him solid preparation for the exam.

Victory or Defeat?

Wolf passed the EIT exam on his first try. While conceding that the exam was an intimidating experience, he says that, ultimately, it was just "one more test." He considered it a measuring stick, a way of evaluating himself to see how well he had learned the engineering curriculum. Wolf took the EIT exam in the spring of his senior year. He was taking three courses that quarter, and feels his credit load was too large to allow easy preparation for the exam. He recommends that students take the exam the first chance they have *after* graduation.

Fundamentals of Engineering Review
ed. by Merle C. Potter
Great Lakes Press, Inc.,
Hardcover, 1986,
350 pages, $25

Available at the ASME office in Room 139, old EE building. It includes an eight-hour practice exam. The ASME office also has EIT exam application forms.

Professional Status Matters

For engineering students preoccupied with finding enough time in the day to complete their studies, professional registration may seem like a distant concern. Yet the future has a way of becoming the present. The advancement of the professional status of your chosen field is an issue that each of you must address in your own way. Professional registration is one way of demonstrating your commitment to engineering. Samuel Florman summarizes this attitude by reminding us of the ethical responsibilities and "higher calling" of those in engineering:

> Lately, we have heard a lot of well-intentioned platitudes about engineering ethics. What could better show our seriousness than to insist that all engineers (or at least all future ones) obtain licenses? Possessing a license—something that is hard-earned yet can be taken away—can do wonders for the conscience. I have heard many a consulting engineer say, "Why, I wouldn't think of doing that; it could cost me my license." Clearly, no test can establish competence nearly as well as a degree from an accredited engineering school. Still, engineering is more than just a job. In many respects, it is a calling. If engineers are committed to serving the community, then their acceptance of state licensing helps make this commitment manifest.

As students who will soon join the ranks of engineering professionals, we can demonstrate our commitment to excellence and to engineering's future by pursuing professional registration. □

Sources:

"Board of Architecture, Engineering, Land Surveying and Landscape Architecture Rules," October 1988, Minnesota Documents Division.

Constance, John D. *How to Become A Professional Engineer*, 1978, McGraw-Hill Book Company.

Florman, Samuel C. "License to Skill," *Technology Review*, January 1990, p. 62.

"Guidelines to Professional Employment for Engineers and Scientists", *Mechanical Engineering*, April 1978, Volume 100, No. 4.

Webster's Deluxe Unabridged Dictionary, 2nd Edition, 1979.

Wolf, Gary. Interview, November 1989, Honeywell Military Avionics.

Just the Facts

•What does "EIT" mean?
The Engineer-In-Training examination is the first step toward professional registration.

•Who may take the EIT exam?
Any graduate of an accredited engineering curriculum.

•What's on the exam?
The exam contains multiple-choice questions in fundamental mathematics and the basic and engineering sciences. Exam review books are available for $25 from the ASME office.

•When and where is the exam offered?
The exam site is the U of M's Fraser Hall. The EIT exam is offered twice per year, in the spring and fall. The registration deadline for the spring exam has already passed. Fall exam (October 27th) registrations must be submitted by August 15,1990.

•What's the cost?
The initial EIT exam fee is $30. For those taking the exam a second time, the fee is $25.

•Open or closed book?
Handbooks, reference books, bound tabular material, notes, and hand-held calculators are permitted.

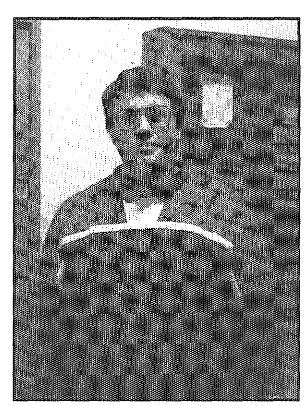
•When's a good time to take the exam?
Students should take the exam the final quarter of their senior year, or as soon after graduation as possible.

•And if I fail?
An applicant not receiving a passing examination grade may apply to retake that examination. The board may require an applicant who has failed an exam two or more times to submit evidence of improved qualification before an additional retake exam is permitted.

•Where can I get more info?
Applications or information are available at:
Board of Architecture, Engineering, Land Surveying,
and Landscape Architecture
402 Metro Square Building
St. Paul, MN. 55101
Phone: (612) 296-2388

minnesota
TECHNOLOG

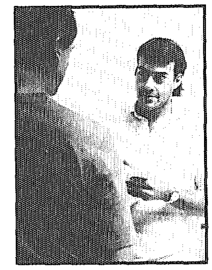
Writer Profile: Tom Halvorsen



Tom is an ME junior who has spent the past decade starting a family and working as a carpenter and wayfaring Lutheran troubadour. Tom blames his current haircut on an unlicensed barber, an experience that forever changed his attitude toward professional registration. Tom is shy, writes well, and doesn't sing worth a darn. We suspect that he's Garrison Keillor *incognito*.

The GPA Roller Coaster

by Steve Subera, Staff Columnist



GPA requirements were a quick fix intended to slow the stream of students hoping to cash in on the early 1980s engineering boom. Are they still necessary?

The proliferation of innovative technologies during the early 1980s created a demand for engineers and strained college engineering departments. Inundated with students wishing to major in engineering, schools across the country revamped their admission policies, often raising grade point average (GPA) requirements or admitting only the upper percentile of applicants. Our own Institute of Technology also jumped on the bandwagon and implemented admission restrictions. Beginning fall quarter 1982, entering students were subject to minimum GPA requirements when applying for admission into upper division. According to the *IT Student Guide,* these requirements were necessary "in order to limit enrollment due to lack of faculty and resources."

Apparently there is still a lack of faculty and resources because eight years later the GPA requirements remain and in several departments have actually increased. Minimum GPA currently ranges from a low of 2.3 for several majors to a high of 2.8 for freshman and sophomore computer science students.

Associate Dean Russell K. Hobbie chairs the Academic Standards committee, which reviews GPA requirements each year. Based on enrollment projections, student grades, and discussions with the engineering departments, the committee decides whether or not a GPA adjustment is needed for the incoming freshman class; once it is set, the requirements will not be changed for that class. However, raising and lowering the GPA requirements for each new class does create a rollercoaster effect. Is it fair to raise the requirement for one class of students to a 2.8 GPA, while the class a year ahead of them needed only a 2.6?

Hobbie would like to see the higher requirements eventually brought down to the vicinity of 2.3 or 2.5. He believes this is possible because of fewer high school graduates and competition from the engineering programs at other schools such as UMD, Mankato State, and St. Cloud State. Class sizes are already shrinking, having fallen from 1000 to less than 800. Unfortunately, further reductions will probably not result in an end to the minimum requirements, presenting a double standard that troubles Hobbie. "I am personally bothered by a situation where we say a 2.0 is passing, but we say you must have a 2.5, 2.6, or 2.7 to continue into your junior year," he said. In the worst case, a student who spends two years familiarizing herself with IT and the University may be told that her 2.7 GPA is not good enough for admission into upper division in her major, forcing her to attend another school or change majors, both of which will most likely result in lost credits, extra time in school, and greater expense.

> **"'I am personally bothered by a situation where we say 2.0 is passing, but we say you must have a 2.5, 2.6, or 2.7 to continue into your junior year.'"**

While Hobbie is working towards lowering GPA requirements, Professor Marvin Marshak, head of the Physics Department, vehemently dislikes the requirements (his department has none) and believes they should be abolished. One possible solution proposed by Marshak is that other IT departments with low student-to-faculty ratios assist the overloaded ones. For example, he believes a physics professor could teach an introductory electrical engineering course. Marshak said this may result in some accreditation problems, but they could probably be worked out. "Otherwise," he says, "there's no point in having a college. The situation now is you have a bunch of departments, and the faculty don't communicate very much, and they don't have much common interest in teaching."

Marshak would prefer that the University accept a planned number of students and absorb any fluctuations in student supply and demand. Students would be free to

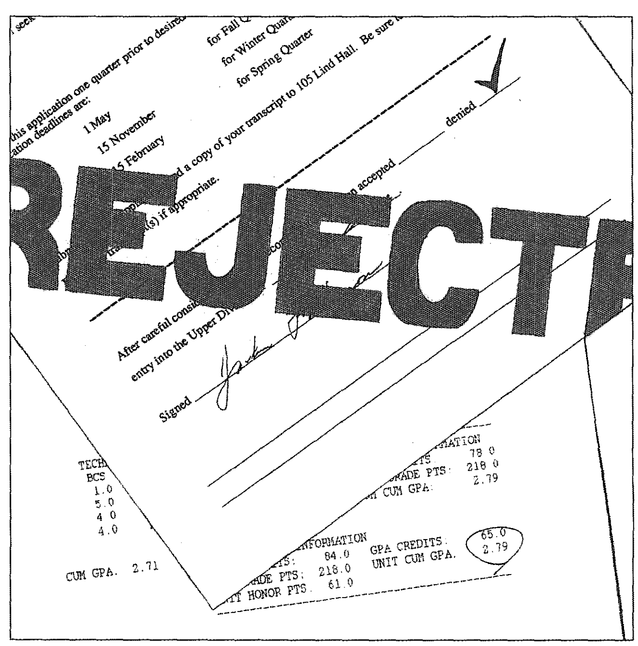


 ILLUSTRATION BY BYUNGHO HAN AND JOYCE RAJENDREN choose any major, but to alleviate potential problems they would declare a major upon admission, thus identifying which degree programs are likely to experience the greatest demand.

Another solution, though costly, is to simply increase the number of faculty positions. This would reduce high student-to-faculty ratios as long as IT did not increase the number of students it admitted. Richard Goldstein, head of the Mechanical Engineering Department, blames the lack of faculty and other ME support staff for the need to raise their minimum requirement from 2.5 to 2.7 for the 1989-90 school year. The Mechanical Engineering Department has a student to faculty ratio of slightly more than 6:1. Most other schools with comparable departments have ratios closer to 4:1. In the face of increasing ratios, the available ME faculty has become overwhelmed. Goldstein says more mechanical engineers are needed in Minnesota (and in the midwest in general) and that a higher GPA requirement will be detrimental. "A student who has a 2.5 or 2.6... Why can't they go on? Because we don't have the resources. We need more faculty," he said.

"'You have a bunch of departments, and the faculty don't communicate very much, and they don't have much common interest in teaching.'"

Is the current GPA requirement in the best interest of students? No. It may motivate incoming freshmen to keep their academic standards high, but more likely it simply adds to the burdens already placed upon them. The GPA requirement is merely a convenient and cheap solution to control engineering overcrowding and compensate for inadequate staffing. □

STEVE SUBERA is an interminable EE senior. He becomes a free agent at the end of this year. We're trying to trade him to the Wisconsin Engineer *(UW-Madison), but negotiations are not going well.*

Up Front

Continued from page 3...

modified extension of lecture-based undergraduate education. This study also pointed out that undergraduates don't realize the amount of financial aid available to graduate students.

The solution to this problem is obvious: Educate undergraduates about graduate school using all available avenues. At the very least, administrators must strongly encourage all advisors to discuss graduate school with their students. Additionally, offer seminars and workshops concerning graduate school. Perhaps offer a one-credit course for juniors who have moderate interest in graduate school, providing information about curriculums, financial aid, how to apply, admission tests, choosing a school, etc. A particularly innovative idea proposed by Assistant Dean John Clausen is the graduate school equivalent of the annual career fair. Representatives from top graduate schools around the country would gather at IT and distribute information about their particular programs.

In addition to discovering that undergraduates are in the dark about the details of graduate education, the NASA study also found that students who participated in some sort of research project felt an increased interest in graduate school. This suggests that more students should be encouraged to get industry experience through internships or co-op positions, since this will probably increase their appetite for graduate school, not diminish it. Within IT itself, the Undergraduate Research Opportunities Program (UROP) already exists to give students a taste of research, and efforts should be made to increase participation in the program. Better yet, research experience should be integrated into the existing curriculum, particularly the labs, supplanting some of the absurdly poor methods of lab instruction used by many departments.

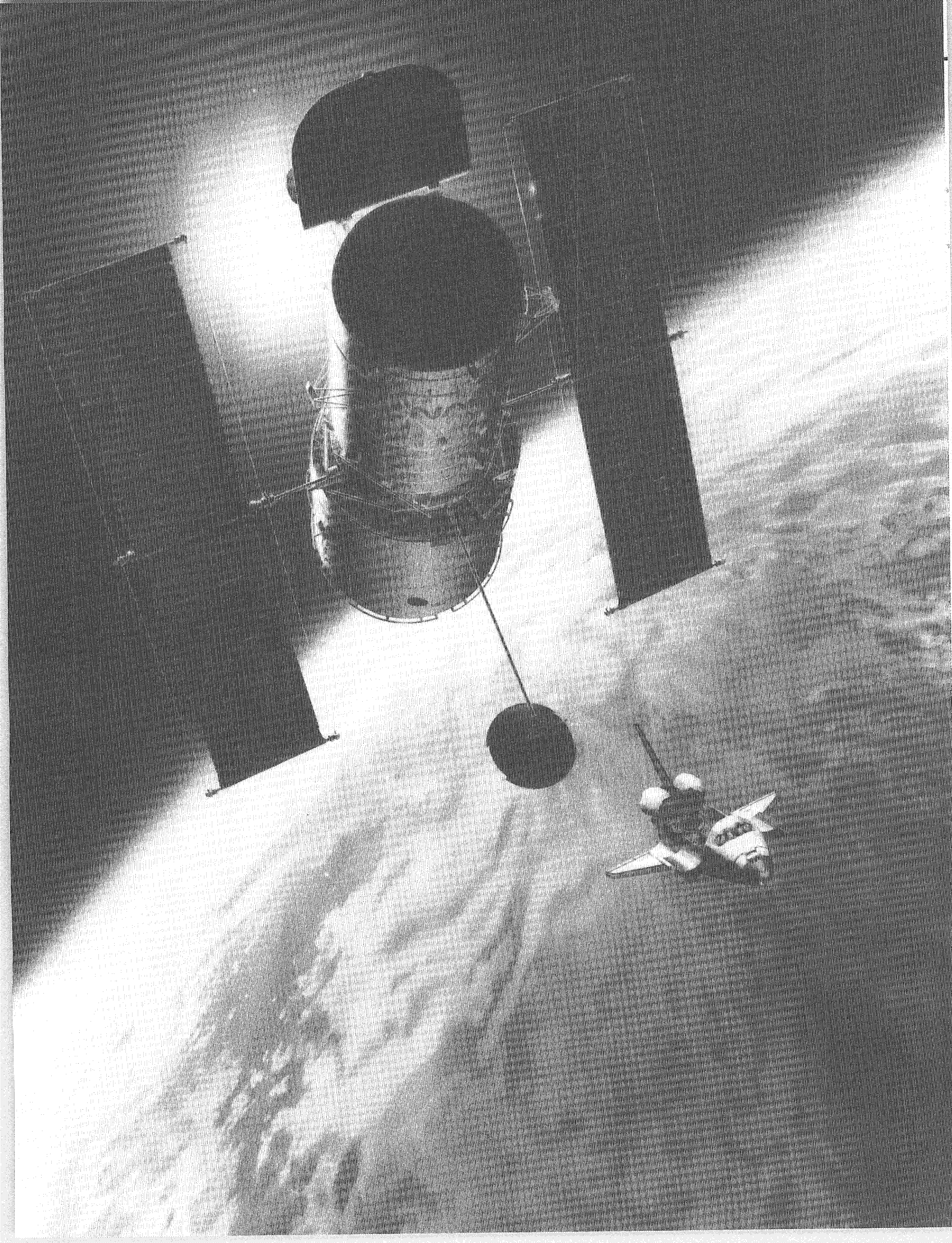
Earlier I mentioned the two primary factors that dissuade graduating seniors from choosing graduate school: They're sick of school, and they want to begin earning a good income. When it comes to competing with the hefty starting salaries offered to graduating seniors, graduate schools are largely helpless—they simply cannot afford to become tangled in a bidding war with industry.

The problem of school burn-out, on the other hand, is directly within the control of administrators and demands their serious attention. Though difficult to implement, the solution is easy to state: Improve the quality of undergraduate education. Students routinely face courses that are so overloaded with minutiae that the fundamental concepts are buried in the avalanche. Worse yet, students routinely face instructors who are either incompetent or just don't give a damn about teaching. Under these conditions, even the best students can develop a deep-seated contempt for academia. Until a rational four-year curriculum and qualified instructors become the norm in engineering and science schools, graduating seniors will continue to scorn graduate school in droves.

"Though students don't realize it when pondering the graduate school option, America's technical health has a stake in their decision."

As uninformed and embittered undergraduates continue to ponder the question "Should I go to graduate school or not?" it's time for administrators in IT and around the nation to ponder the question "What can we do to help them say yes?" Implementing some of the suggestions outlined above will require a significant commitment of time and money, but the alternative is a continuation of the status quo, much to the harm of America's technical health. Until things change, graduate school will remain the option that most graduating seniors never choose, and who can blame them? □

LOREN THOMSEN, Technolog's *tyrant-in-chief, is an EE senior. Upon graduation (in one year, he claims) he will hone the math and physics skills of young seamen at Navy Nuclear Power School in Orlando, Florida.*



Knocking Down Heaven's Door

by Lee Klancher

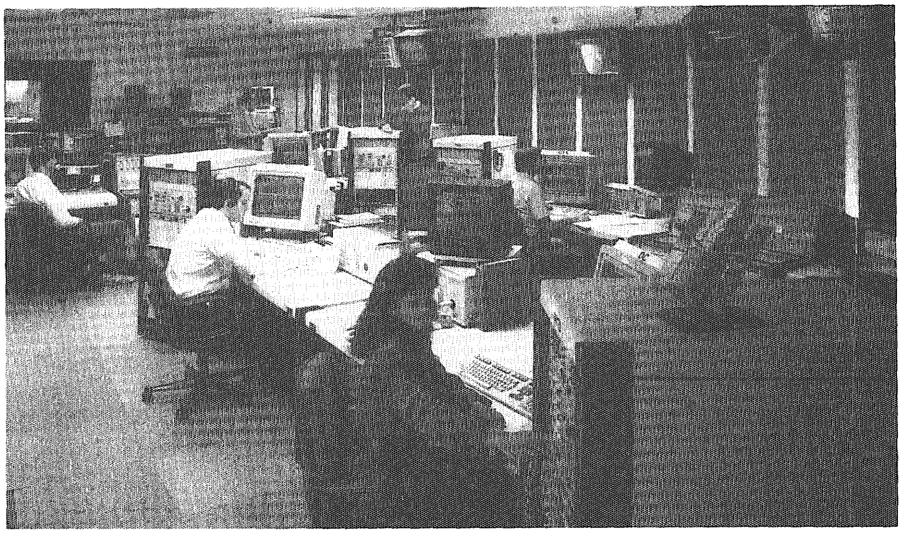
NASA's $1.4 billion Hubble Space Telescope (HST) is scheduled to launch aboard the Space Shuttle on March 26, 1990. NASA optimistically predicts the HST will serve astronomers 15 years or more and expand the known universe 350 times. Less than optimistic critics point to questionable guidance control software, hardware problems, and dated onboard control systems. Researchers, caught in the middle, alternatively drool over the HST's capabilities and bemoan its shortcomings.

The HST is a medium-sized reflecting telescope that will observe the cosmos from an orbit 370 miles above the earth. Equipped with five onboard data-acquisition systems, the HST can take photographs, make spectrographic observations, and measure the brightness of stellar objects. An assortment of guidance instruments, position sensors, gyroscopes, and control systems will direct its movement through space.

The obvious advantage of an orbiting telescope is that the earth's atmosphere is bypassed. The blurring of images caused by the atmosphere (which appears as twinkling) will be eliminated and allow the HST's scientific instruments to measure spectra, luminosity, and locations of stellar objects more accurately and precisely than possible from the surface of the earth. Also, the HST will be able to make observations in the ultraviolet range of the spectrum, which is blocked by the atmosphere and impossible to observe from the surface of the Earth. With the atmosphere out of the way, the HST's resolution will be seven times greater than any ground-based telescope and capable of detecting objects 50 times fainter than those presently observable.

NASA's high-tech, high-power Hubble Space Telescope will drive back the boundaries of the known universe...if it works.

PHOTO PROVIDED BY NASA



The Mission Operations room, where the complex task of controlling the HST will be done. This facility is located in Greenbelt, Maryland, and is staffed by up to 125 people during the course of a 24-hour day.

U of M Profs Seek a Peek

Kris Davidson and Roberta M. Humphreys are two astronomy professors at the University of Minnesota who hope to take advantage of the HST's remarkable capabilities. They are proposing to use the HST's Faint Object Camera to observe the luminous star Eta Carinae, and its Wide Field Camera to observe the Crab Nebula (see sidebar, page 14).

However, there is no guarantee that Davidson and Humphreys will actually be able to use the HST for their projects. The process of being allowed to use the HST for research ("obtaining time") is a slow one. About 600 rough proposals were initially submitted to the Space Telescope Science Institute. Of those, only a select few were accepted by NASA. Davidson and Humphreys are part of several such conditionally-accepted proposals, and they will have to submit secondary applications providing more detailed descriptions of their projects. At that point, NASA will evaluate each proposal and, provided it's feasible, approve it. While Davidson is hopeful that his and Humphreys' projects will pass NASA's scrutiny, he is not overly optimistic. "We're a little nervous," admitted Davidson. "NASA may decide it doesn't care to do what we propose, even if it is technically possible."

Davidson and Humphreys also described other problems involved in gaining access to the HST. Teams of scientists and engineers from industry and universities were formed to develop each instrument employed by the HST. These teams are rewarded by NASA with guaranteed access to the HST. These research groups are referred to as "guaranteed time observers" (GTOs), and the first six months of the HST's observations will be reserved exclusively for them. In ensuing years, proposals submitted by non-GTOs will be given a higher percentage of the HST's time.

"The HST will spend only about 35 percent of each orbit actually gathering data, roughly equivalent to the observation time available to a ground-based telescope."

GTOs are given the right to choose which objects they plan to observe and receive almost exclusive rights to them. "There is a list of GTO objects which is sort of a forbidden list," says Humphreys. "There is no real competition for observation of these objects." The data collected during observation belongs exclusively to the GTO team for six months to one year, after which time the data will be accessible to the general public. "In addition to the funding necessary to build the instrument," says Humphreys, "they have first crack at the 'wonders of the universe.'"

Those "wonders of the universe" to which Humphreys refers will actually be unviewable by the HST most of the time. One of the HST's major drawbacks is that a large portion of its time is spent preventing the telescope and its instruments from being damaged. The highly sensitive instruments would be instantly destroyed if the HST was pointed at, or close to, the sun. Light from the Earth and moon also must be avoided, not because it would cause damage, but because it would ruin images taken by the telescope. Pointing the HST directly forward into its direction of travel would be catastrophic for the primary mirror. The barrel of the telescope would act as a scoop for particles of rarefied atomic oxygen, and the impact of these highly reactive particles would both fog the image and quickly corrode the primary mirror's surface. Because of these factors, the telescope will be unable to view certain portions of the sky.

The HST will also be constricted in the South Atlantic Anomaly, an area where the HST's orbit dips into the earth's radiation belt. Random electronic noise in this region will garble data collection, hence the HST must shut down when passing through. Adding up all the constraints, the HST will spend only about 35 percent of each orbit actually gathering data, roughly equivalent to the observation time available to a ground-based telescope.

Seven Year Itch

However, available observation time is the least of NASA's worries. Troubles have plagued the HST throughout the past decade. The HST is currently scheduled to be put into orbit in late March 1990, seven years behind NASA's original schedule. Costs have spiraled to $1.4 billion, a figure almost five times the original $440 million estimate.

Here's a review of some of the major problems encountered:

• Initial versions of the Fine Guidance System didn't work and the solar arrays did not produce enough power to operate the telescope.

• Latches that held the scientific instruments in place loosened during movement of the HST; if this had been left uncorrected the instruments could have become misaligned during launch and proven worthless once the HST was aloft.

PHOTO PROVIDED BY NASA

• Dust was allowed to settle on the surface of the mirror. This could have irreversibly damaged the mirror. Fortunately, Perkin-Elmer (the manufacturer) was able to remove the dust by blowing dry nitrogen across the surface of the mirror and sucking up the tiny dust particles with vacuum hoses.

Another source of difficulty has been the Science Operations Ground System (SOGS), a computer program responsible for managing the HST's functions. Owing to the complexity of the HST, making optimal use of its time is incredibly difficult. Used by scientists to plan and control the observations being made by the HST, SOGS will determine the most efficient use of the HST's instruments. More simply stated, an operator will list the observations to be made and SOGS will program the instrument required, aim the HST, and initiate tracking.

NASA issued a contract detailing specifications for SOGS, and in 1981 TRW won the bid and was awarded the task of writing SOGS software. By 1983, finished programs began to arrive at NASA's Goddard Space Flight Center. The result

"Scientists now admit that if the telescope had launched in 1986, they would have had to operate the $1.4 billion HST under manual control."

was a complete failure. Scientists at the Space Telescope Science Institute now admit that if the telescope had launched in 1986, they would have had to operate the $1.4 billion HST under manual control.

The culprit of this failure was not the programming, but a conceptual error. The software met all of NASA's requirements, monitoring each minute-by-minute detail; unfortunately, the HST could perform tasks about ten times faster than the software could schedule the observations. With extensive reworking by TRW and the addition of supplemental software packages (including an artificial intelligence system called Spike), project scientists are now confident SOGS will work by launch time.

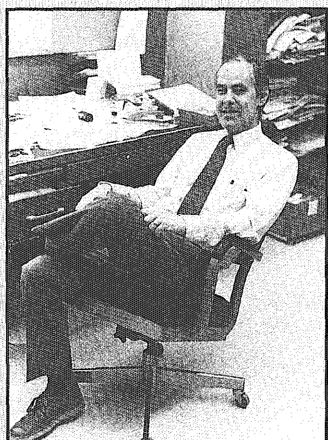
Despite all the problems, NASA is optimistic that the HST will help determine the scope of the universe and last 15 years or longer. With a price tag of $1.4 billion, NASA can promise no less. Others will be satisfied if all the systems merely function

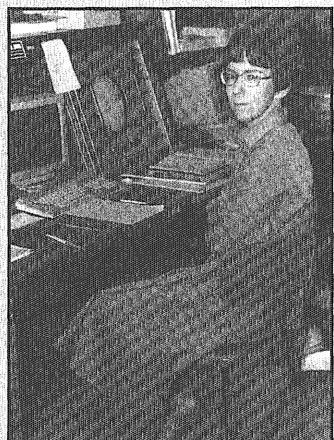
SPACE TELESCOPE
Continued on page 18...

Star Search

University professors Kris Davidson (principle investigator) and Roberta M. Humphreys (co-investigator) have proposed to use the HST to study Eta Carinae, a star visible in the sky of the southern hemisphere. Extremely luminous and massive, Eta Carinae exploded in 1840, temporarily becoming the second brightest star in the sky. The star remained intact after the explosion, surrounded by a cloud of gas and dust.

Eta Carinae's explosion shed an amount of matter roughly equal to the weight of our sun, or one solar mass. The star's mass is estimated to be around 100 solar masses and the surface temperature is thought to be a blazing 30,000° Celsius. "At that size, this star is about a million times more luminous than the sun," said Davidson, "and that makes it one in a billion."





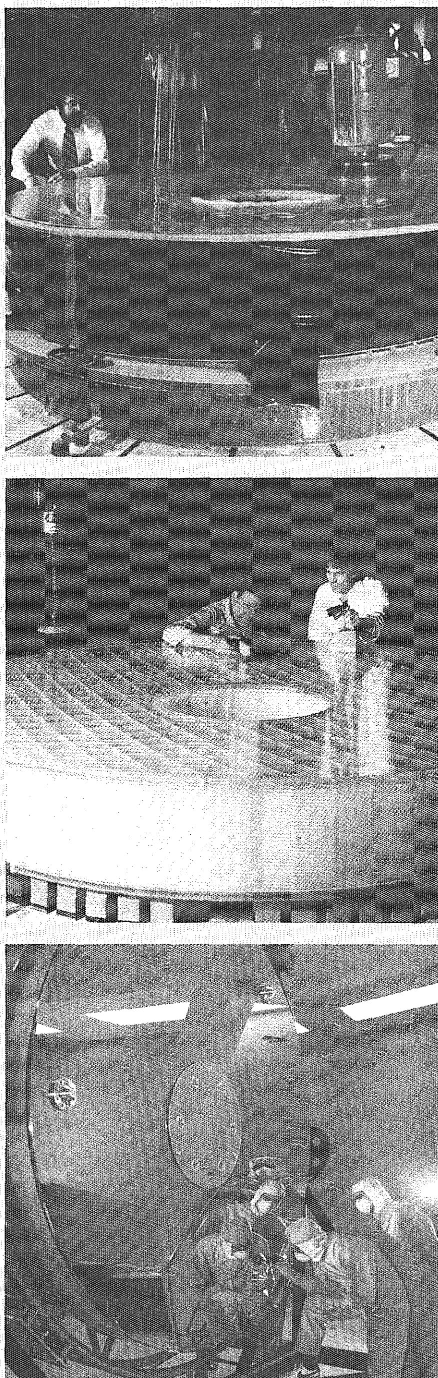
University astronomy professors Kris Davidson and Roberta M. Humphreys are hopeful that they will use the HST to study the Crab Nebula and Eta Carinae.

Why and how such large stars explode is the question Davidson and Humphreys hope to answer with the HST. This question ties into research Humphreys did about ten years ago in which she discovered that very large stars do not seem to evolve into red supergiants, as smaller stars do. Humphreys theorized that turbulence and mixing combine with the pressure of nuclear reactions to maintain the size of these stars. She hopes that information gathered by the Faint Object Spectrograph on the HST will shed light on the hows and whys of Eta Carinae and similar large stars.

The Faint Object Spectrograph (FOS) will be used to look at the spectra of smaller portions of Eta Carinae than has ever been possible. Because it is not constrained by the earth's atmosphere, the FOS can observe an area only 1/10 of an arc second (1/36,000 of a degree) across. Resolution of this degree is not possible with earth-based telescopes. Eta Carinae is of special interest because German astronomers, using a special technique called specleinterferometry, have discovered multiple radio sources in Eta Carinae, suggesting it may actually be a system of large stars. Observations made by the HST's instruments would allow determination of the existence, number, and size of these other stars.

Davidson is also the principle investigator of a proposal to study the Crab Nebula using the Wide Field Camera. His objective is to study the chemical composition of the debris in the nebula filaments by taking images of them in visible and ultraviolet light. With this data, Davidson hopes to resolve disagreement over the Crab Nebula's type of supernova and will attempt to understand the forces involved in maintaining the physical structure of the filaments.

PHOTOS BY STEVE HONG



The 2.4 meter HST primary mirror, in various stages of creation. (Top) The mirror being ground to a roughly spherical shape at the Perkin-Elmer Corporation. (Middle) The mirror was one of the first to be ground with small, computer-controlled tools. (Bottom) In a "clean room" the finished mirror is ready to be placed into its graphite-epoxy frame.

Mirror, Mirror...

A super-smooth mirror, six observation instruments, and a sophisticated guidance system make the HST a piece of especially high-tech hardware.

The Hubble Space Telescope is a masterpiece of astronomical technology. The Optical Telescope Assembly (OTA) is simply a fairly large reflecting telescope, but the instruments and guidance system represent what is probably the most sophisticated and complex technology ever used in astronomy.

The telescope assembly is a Ritchey-Chretien reflecting telescope and consists of two concave mirrors of unequal size. Light is admitted to the primary mirror and reflected to the smaller secondary mirror. The secondary mirror then reflects the light back through a hole in the center of the primary mirror. The point of focus, or focal plane, is just behind the primary mirror.

The 2.4 meter primary mirror was manufactured by Perkin-Elmer and is made of ultra-low expansion titanium silicate glass with an aluminum-magnesium flouride coating only a few millionths of an inch thick. It holds the honor of being the most precise large mirror ever made. If the Pacific Ocean was as smooth as the mirror, the largest waves would crest a mere 0.004 mm high.

The optical telescope assembly collects light for six different instruments: two spectrographic instruments, two cameras, an instrument that measures luminosity, and an instrument that measures spatial relations between stellar objects.

The Instruments

The Wide Field/Planetary Camera (WF/PC) will be used to observe large areas of the sky and nearby planets. The camera can observe light from the far infrared to the near ultraviolet by using one of five available spectral filters. Resolution of this camera is expected to be ten times clearer than that of ground-based equipment, yielding images of Jupiter comparable to those taken by the Voyager spacecraft.

A "pick-off mirror" channels light from the primary mirror to the camera, where a pyramidal mirror divides the beam into four separate portions. Each portion is directed to a charged-coupled device (CCD) that breaks the light beam into 640,000 individual units, or pixels. The light intensity of each pixel is transmitted back to earth, where the data will used to construct an image of the object being observed.

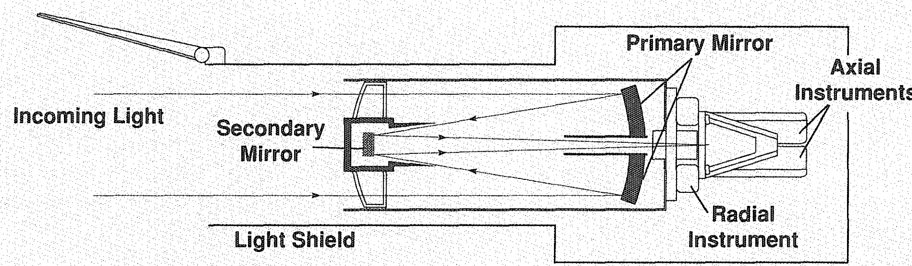
"If the Pacific Ocean was as smooth as the mirror, the largest waves would crest a mere 0.004 mm high."

The Faint Object Camera (FOC) will utilize the full optical performance of the HST, peering as far as possible into the visible universe. The European Space Agency contracted British Aerospace to construct the unit. The camera has the capability to effectively suppress light from bright objects while observing faint sources nearby, as well as select an incredibly small field of view.

The FOS will be used to study the chemical composition of distant galaxies, mysterious "jets" produced by quasars, and the physical make-up of quasars. In essence, it will provide low and moderate resolution spectra of extremely faint objects in the ultraviolet and visible wavelengths. Two magnetically-focused, photon-counting Digicon sensor systems are the workhorses of the FOS. Before reaching these sensors, light is refracted by a grazing mirror and can be run through a wide variety of filters.

The High Resolution Spectrograph (HRS) is similar to the FOS in that it uses two Digicon Sensor Systems and will observe

PHOTOS PROVIDED BY NASA



The HST is essentially a standard Ritchey-Chretien type reflecting telescope. Light enters the telescope assembly and strikes the large primary mirror that reflects the light to the smaller secondary mirror. The concentrated image is then channelled to the HST's various instruments by small pick-off mirrors.

spectra of distant objects. The HRS will use more light than the FOS and break the light into smaller increments, providing higher resolution. It differs in that it will look only at the ultraviolet wavelengths, unlike the FOS which observes both ultraviolet and visible light. The composition of supernovas, the stages of star evolution, and the chemical composition of comets are all subjects to be studied with the HRS.

The High Speed Photometer (HSP) is simply an instrument that will accurately measure the brightness of an object. The HSP is sensitive enough to detect the light from a flashlight 250,000 miles away and will be able to separate fluctuations in brightness that occur within as little as 16 microsecond intervals. Objects that fluctuate within less than one second must be made of incredibly dense material in order to hold something in a one-second orbit. White dwarfs, neutron stars, and black holes are the only known objects dense enough to support such rapid luminous fluctuations, and will be subjects of study with the HSP.

Ready, Aim,...Transmit

Aiming the HST at a given point in space with the precision necessary was a task unlike anything the scientific community had previously attempted. Charles Robert O'Dell, project scientist for the Space Telescope, compared directing the HST to attempting to drive a car by remote control from Los Angeles to a specific parking spot in Boston.

To achieve such accuracy, the pointing control system uses information provided by six gyroscopes and two Fine Guidance System (FGS) light sensors to keep the telescope locked on a target. The guidance system is so accurate that, once locked on target, a beam extended 1000 km from the telescope's end would move no more than 3 cm off-center.

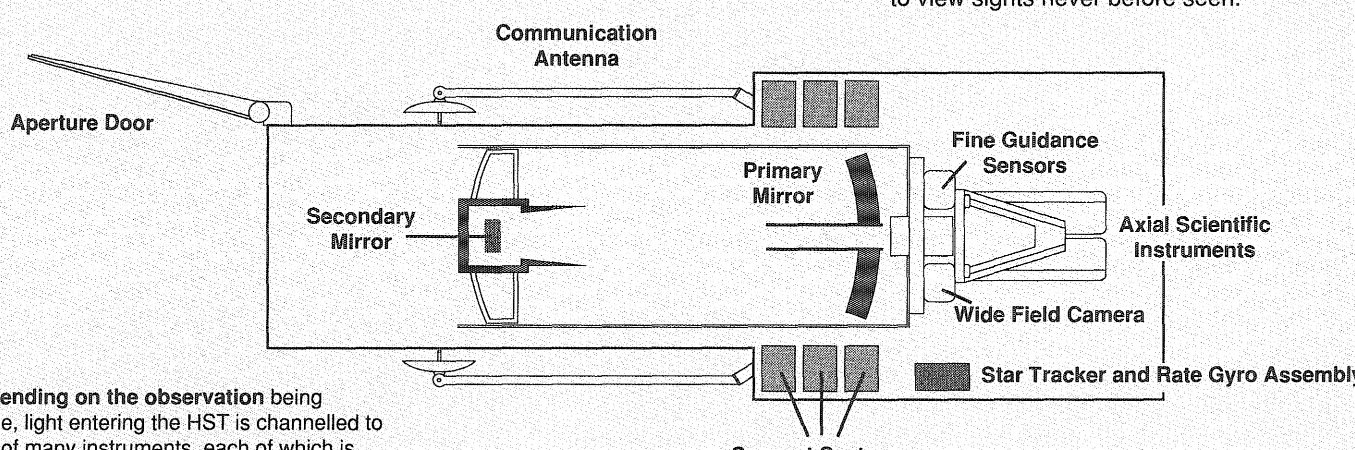
"The HSP is sensitive enough to detect the light from a flashlight 250,000 miles away"

The Fine Guidance System (FGS) is actually considered a sixth instrument due to its ability to measure the relative movement of stellar objects. The FGS has three light sensors, two of which will be used in conjunction with a complex system of mirrors for locating and locking onto a target. The third light sensor can be used to make astrometric observations while the telescope is changing position.

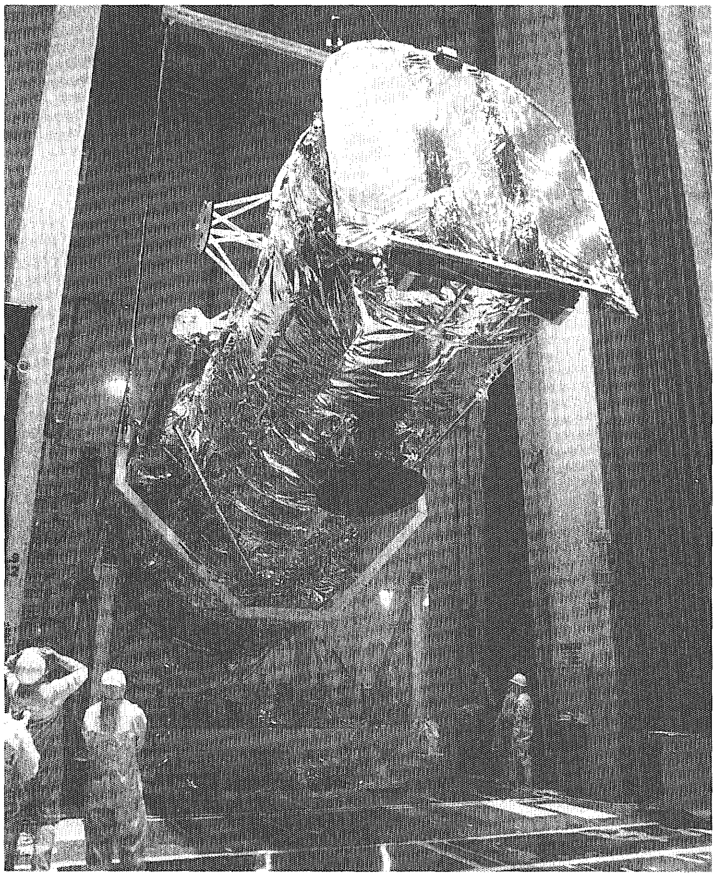
Once the telescope has collected data, it will be beamed to one of the two satellites in NASA's new Tracking and Data Relay Satellite System (TRDSS). From the TRDSS' orbit 36,000 km above the earth, the data will be beamed to a station in White Sands, New Mexico, then up to a commercial communications satellite, and down again to Goddard Space Flight Center. The data will then be transmitted 40 km, via land line, to the Space Telescope Science Institute on the campus of Johns Hopkins University.

Should that data prove useless because of a failed or weak HST component, removable panels allow access to modules in the equipment section and to the instruments themselves. To facilitate maintenance by an astronaut, the aft shroud is fitted with handrails and portable foot restraints. The space mechanic would simply open an access panel from the outside, unplug the component, and install its replacement.

The sophisticated components of the HST represents a massive design and engineering effort, not to mention $1.4 billion. The extensive capabilities of the HST will expand the known universe and allow us to view sights never before seen.



Depending on the observation being made, light entering the HST is channelled to one of many instruments, each of which is best suited to a particular intensity and frequency of light.



The HST, prepared for shipping to Kennedy Space Center, is shown above being moved from the assembly room at Lockheed Missles and Space Company in Sunnyvale, California.

Space Telescope
Continued from page 15...

as they are intended to. Davidson feels that NASA's 15-year estimate probably reflects what the public needs to hear and is not based on fact. He goes on to state that in the field of astronomy, "no one will be surprised if it fails." It's rumored that NASA was told there is a good chance that one of the five scientific instruments will fail on launch and that another will fail within the first year.

Launch dates have been pushed back and millions of dollars spent to bring the HST to acceptable specifications. Despite the limited time the HST will be able to make observations, the limited access for the average researcher, and its questionable lifetime, the HST, if it works, will be an unprecedented astronomical achievement. If it fails, other precedents will be set, but they probably won't be beneficial to the world of astronomy, or to the field of space research.

NASA cites approximating the age and size of the universe, testing the "big bang" theory, and observing planets in nearby solar systems as the HST's primary objectives. In reality, the more valuable data gathered by the HST will probably pertain to the known universe and its composition. "The only thing sure to be discovered," says Davidson, "is the unexpected." ☐

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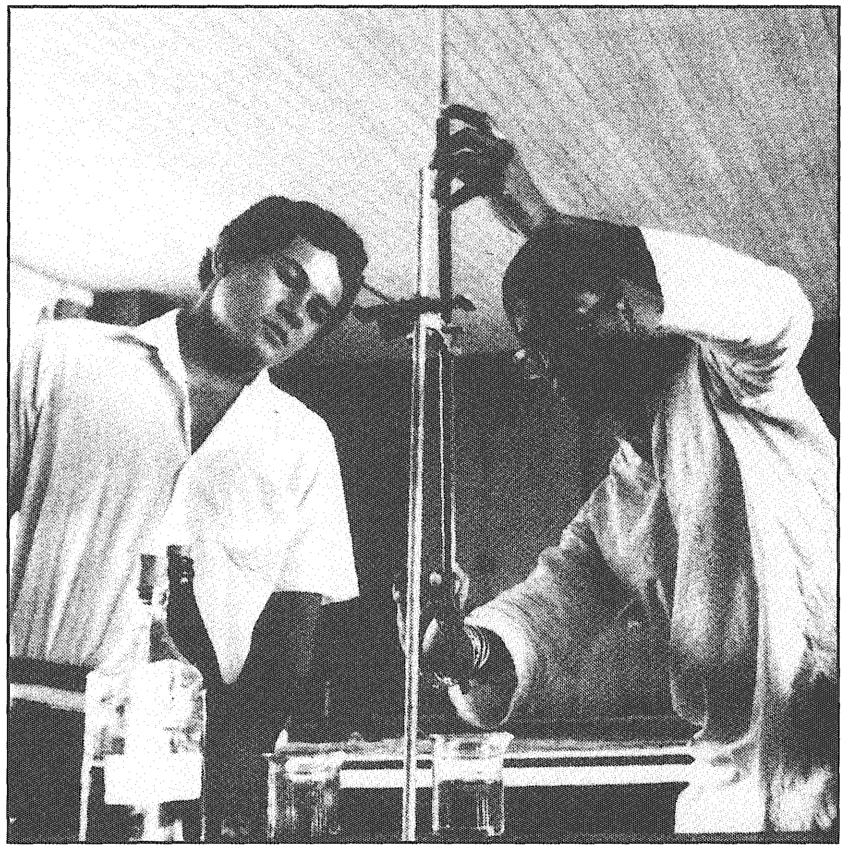
minnesota
TECHNOLOG

Writer Profile: Lee Klancher

Lee Klancher is a former engineering student who has opted for the glamor, respect, and fat paychecks of journalism. A science enthusiast, he hopes to be the next Isaac Asimov, "but without the sideburns." Lee is the complete *Technolog* package—he edits, writes, and does layout.

PHOTO PROVIDED BY NASA



The Overseas Option

by Paula Zoromski

Set aside the 1960s imagery. Today's Peace Corps offers the technical graduate challenges unavailable from corporate America.

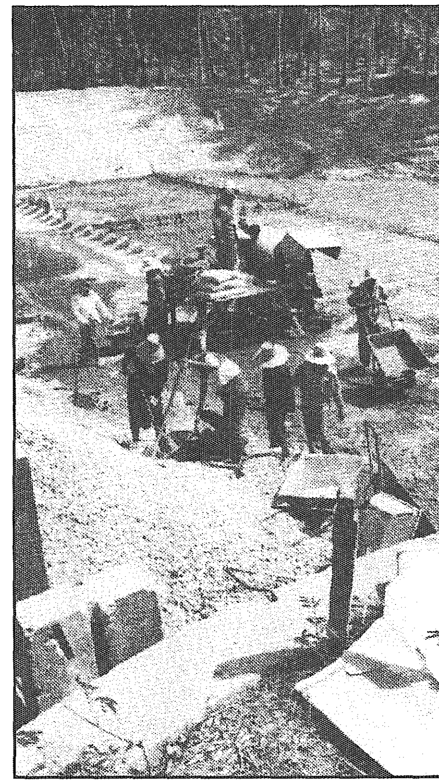
For the past four or five years you have labored diligently over your textbooks. Integral calculus, differential equations, inorganic chemistry, and physics have filled your days and nights. Finally, after all this hard work, you are going to do the formerly unimaginable: graduate. You have been a student for as long as you can remember, but now it's time to enter the "real world."

As an Institute of Technology graduate, your options are many. The most popular choice comes first to mind: Sign on with corporate America and start earning a respectable salary so you can pay back those student loans. Live the American dream. Buy a car, a boat, a house in the 'burbs.

A second option is the plunge into grad school—a fairly painless alternative. After all, you're experienced at school. After five or six additional years of education, you could move to the other side of the podium as a professor. It has been predicted that by the year 2000 there will be a grave shortage of engineering professors. You're sure to find a job in academia.

If neither of the first two options are appealing, but you don't want to drop out of technology altogether, there is another option to consider: What about working for an international development program such as the

Pictured at right is Melissa J. Lang, a water resources engineer in Thailand. As a Peace Corps volunteer, she designs small dams, spillways, and water supply systems. (Photo provided by Peace Corps)



Peace Corps? If you want to travel, promote technical advances in underdeveloped countries, experience another culture, and see the world from another perspective, this may be a path worth considering. Contrary to what you may think, the program did not die with 1960s idealism, but actually survived the self-centered 1980s and continues to thrive.

Function and Goals

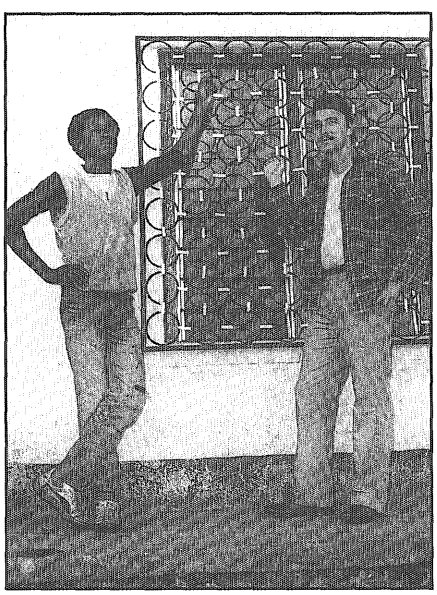
The Peace Corps was inaugurated in 1961 under the Kennedy administration. The primary goal was, and still is, to supply interested countries with trained Americans who possess specific skills. Additionally, America benefits by becoming more familiar with the countries served, as well as being better understood ourselves.

"If you want to travel, promote technical advances in underdeveloped countries, experience another culture, and see the world from another perspective, this may be a path worth considering."

More than 60 countries around the world benefit from the Peace Corps. These countries request skilled people from the United States, and the Peace Corps agency matches applicants with the requests. Technically skilled people trained in math and science are in demand. Volunteers are employed to teach secondary school and work on development projects ranging from water sanitation to tree planting.

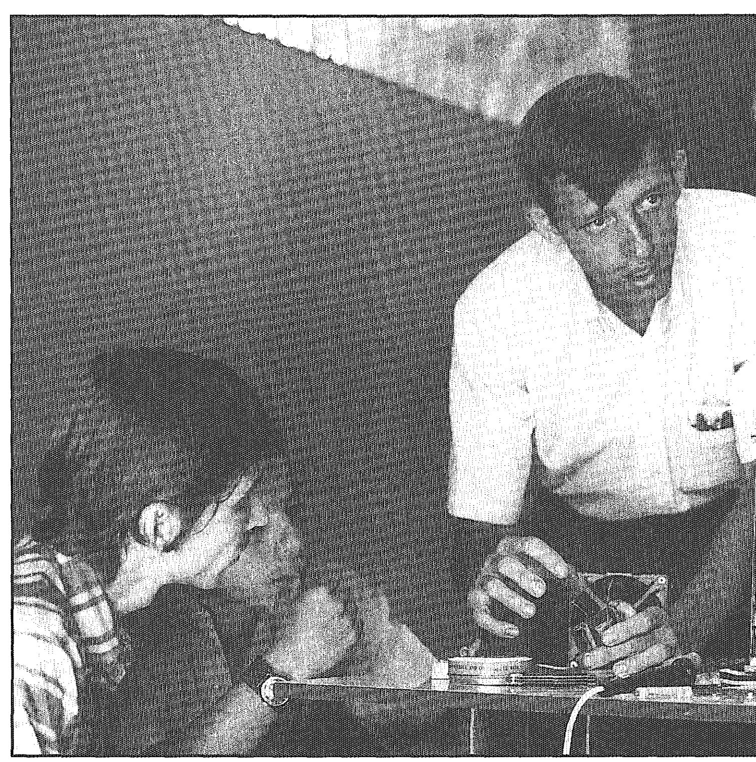
Qualified volunteers are informed of an opening in a foreign country at least four months before their training is scheduled to begin. Training takes place in the host country. According to Steve Schrenk, a 1984 participant who worked as a physics instructor in Cameroon, the training was intensive and prepared him well for his experience. During his training session he stayed in the dorms of a mission school. For three weeks, Schrenk and two to four other Peace Corps volunteers were taught French by Cameroonian instructors. Next, he spent one week observing an active volunteer. Finally, the Peace Corps set up a five-week model school that was open to anyone in the community who wished to attend. Schrenk and the other volunteers prepared the lessons and practiced teaching. Following each school day they were critiqued and advised on teaching methodology.

Pictured below is Steve Schrenk, Peace Corps volunteer in Cameroon during 1984 and 1985. He's pictured with his Cameroonian roommate, a struggling young artist.



Volunteers are sent to fulfill their assignments when the training period is over. Living conditions and contact with other volunteers vary from country to country. In some cases a participant may be alone in a town, while in others there are many volunteers. In Schrenk's case, six volunteers worked in the same area.

In Schrenk's school, classes were taught in English and followed the British curriculum. Course content was fixed because students had to take national entrance exams to enter high school and col-

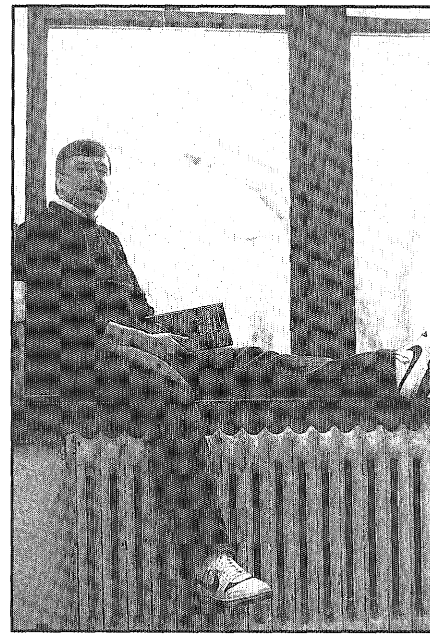


Pictured at right is Michael Crownly teaching electrical engineering at the Polytechnic Institute in Guayaquil, Ecuador. He has a Masters degree in electrical engineering from Santa Clara University in California. (Photo provided by Peace Corps)

lege. However, Schrenk was free to choose his method of teaching.

It was easy to see the impact of the Peace Corps in Cameroon. The principal of Schrenk's school, as well as most government officials, had at some point been instructed by a Peace Corps volunteer.

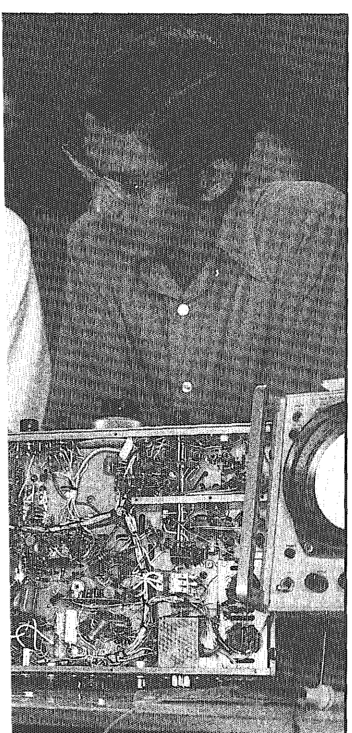
Beyond teaching or working on development projects, Peace Corps volunteers also represent the United States. Schrenk commented that people in Cameroon, "... have a distorted impression of the U. S. They want to live here (U.S.), but think it's a violent place." Unfortunately, they form their impressions of America from such popular movies as *Rambo*. Another common stereotype was that all Americans are very religious. Since Cameroon is not a hot American tourist spot, most of the Americans encountered by Cameroonians are missionaries.



Pictured above is Steve Schrenk, back from Cameroon and working on a Ph.D. in physics here at the University.

"Beyond teaching or working on development projects, Peace Corps volunteers also represent the United States."

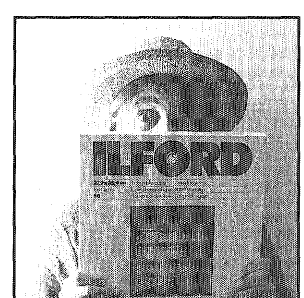
Participating in third-world development, learning about foreign cultures, and representing the United States abroad are some of the many benefits of Peace Corps service. However, there are some financial rewards as well. While in service, living expenses, health services, and transportation costs are paid by the Peace Corps. Volunteers receive six weeks of paid vacation time for a two-year commitment. And on return to the United States each volunteer is given a $200 readjustment fee for every month of service. Several universities offer returning volunteers credit or scholarships for the experience. Finally, repayment of government loans is reduced and interest does not accumulate during the period of service.



The Peace Corps is not a wise choice for every technical student. When you are choosing your career, you should consider all available options and pick the one that's best for you. But, if you're ambitious, adaptable, and adventurous, then the Peace Corps just might be the ideal beginning to life in the "real world." □

minnesota TECHNOLOG

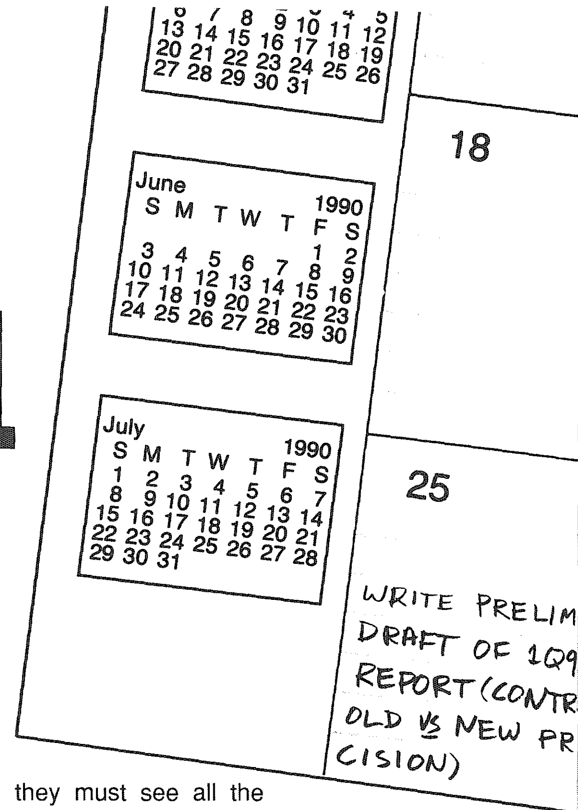
Writer Profile: Paula Zoromski



Paula Zoromski is a fifth-year ChemE senior. She's also a staff photographer, specializing in dogs and IT professors. Her subjects rarely bite, slobber, fidget, or urinate on her (at least the dogs, anyway). Currently, she's hell-bent to graduate, and plans to begin her career with a few years in the Peace Corps or some other international program.

Getting Technical

by Bonnie Knapp



Memos, presentations, reports, technical papers?! Surprise. Technical students have to *communicate* with people when they get out of school.

I sit at my desk, the computer staring me in the face, begging me for the right words. Interview notes and resource books surround me, suffocating me with information. My deadline is long past, and I know that in less than three hours the editor will greet me with a forced, cheery smile, asking, "So, is it done?"

The words are there. One thousand, thirty-five of them. My computer can count. But the words aren't the right ones. Here I am, a technical writer and former writing teacher, trying to create an article for engineering students about the virtues of writing, and I can't write it. The ultimate irony.

Frustrated and tired, I head for a nice hot shower—sure stimulation for a tired brain. As the water pounds on my face, a realization about my writing hits me. The very thing I want to stress in this article is the very thing I have failed to do. I have neither focused clearly on my audience nor determined a purpose for the article. Instead, I have immersed myself in everything I know and want to say about the writing process, in everything my interviewees expected me to discuss, and in everything I think the editor is expecting to see. In doing so, I have forgotten about you, the readers.

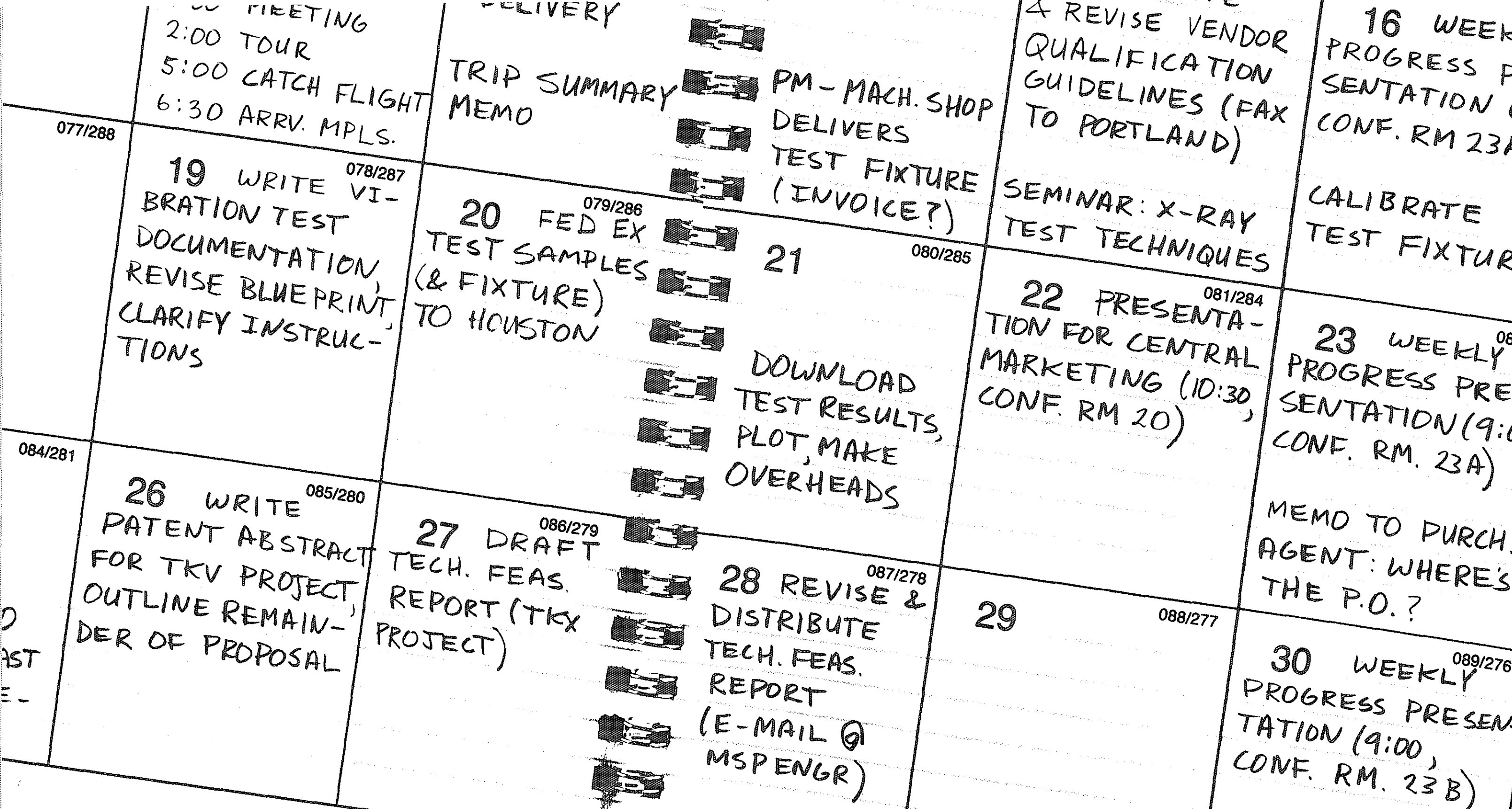
And so it is when experts write about their areas of expertise. They become so enamored with all the technical details they find interesting and important that they forget to consider what their readers need to know. Carol Fey, in *Engineering Good Writing*, characterizes technical people as inductive thinkers. She explains, "They are extremely detail-oriented; they must see all the pieces before they can formulate the whole picture."

As engineers, you will be faced with that dilemma daily. You will often find yourself steeped in information and details that may not be relevant to everyone in your workplace.

Consider some typical expectations once you are assigned to a design project. After you have reviewed the project and formulated some ideas, management and marketing will demand a proposal that convinces them your idea is a sound one. Later, after you've traveled to the coast to see a similar project in action, your manager and the accounting manager will want a trip report justifying your expenses.

"One of the greatest strengths engineering students bring to the writing process is their problem-solving ability: 'They grab abstract concepts quickly and can organize their thoughts well.'"

There will be memos to other team members, keeping them apprised of your progress; a report summarizing the results of a feasibility study; and certainly oral presentations along the way for management, marketing, and your co-workers. If your



design enters a manufacturing environment, or is something that will be sold to a customer, you may eventually have to write documentation explaining its operation.

As you might expect, your job performance will probably be evaluated on more than just your technical engineering abilities. Because a major part of your job is the communication of those abilities, your success will also be determined by your ability to create effective written and oral presentations.

According to Faith Jaycox, a composition instructor who teaches "Technical Writing for Engineers" at the University of Minnesota, when her students go out and interview engineers, many are surprised to find out how much writing engineers actually do and the degree to which that writing determines their success in the business world. You can be the best technical expert in the company, but unless you can clearly communicate your technical expertise to people who have varying levels of interest in your area, few will know or care that you are the best.

After spending a lengthy period of time in an academic environment, you may find that the criteria on which your communication is judged will change after graduation. In school you are often rewarded for the accuracy of your facts and the quality of your thinking. In many science and technical classes, the form those facts take and the format in which they are presented are overlooked in honor of the technical content. Suddenly, out in the business world, you have to be concerned with translating those facts and ideas into a form that laypeople can understand.

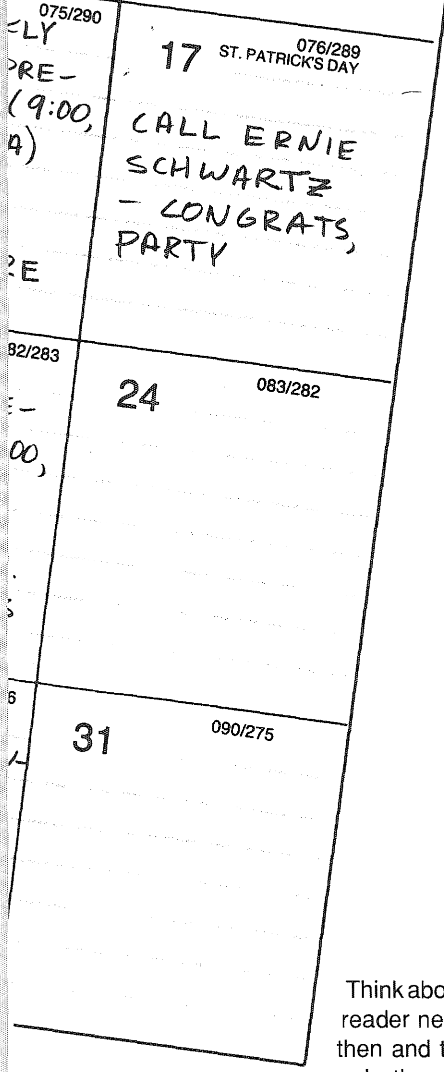
Joyce Malek, Assistant Director of the University of Minnesota Center for Interdisciplinary Studies of Writing and an instructor for the "Technical Writing for Engineers" course, explains that students who are used to working with equations and graphs in their classes sometimes have trouble translating their work into something that non-technical people can understand.

"By using the same analytical skills you would use with any design project and focusing on your audience, you will find writing less overwhelming."

Both Malek and Jaycox agree that one of the greatest strengths engineering students bring to the writing process is their problem-solving ability. "The engineering students in my classes tend to be bright," Malek stresses. "After all, they have to work very hard to succeed in IT. They grab abstract concepts quickly and can organize their thoughts well." Many students, however, are uncomfortable with writing because they lack the proper background in the writing process.

If that description characterizes you, then your challenge is to let go of any anxieties you have about your own writing abilities and approach the writing process much as you would any other technical problem. As a technical writer, you must first determine audience and purpose. In *Writing with Power*, Peter Elbow advises, "As you start to write, or even before, picture your audience in your mind's eye and figure out just how you really want to affect them—and then write very much *to* them. If this strategy works, it will save you much time and effort."

If you're writing instructions for line operators, for example, remember that they probably do not need to know the detailed theory behind the equipment's operation, nor do many of them care to know. Similarly, if you are writing a proposal to the marketing department, they will be more concerned with the likelihood of the project's success than with the intricate details of its operation and implementation.



"Writing Across the Curriculum"

In 1988, the Bemis Company Foundation, a corporation committed to the improvement of the communication skills of engineering students in the Institute of Technology, gave a $75,000 grant to the University of Minnesota Center for Interdisciplinary Studies of Writing. The money was earmarked for a project called "Writing Across the Curriculum in the Institute of Technology."

The project, designed to help engineering students gain the effective communication skills they will need to succeed on the job, focuses on three elements: 1) Workshops for faculty; 2) The addition of speaking instruction to the existing "Technical Writing for Engineers" course; and 3) An improved curriculum designed by teams of practicing engineers and faculty in engineering and liberal arts.

According to Greg Gaut, project coordinator, the workshops for the IT faculty have resulted in several faculty members expressing interest in integrating more writing into their courses. The focus so far has been on senior design courses in mechanical and chemical engineering. Instead of asking students to magically appear one day with collaborative reports done, instructors require a rough draft of the final report and the students attend a peer review of their work, much as they might have to do in the corporate world. "We picked the senior design courses because they are the capstone courses for these programs. Students should be preparing professional level presentations at this level," Gaut explained.

Unfortunately, even though Gaut believes that the project has raised a lot of consciousness and allowed them to build a core of concerned faculty, the mechanical engineering and chemical engineering programs are only two out of eleven IT programs. Ideally, however, through the implementation of other activities resulting from the grant, students will be given more opportunities to hone their writing skills before they graduate.

Think about what your reader needs to know then and there. Don't make the same mistake I did as I sat down to write this article—wanting to tell you *everything* I knew about writing. Decide what purpose your communication will serve. Must you motivate someone to follow a process correctly? If so, your communication must be clearly written and formatted in such a way that they will want to use it. Must you convince someone that your ideas are sound and worth an investment of time and money? In that case, you must be persuasive and to the point. Or must you explain your progress on a technical project to your supervisor who has an MBA? Then your communication must be easy to understand—free of jargon and technical details that only another engineer could comprehend.

Effective communication can indeed be a problem, but it doesn't have to be a barrier. By using the same analytical skills you would use with any design project and focusing up front on your purpose and audience, you will find your job less overwhelming. You will also find yourself far more efficient and productive if you first do a quick analysis of your task. Not only will your supervisor, the line operators, and anyone else with whom you communicate thank you, but your computer will thank you for giving it the right words before your deadline is past. ☐

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Jaycox, Faith; interview.

Malek, Joyce; interview.

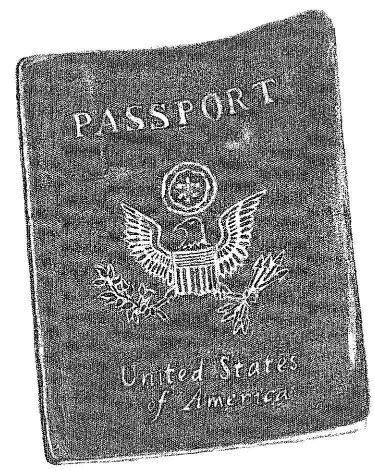
minnesota
TECHNOLOG

Writer Profile: Bonnie Knapp

Bonnie Knapp is pursuing a Ph.D. in training and development here at the University. She believes that those engineering and science students who develop their communications skills will go far in corporate America, while those who don't must be content to serve as groveling toadies to tyrannical management types. Oh, and she's from Ohio.

Studying Down Under

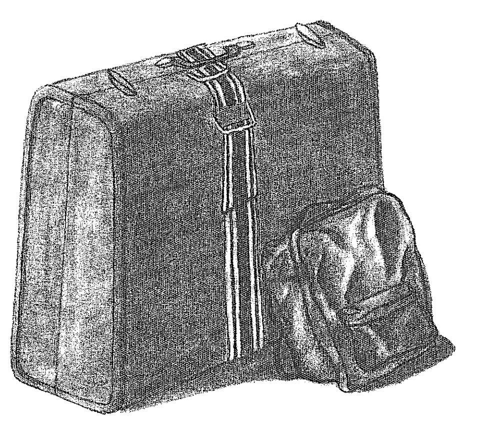
by Sue Luedtke



Studying abroad—It's not just for liberal-arts majors anymore. In fact, overseas schooling may even give you an edge in the engineering and science job market.

The toughest job you may have after graduation is finding that first real job in your field. You will fill out applications, make phone calls, attend interviews, and face more rejections than you will care to admit. How can you make your resume stand out in the sea of applications your prospective employers will read?

The answer may lie in student exchange programs, according to Ian Fairnie, executive vice-president of the North American office of Curtin University, a school located in Perth, Western Australia. One of the reasons Fairnie encourages students to study in Perth is to give them an edge in the business world. Fairnie claims, "If you've been to Australia and you've been to Perth and you've picked up an internship with a large Western Australian engineering company, when the people employing you look at all of the applications in front of them, this will stick out because you're different and you've shown an interest in the world."



Fairnie is a former dean of the College of Agriculture at Curtin. Since he has been directing Curtin's North American office, near the Minneapolis-St. Paul International Airport, Fairnie has been responsible for developing and promoting faculty and business liaisons in North America, as well as encouraging students to study at Curtin.

Curtin University, with almost 17,000 students, is the largest university in Western Australia. Curtin was established as an institute of technology twenty-one years ago. It became a full-fledged university in 1987 when it expanded to include a liberal arts curriculum. According to Brian Dibble, a comparative literature professor from Curtin who is on an exchange program here at the University of Minnesota, surveying, chemical engineering, physics, biology, chemistry, and atmospheric physics are strong programs at Curtin.

ILLUSTRATIONS BY JOYCE RAJENDREN

Destination: Perth, Australia

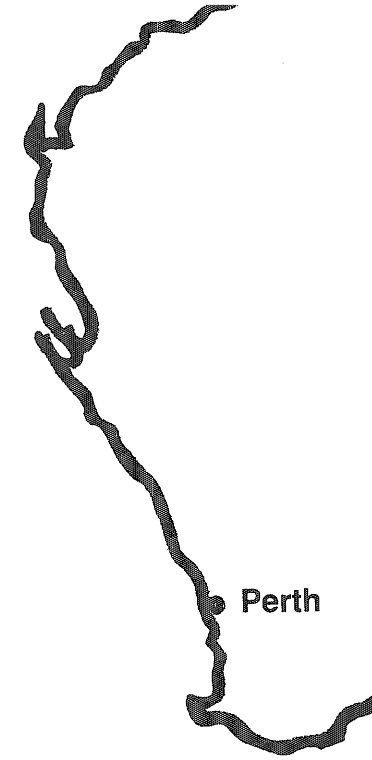
For those of you who are tired of Minnesota winters, Perth, Western Australia, may be the place to go. "It never snows in Perth," said Ian Fairnie, executive vice-president of Curtin University's North American office. "It's probably the most beautiful city in Australia."

The climate in Perth is much like San Diego's. "Almost every day that it rains, the sun shines too," said Brian Dibble, a comparative literature professor from Curtin who is on an exchange program here at the University of Minnesota.

Perth, with a population of one million people, is located on both the Swan River and the Indian Ocean. The city is protected by Rottnest Island, which is ten to twenty-five miles offshore in the Indian Ocean. Dibble said the island was named by Dutch explorers who found small kangaroos, called quokkas, on the island. The Dutch thought the little marsupials were rats, and therefore called the island a "rat's nest," or, in Dutch, "Rottnest."

Perth is essentially a non-industrial city, Dibble said. As a result, it is a very clean city with little pollution. Fairnie described Perth as a "very outdoorsish sort of place." Dibble advises visitors can expect a "lotus land" in Perth, offering a physically nice place with friendly people.

Americans who visit Australia must look at things in Australia through different eyes, Dibble warns, because Americans are very ethnocentric. "Australia is a very good place for Americans to discover what living in America is like."



Most students who study abroad, however, are not science or technology majors. Fairnie points out that the vast majority of U.S. students who study abroad are white, affluent, female liberal-arts majors. He gave two reasons why other students who are interested in studying abroad do not go: Cost and faculty support.

"The perception is that it's expensive," Fairnie said. "When you take airfare out of the equation, it probably isn't any more expensive than hanging out in Minneapolis."

Faculty, particularly in a school such as IT, may feel they need to maintain high academic standards, which they fear might be jeopardized by transferring credits from other universities. As a result, faculty tend not to send positive signals about foreign study to their students, Fairnie said. Negative faculty attitudes cause many IT students, in turn, to worry about whether the study-abroad credits will transfer into their rigid academic curriculums.

"If you've picked up an internship with a large Western Australian engineering company, then when the people employing you look at all of the applications in front of them, this will stick out because you've shown an interest in the world."

Fairnie suggested two ways of overcoming the curriculum difficulties. Some engineering students are picking up their liberal arts credits in Australia, while others wait until graduate school to study abroad.

There are drawbacks to studying abroad, Dibble warns. For example, someone studying law would be studying Australian law, not American law. For architects, building codes can vary from country to country. But Dibble says these experiences can be positive. "By the same token, that can be a very eye-opening experience," he said.

In order to help faculty better understand what Curtin University offers, Fairnie said he would like to develop a faculty exchange program. Dibble and Barbara Milech, an English professor from Curtin, set up their own exchange program to come here. Curtin does have faculty exchange programs at other universities.

Along with developing a faculty exchange program and encouraging students to apply at Curtin, Fairnie's office develops links with corporate America, especially those corporations with significant activities in Australia. Joint research projects between Curtin and American companies are in the works, Fairnie said. Possible joint projects may involve aerospace, defense, computer science, and management of technology transfer. In fact, one of the advantages of setting up the North American office in Minneapolis is the proximity of large high-tech corporations. Control Data Corporation is right across the street from Fairnie's office. Minneapolis is also a very central location for Fairnie's interactions with the United States and Canada.

Not everyone shares Fairnie's optimism that Minneapolis is the right place to locate Curtin's North American office. Dibble feels

Minnesota is not a good place to locate in the sense that Minnesota is geographically and educationally isolated because most colleges and universities are found on the coasts. Dibble said the colleges in the Midwest are generally quality schools, however.

> **"'Of the largest corporations in the United States, 40% have significant overseas operations," Fairnie said. "A company would be interested in talking to you about further international experience.'"**

Fairnie acknowledged some people worry Curtin is making a mistake by locating an office in Minnesota. Most of the objections come from people on the East Coast who worry about Minnesota's climate. "The people in California don't care. The people on the East Coast are really intrigued," Fairnie said. They don't see how Minnesota's climate can sustain life as they know it, he joked.

Regardless of the location of the North American office, it's here to help students as they plan to study abroad. Currently Curtin is developing its summer programs. Fairnie said he is also putting the finishing touches on the proposed reef and rain forests summer program, which will probably be available to U of M students. Fairnie said he plans to talk to the international study groups on campus and may take out a permanent ad in the *Minnesota Daily* to advertise the Curtin program.

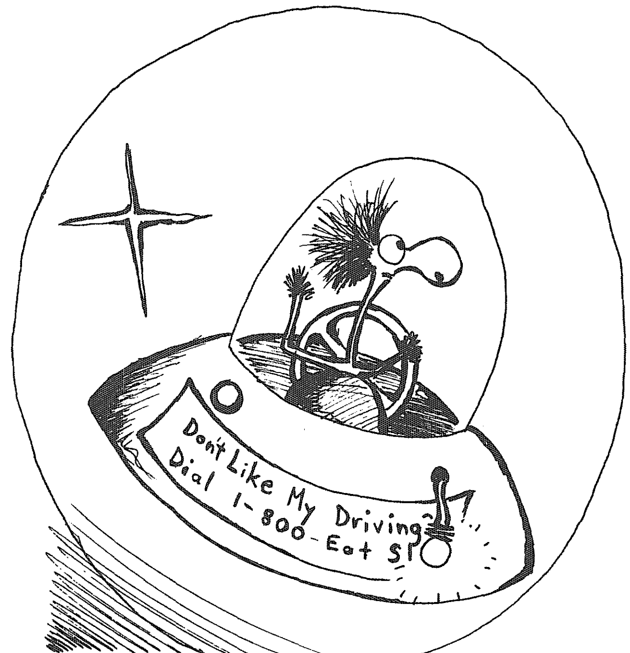
For those who do find their way to Curtin University, Fairnie has some advice: "View your time in Perth as a time to get to know regional issues, oil, defense, and mining." It is this education, along with internships at Western Australian corporations, that can give students an edge on the competition after graduation. "Of the largest corporations in the United States, 40% have significant overseas operations," Fairnie said. "A company would be interested in talking to you about further international experience." ☐

minnesota TECHNOLOG

Writer Profile: Sue Luedtke

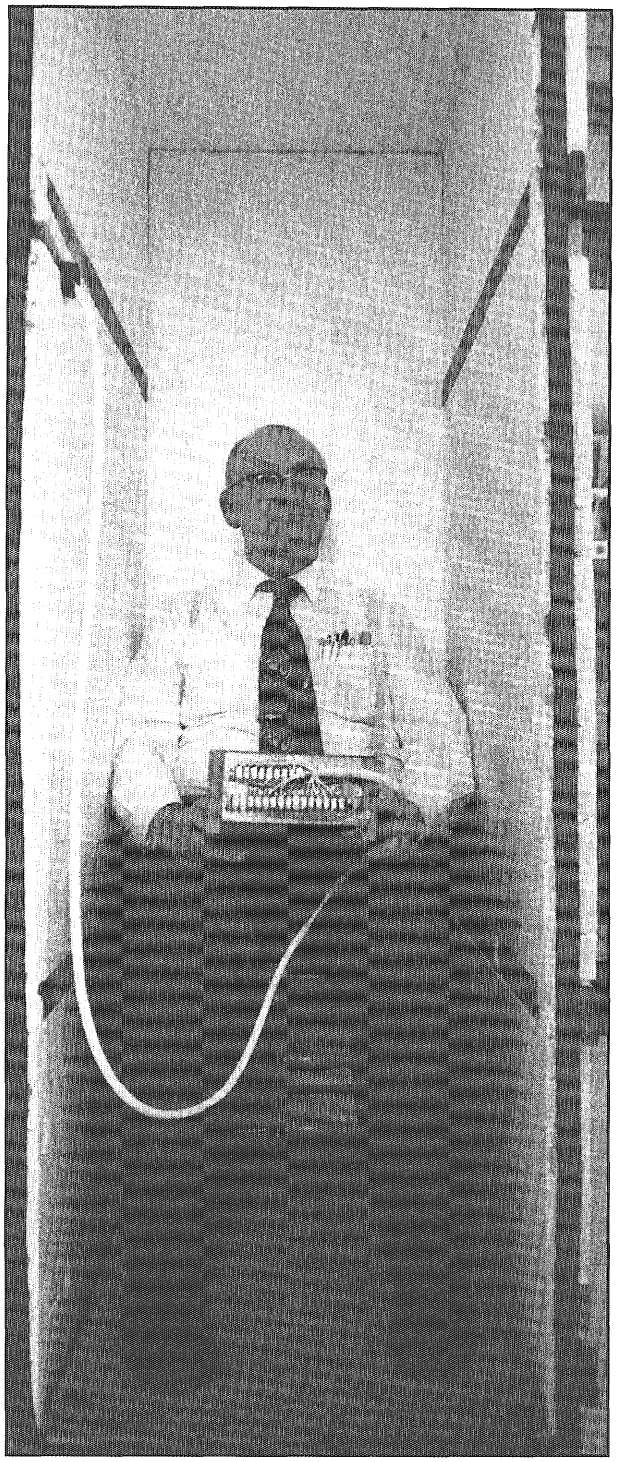
Sue Luedtke, a junior majoring in journalism, is a staff reporter for the *Minnesota Daily*. In her own words, she aims to be "*the* newspaper writer of the 1990s." With an insatiable appetite for chocolate and the ability to say "journalistic ethics" with a straight face, Sue brings a sense of adventure to *Technolog*.

ILLUSTRATION BY JOYCE RAJENDREN



NASA's first view through the Hubble Space Telescope.

Announcing the Minnesota Technolog Caption Contest! ©



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April 1990

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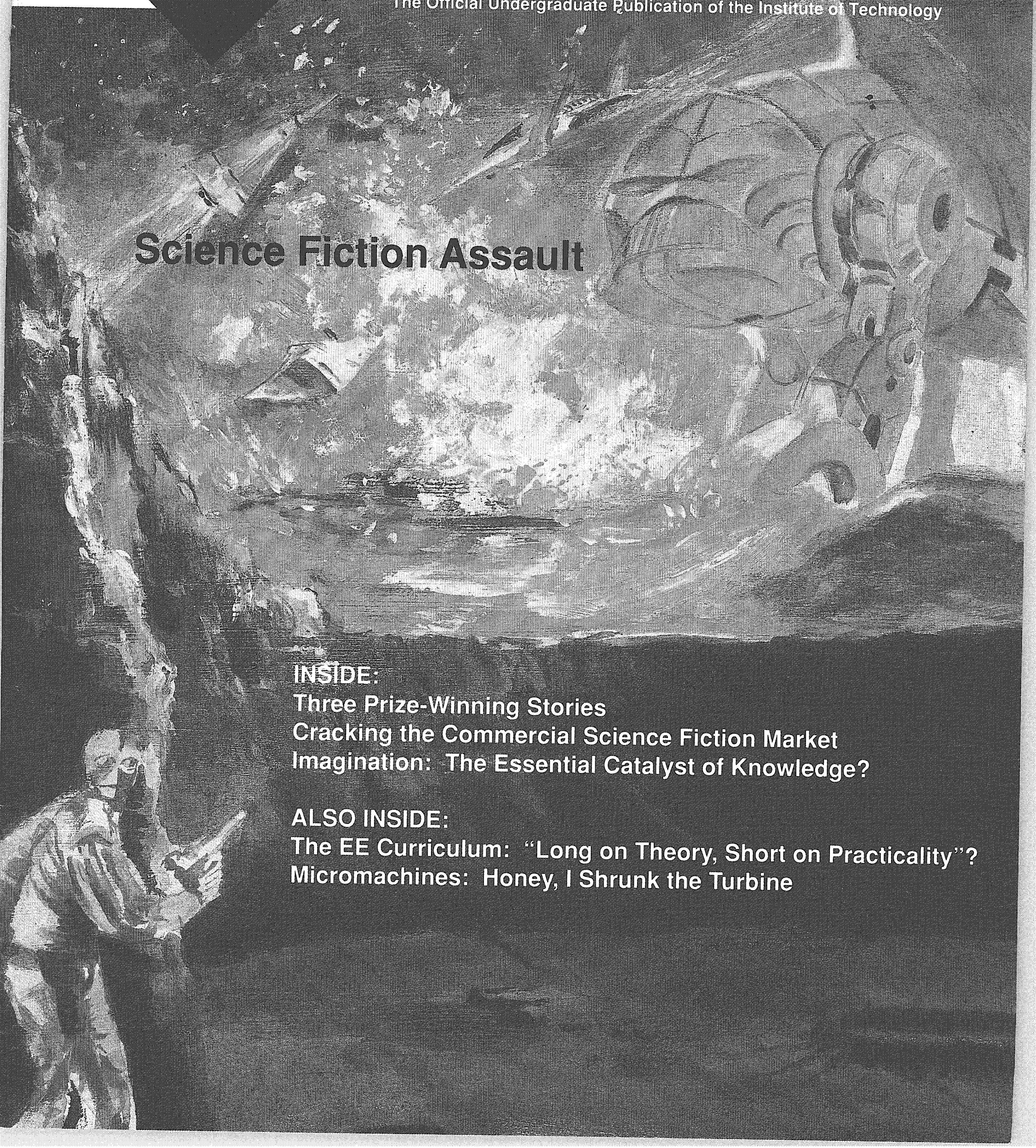
The Official Undergraduate Publication of the Institute of Technology

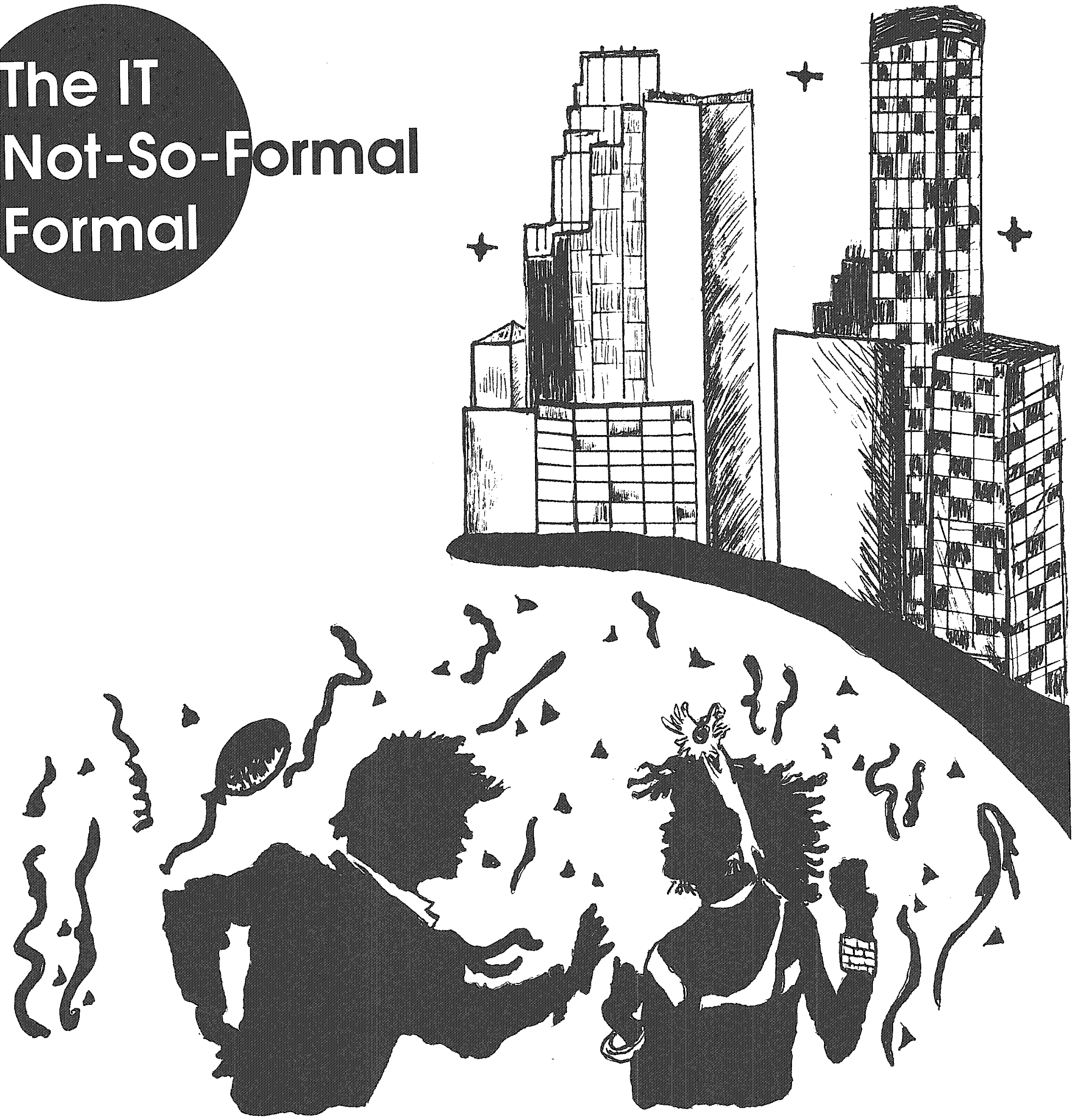


Science Fiction Assault

INSIDE:
Three Prize-Winning Stories
Cracking the Commercial Science Fiction Market
Imagination: The Essential Catalyst of Knowledge?

ALSO INSIDE:
The EE Curriculum: "Long on Theory, Short on Practicality"?
Micromachines: Honey, I Shrunk the Turbine

The IT Not-So-Formal Formal



Head for the Bright Lights This City Night...Friday, May 11, 1990

Tickets available beginning Monday, April 23, 1990.
Read the *IT Connection* for more details.

April 1990

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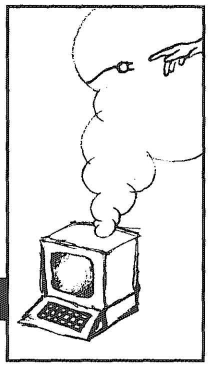
Volume 70, Number 5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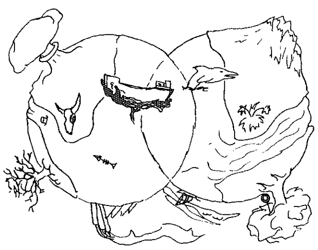
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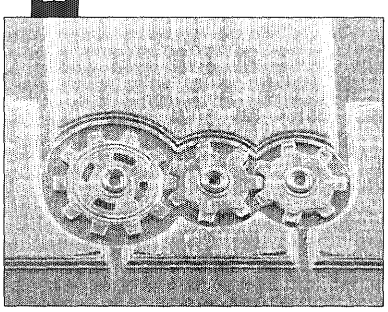


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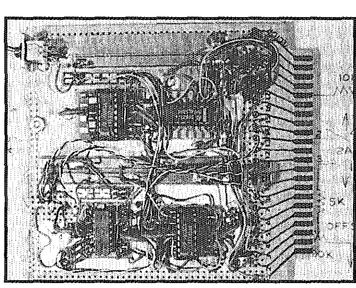
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DEPARTMENTS

COVER ILLUSTRATION BY KET KHAMBOUNMY

Professing Incompetence

by Loren Thomsen

Will the University's long-standing tolerance of inept teaching ever end? Will research always reign supreme?

As they do every spring, the IT Student Board recently solicited nominations for the "Best Professors of the Year" awards. Wishing to encourage good teaching, I made a mental list of the professors I've had during the past year to see if any merited nomination. Ironically, as I reviewed potential "Best Professor" nominees my mind turned to recent instructors who had etched themselves in my memory by being inept, boorish, or just plain jerks. Wouldn't it be nice if there were "Most Abominable Professors of the Year" awards?

Alas, there are no such awards, and perhaps it's just as well. The majority of IT professors are passably good instructors, and a few are even excellent. Nonetheless, a significant number of professors are, well, bad, if not completely unfit to be in front of a classroom. In fact, the number of incompetent instructors is so significant that you're almost certain to have at least one every quarter.

In the short term, inept instructors frustrate and anger their students. In the long term, inept instructors generate more serious problems. While good instructors help their students become fully informed engineers and scientists, bad instructors leave embarrassing gaps in the knowledge base of their students, preventing graduates from developing their full potential. Good instructors stimulate their students, making graduates more likely to pursue an advanced degree. Bad instructors, on the other hand, extinguish interest in engineering and science, often convincing students to leave IT.

> **"A significant number of professors are completely unfit to be in front of a classroom."**

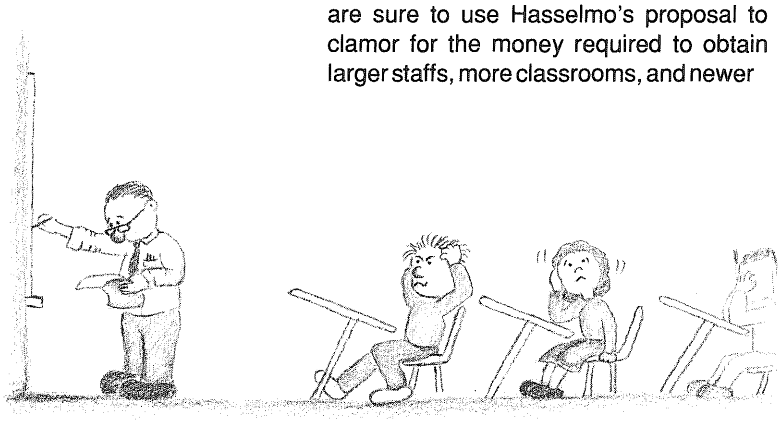
Given the importance of retaining students and providing them with a complete, if not pleasant, education, how do bad instructors manage to entrench themselves in academia, an institution that is, in theory, dedicated to teaching? The answer is simple: teaching doesn't matter if you want to be a successful professor. Fred Beaufait and Wesley Harris, deans of engineering at Wayne State University and the University of Delaware respectively, admit that teaching pales in importance when compared to research:

> Research—in terms of the number of proposals submitted, the value of contracts awarded, and the number of technical papers presented and published in refereed journals—is becoming the dominant force at most schools of engineering and the measure of faculty performance.... Though all faculty members are expected to teach, research and publication are, in fact, the basis of recognition. Faculty members are quick to learn this and adjust their priorities accordingly.... [A]t many research institutions, [teaching] receives little support and the equivalent

of a nod during performance reviews for pay raises, tenure, and promotion. (*Engineering Education*, July/August 1989)

Research Versus Teaching: Mutually Exclusive Goals?
In essence, rewards for good research are many, and penalties for bad teaching are nonexistent. Should it be any surprise that many students are unhappy with the quality of instruction they receive?

University President Nils Hasselmo is also unhappy with the ascendancy of research at the expense of teaching and in January released a tentative draft of an "Initiative for Excellence in Undergraduate Education." Regrettably, administrators throughout the University are sure to use Hasselmo's proposal to clamor for the money required to obtain larger staffs, more classrooms, and newer equipment, ignoring the central task at hand. What the University (and IT in particular) needs is harder to get than money: a system that recognizes and rewards good teaching.



Such a system sounds suspiciously easy to obtain. After all, couldn't Hasselmo single-handedly impose it? Hardly. Every large institution such as a university has its own culture, complete with inherited values and behavioral norms. For example, in the University of Minnesota culture, good research is valued, and bad teaching is accepted behavior. And the University's enormous inertia will make sure this doesn't miraculously change overnight, regardless of the wishes of its leader.

Fortunately, the language of Hasselmo's "Initiative" indicates that he realizes the difficulty of his mission. If he is to ultimately improve the quality of undergraduate education, two items must be emphasized. First, administrators must communicate to instructors that teaching and research are equally important and that excellent research does not excuse poor teaching. It must be made clear that substandard teaching bodes ill for themselves, their colleagues, and the University, and does a gross disservice to students and the community at large. In essence, the University must adopt a culture where inadequate teaching is as unacceptable as inadequate research, and has exactly the same dire consequences: denial of tenure and promotion.

"What the University needs is harder to get than money: a system that recognizes and rewards good teaching."

Second, once administrators identify excellent teaching as a goal, they must give professors the means to achieve it. In addition to making teaching performance a criteria for obtaining tenure, administrators must offer training in effective teaching, provided by education experts or excellent instructors

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ILLUSTRATION BY BYUNGHO HAN

in the senior faculty. Untenured professors in particular will benefit from such training and constructive criticism from their colleagues, and perhaps establish career-long habits of striving for teaching self-improvement.

If Hasselmo can accomplish these two things, radically altering the manner in which faculty are trained and judged, undergraduates in the 1990s and beyond will owe him an enormous debt. For the time being, in spite of Hasselmo's efforts, every IT student will ultimately encounter gibberish-covered chalkboards and droning dullards. Candidates for "Most Abominable Professors of the Year" awards may someday be an untolerated minority, but don't hold your breath. ☐

LOREN THOMSEN, Technolog*'s lame duck editor-in-chief, is a senior in EE. He's former assistant editor of* The MacNorton Times, *official newsletter of young, rural malcontents. He holds the* Technolog *record for receiving the most hate letters and irate phone calls in one year.*

LETTER

In Defense of Analysis

Dear Editor:
I feel I must respond to your **UP FRONT** editorial, "Made in Japan (But Analyzed in America)." You feel that the downfall of the American engineer is due in large part to the decline of design content in the engineering curriculum, which has been replaced by an emphasis on mathematical analysis. You feel that professors do not have a clue about the actual practice of engineering. I disagree with much of what was stated.

I graduated from the Institute of Technology several years ago. As a student, I worked for Control Data, Bell Labs, and Honeywell. After graduation I went to work for 3M as a digital design engineer but have recently returned to the University as a full-time Ph.D. student. Since I have been both a student and a designer I think I can comment with some knowledge on your analysis-versus-design editorial.

When I began work as a design engineer, it was true that I knew little about the actual practice of design. The key word here is practice. You cannot become a good engineer without it. What I had learned was a broad base of analysis techniques good for a number of different problems. This was good because every design problem begins with analysis. Until the particular problem has been thoroughly analyzed, you cannot create a good design that will solve your problem in a timely manner.

Yes, it might help to have more hands-on design classes in the engineering curriculum. However, there are two problems with this. One, design classes must deal with actual technology—unfortunately, especially in electrical engineering, technology changes rapidly. What you design

"You feel that professors do not have a clue about the actual practice of engineering. I disagree with much of what was stated."

with today will rarely be used a second time. Therefore, a design class must use dated material, which diminishes its effectiveness. Two, today's design problems frequently require several designers, high-powered CAD tools, and much time to come up with a solution. How do you choose something that can be effectively taught in a ten week course? These two problems are why I think you'll find design content in America's engineering coursework has declined.

Are our professors ignorant of the actual practice of engineering? I highly doubt it. Look around you. I think you'll find many of the professors consult for industry, especially during the summer. Also, many of the research grants come from industry, where they expect value for their money. And a number of professors have come directly from industry.

So, do Japan and Germany do a better job of training their engineers? Germany has more design coursework but they also have a five-year program. Japan has the same curriculum as the U.S. Does Japan's industry do a better job training its engineers? Perhaps. I think that as the U.S. has lost manufacturing expertise, the ability to teach it has declined, both in U.S. engineering schools and at the industry level.

Why has the U.S. lost out to Japan and the Germans in manufacturing expertise? I think this is not so much the loss of design classes in the engineering curriculum so much as the difference in the societies of Japan and Germany versus the U.S. When I was a new graduate interviewing for jobs, half of my job offers came from the defense industry. I personally think that a lot of design and manufacturing expertise has been lost to the need of the U.S. to maintain its defense industries. Japan and Germany do not need to maintain the same massive defense expenditures as the U.S. That is why I think there is more hope for the future.

While it's true that some changes can be made to improve our engineering education, I don't think the current lack of design classes has led to our dismal performance in the global commercial market. Maybe U.S. schools should consider formally expanding to five year programs. The additional time could be used to include more design and manufacturing classes. However care must be taken to prevent the curriculum from becoming that of a trade school. Perhaps the fifth year could apply directly toward a master's degree, so that it would still be possible to get a master's degree in six years. Also, I think that professors should be taught how to teach. Although the majority of professors do a commendable job, many (especially new professors) would benefit from some teaching classes. After all, we expect our high school teachers to have been taught how to teach. The same should apply to college-level teachers.

Sincerely,
Lori Lucke
EE Grad Student

In Defense of Design

by John Demskie

In the first issue of the *Scope*, the Electrical Engineering Department's official newsletter, I casually stated that our curriculum was "long on theory and short on practicality." I thought I was simply stating a foregone conclusion—something no one would argue with. Well, it turns out I was wrong. Apparently several professors in the EE department took offense to what I said. Their point being well taken, I realize I shouldn't have made such a statement without qualifying it. So here are my observations, opinions, and conclusions about what is right and wrong with the EE curriculum at the University of Minnesota.

The University has long enjoyed a national reputation as a top electrical engineering school. It has earned the respect of both industry and academia and continues to meet all ABET guidelines. In addition, the construction of new facilities and the recruitment of top researchers certainly shows a commitment to improve. These are all good and I don't wish to dispute their importance. Unfortunately, these are all external qualities—they make the department look good on the outside but say nothing about the actual quality of education received by the students.

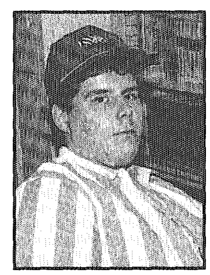
"Why are all EE students at this university exposed to a curriculum that prepares them for grad school when the majority of them will enter industry upon graduation?"

Our curriculum cannot be accurately called electrical engineering. We are being taught electrical engineering theory, the science of electrical engineering, and, of course, engineering mathematics. What we are not being taught is how to be an electrical engineer. Why? Why are all EE students at this university being exposed to a curriculum that prepares them for graduate school when the vast majority of them will be entering industry upon graduation? I believe the answer is related to the fact that the EE faculty is composed entirely of academics and experts at theory and research. There is nothing inherently wrong with this; many of them are among the best at what they do and we have a lot to learn from them. As future engineers, however, we should also be learning things that our professors can't or aren't interested in teaching us. This includes creativity, practicality, and design.

I admit that creativity and practicality are things that really can't be taught; they can, however, be emphasized. For instance, why not put an end to the infamous "plug and chug" tests that only require a good memory and a lightning-fast pencil? Engineering students should be tested on their understanding of technical information as well as their ability to apply it creatively. After all, this is the essence of engineering—using mathematic and scientific principles in new and creative ways to develop practical designs. This is what engineers do and this is what engineering students should be learning. Throwing theory at students for four or five or six years with little or no application is boring, tedious, and generally unnecessary. It wouldn't take much to make learning electrical engineering more interesting and possibly even—gasp—fun! How about

In Defense of Design
Continued on page 27...

JOHN DEMSKIE is an electrical engineering junior and member of IEEE. Very much a hands-on person, John is manager of the student lab located in EE/CSci 2-103. This document was originally written to appear in The Scope, *the EE newsletter.*



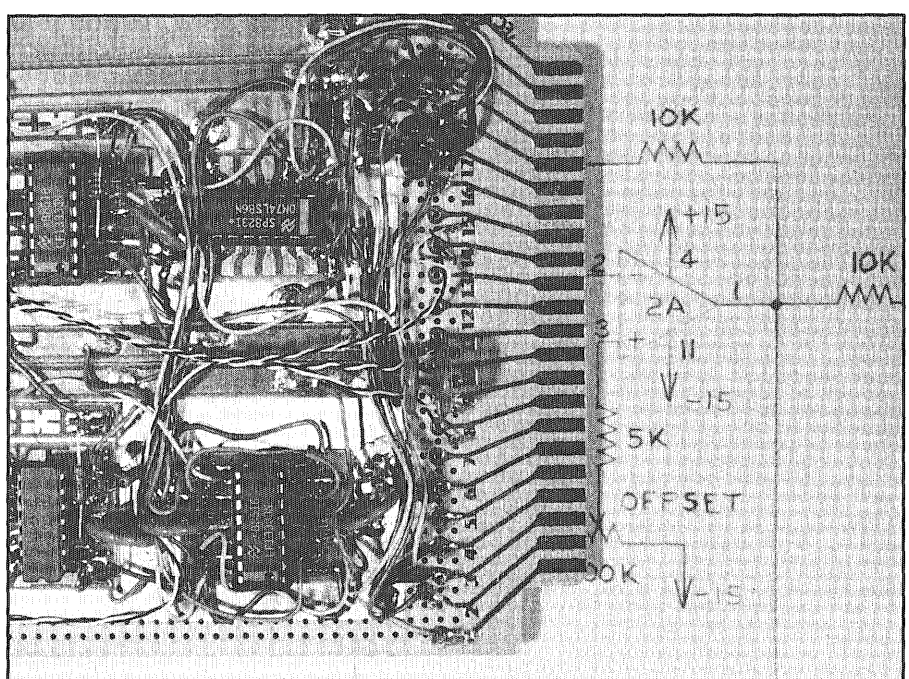


PHOTO BY PAULA ZOROMSKI

Warm Thoughts on the Cold War

by Jim Willenbring

The winter of 1989-90. The Wall was torn down. Free elections are being held in East Germany, Poland, Hungary, Czechoslovakia, Romania, and Bulgaria. East and West Germany are reuniting. A McDonald's in Moscow.

Right now, most of these newly-liberated people are simply wondering how to put food on their tables rather than thinking about world politics and global economics. But what will happen when these countries begin to regain their economic and political footing? Where will we be? By the time the changes in Eastern Europe are sorted out, most of us will be firmly entrenched in high-tech companies and research institutions. Revolution will be old news. The new news is that it's not going to be business as usual.

International politics are shifting from their traditional base of military strength to power based on economics, and the stakes are enormously high. Instead of bargaining for a small city or local market, the economic wheeling and dealing will be for entire countries and subcontinents.

"As international politics shift emphasis from military to economic strength, how will America retain its position as one of the world's premier powers?"

So what will happen to our military complex when the Cold War is declared over? The world, including our country, will shift toward economic competition as a replacement for military conflict. To students, it will mean more than fewer job openings at Honeywell.

Even now, Western Europe is emerging as an economic force to be reckoned with. In 1992, trade barriers between Western European countries will be wiped out. Supported by a more open system, trade between the twelve European Common Market countries will eventually resemble trade between states in the U.S. Once the obstructions between neighboring countries are gone, this group will turn its sights on bigger targets like the United States and Japan. The economic power of the unified group will be much greater than the sum of its individual parts.

In the face of this new economic onslaught, how will the United States retain its position as one of the world's premier powers? By streamlining manufacturing, increasing research and development, and most importantly, changing our high-technology emphasis from military applications to alternative exportable products.

Because of this, we should view our engineers and scientists in the military complex as a high-tech army of workers similar to the Army Corps of Engineers: they can build either military roads or civilian roads. Likewise, our military scientists and engineers can research and apply technology to either the military or society in general.

As an omen of this shift in emphasis from military to civilian, Department of Defense projections show a decline or very little growth in the need for defense engineers for 1992. Aerospace engineers will be especially hard hit; they face a 1.5% decrease in demand. However, the President obviously won't be giving a pink slip to the military on Monday morning—there will always be a need for strong armed forces, but not the huge military complex that has been growing since the Cold War began.

The key for American companies and government is to recognize the changes in our world. If we don't adapt, not only will Japan be beating us economically, but Europe and the Soviet Union will be right in the ring alongside them.

Solutions to this grim future? Think globally. Develop the resources we have and cultivate new ones. Agriculture, for in-

Warm Thoughts...
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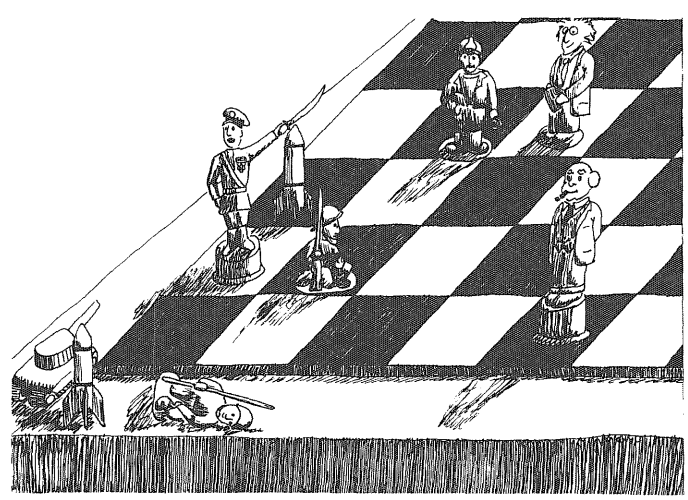
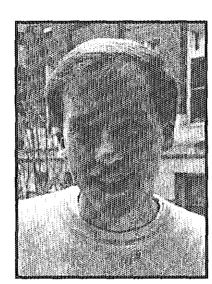


JIM WILLENBRING is an EE senior. He's been hanging around our office since the late 1950s, having served as both Technolog *editor and president of the IT Bored of Publications. Upon graduation in the spring Jim will work for Medtronic, Inc.*



Sci-Fi—A Drug For Depraved Minds?

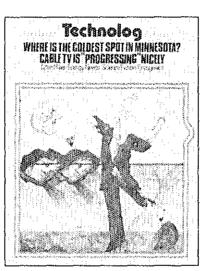
by Robert Holton

The Science Fiction Contest: A Technolog tradition since the late 1960s.

Ladies and gentlemen, as this year's science-fiction contest coordinator, it is my extreme pleasure to introduce this year's student winners. Before I present them, allow me to share my humble opinion of this remarkable genre of literature. Essentially, I've developed two theories to explain the unfathomable popularity of science fiction. Either it's a drug, or it captures an essential vision of mankind and reality. I'm partial to the former. Let's explore the possibilities.

1) Science fiction is a drug. Look at the symptoms. People become so engrossed in a story that a cattle prod may be required to get their attention. Once they've ingested science fiction, they begin to babble incoherently about alternate dimensions, parallel universes, or purple creatures with four arms.

People never read just one. By chance, they pick up a Ray Bradbury or a Fredric Brown and soon science fiction becomes an obsession. They sell their clothes, car, and bottle cap collection to buy every novel they can find. It's a vicious progression. They start out with a short story, thinking they can quit anytime. Soon you find them lying in a dark alley, strung out and philosophizing about Heinlein. And new and more addicting sci-fi authors emerge every year.



So maybe you don't buy that theory. Science fiction could possibly be a legitimate mode of literary expression. Okay folks, this is where we go existential (The Surgeon General requires fair warning for those faint of heart).

2) Science fiction defines the present by exploring the possible. It is a creation of the mind, imagination put to words. This property enables it to encompass the full spectrum of human action and emotion.

> **"After ingesting science fiction, readers begin to babble incoherently about alternate dimensions, parallel universes, or purple creatures with four arms."**

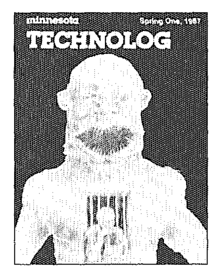
Some would argue that all literature does this. What is unique to science fiction, however, is the ability to manipulate the settings in a nearly infinite number of ways to more perfectly accent or conceal certain factors.

Science fiction entertains with fantasy, allowing us to escape to a different reality, like that of Tolkein's Middle Earth. We can run away to a place in our mind and take a sort of cranial vacation. Harsh and depressing aspects of humankind are captured by the cyber punk styles of William Gibson or Phillip K. Dick, who fuse futuristic technologies with ageless underground crime. Satirical humor is provided in Douglas Adams' classic four-volume *Hitchhiker* series. The grandeur of empires and the universe are encapsulated in Isaac Asimov's *Foundation* series.

An experiment provides a useful analogy. A scientist can alter different aspects of the experiment to reveal properties of an unknown. In the same way, a good science fiction writer will alter one or more aspects of the present to reveal interesting qualities of humanity, reality, or the known universe. Authors can then extrapolate the future, create an alternate past, examine a different universe, or observe our world from the eyes of an insect.

Science fiction offers a vast foundation upon which anyone can construct a sculpture. Unrestrained by the confines of the "known," writers can better examine reality. That is the true appeal and merit of all science fiction; its ability to view anything from any angle.

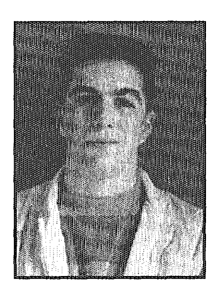
Thus, I am brought back to the task at hand, introducing the winners of this year's science fiction contest. In first place, Ed Peschko's short story examines some of the forgotten subtleties of time travel. Ryan Christiansen's treatment of adolescent changes is second. Emphasis on detail and setting make his story my personal favorite. In third place, Richard Wright explores the future of computer technology from a unique perspective.



My thanks to everyone who entered the contest. Every entry was entertaining and creative. I also would like to thank the judges: David Lenander, the head of the Rivendell Group and the campus Mythopoeic Society; Eric Heidemen, who has reviewed science fiction novels for the *Star Tribune*; and Matt Kemp, an IT student. A special thanks to Phillip Jennings and Thomas Bacig for contributing essays.

Enjoy the stories, but read them at your own risk! ☐

ROBERT HOLTON is a freshman majoring in aerospace engineering. He's currently writing a novel: Pangalactic Gargleblasters: A Bartender's Guide to the Known Universe. *Robert wrote the remarkably boring bios appearing elsewhere in the science fiction section.*



TECHNOLOG COVERS FROM 1973 AND 1987

The Dilemma

by Edward Peschko

Mr. Smith goes to the future for fun and profit. What did he see? Was it good...or evil? Unfortunately, we'll never know. He chose to forget the future—and he can't remember why.

FET Future Technologies is hiring "explorers" today.

You see, Mr. Smith, a valued but expendable employee of FET Future Technologies, appeared suddenly in the middle of a business luncheon three weeks after his departure. People were talking pettily of petty topics, when suddenly there was a flash of blinding light, a whiff of ozone, and Mr. Smith.

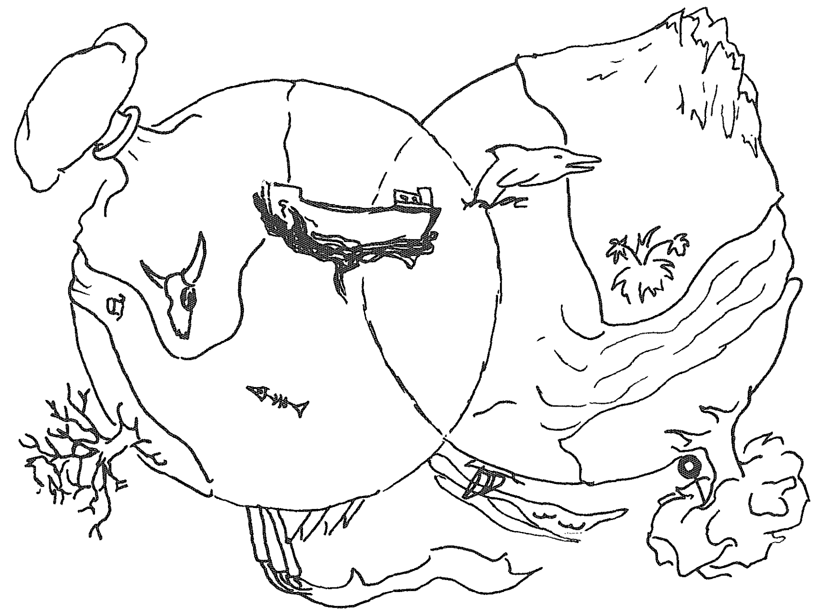
Three weeks before, he unfortunately had been selected for the main project of FET's management, and he was loath to refuse. "Travel through time!!" they chorused cheerfully. "Visit the future!!" they chimed. They promised him double salary contingent upon his return with a good report. He had a report all right. Would they believe him?

He stood there with the standard "Gee, I've had such an experience exploring unknown worlds but I don't know what to say" expression; dazed and confused with the slightest hint of an imbecile smile on his face. People stared at him in wonder. He gasped. He collapsed.

When Mr. Smith came to, he was immediately whisked to the top, top management for interrogation. The entire staff was there. The Company had even hired a consultant to advise them on how they could use Mr. Smith's report for company profit. They waited for Mr. Smith to begin. He didn't. After several pregnant pauses, Boss Johnson asked in his usual subtle manner:

"WELL??"

"Well what, sir?" said Smith.



"You know, what did you see, hear, smell, taste...you know...what was the future like?" a staff member ventured.

"Oh." said Smith and sank further in his chair. Another expectant pause.

"I don't know."

"YOU DON'T KNOW??" bellowed the Boss. He had a way of turning a most exquisite shade of purplish-red in these situations. Odd veins and arteries popped up on his forehead. "TEN MILLION DOLLARS INVESTED IN THIS ONE EXPERIMENT, NOT TO MENTION A POSSIBLE DEFENSE CONTRACT, AND HE DOESN'T KNOW!!"

"Um....not exactly, sir....I guess it would be more accurate to say that I don't remember. Or, rather, that I remember only one thing."

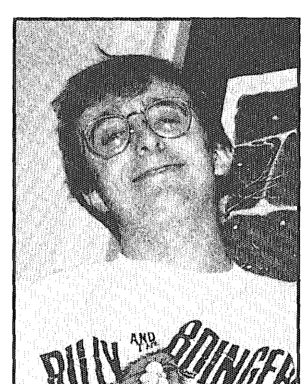
"YES...." Everyone faced him as if at attention. The consultant readied his pen.

"I remember I was given a complete tour of the place, and I was given two choices. One, that I remembered everything I saw, or, two, that I would forget everything I saw, and remember only this."

And that was that. Mr. Smith has revealed nothing new under hypnosis, and the consultant assigned to the problem died of a cerebral hemorrhage analyzing this "damn dilemma." □

minnesota TECHNOLOG

Writer Profile: Edward Peschko



Ed is a CLA senior. He hopes to graduate in less than a decade with majors in philosophy, English, and computer science. He is a fan of twist endings, and enjoys the works of Isaac Asimov, Arthur C. Clarke, Tanith Lee, Robert Anton Wilson, and Micheal McDowell.

ILLUSTRATION BY JOYCE RAJENDREN

Life After George

by Phillip Jennings

A professional writer offers "starving young hacks" some candid advice.

I recently got my first look at *Technolog*'s Spring 1989 science fiction issue. Contest-winning stories were published, which is much like real life, if you happen to spend your time writing and peddling short stories to the commercial fiction market.

I began doing so in 1984 and immediately found out how perverse commercial editors are—they send back *form rejections!* How

"How could I learn to write if nobody bothered to tell me what was wrong with my stuff?"

could I learn to write if nobody bothered to tell me what was wrong with my stuff?

This went on for six or eight months, until I submitted a story to the magazine George Scithers was editing at the time. The note I got in response to my story included phrases like "...hideous, hideous, hideous," and I frolicked around the room as I read it. At last! I'd made contact with a human being at the other end!

The rejections I got from George over the next two years fill an inch-thick folder. I took his advice seriously. By persistence I graduated to the stage where other editors also sent me useful advice and, finally, my stories began to sell.

George is no longer at his former magazine. Beginning in 1986, the role he played fell vacant, unless you're writing the kind of story they want at *Weird Tales.* If you're starting now, and are as bad as I was in 1984, you'll have a harder time than I did becoming familiar with the standards of the science fiction marketplace.

Some of the few advantages of writing short fiction are that you can do it quickly,

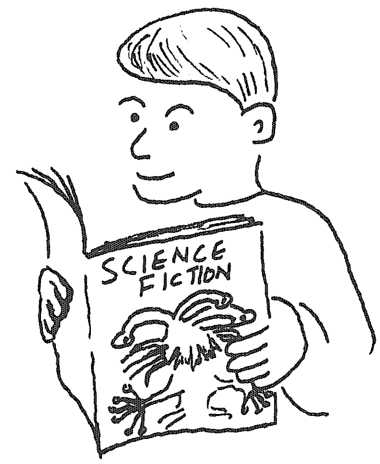
"The note I got in response to my story included phrases like '...hideous, hideous, hideous.'"

mail stories cheaply, and get them bounced back in a couple months, or published inside a year. This is hyper fast compared to the pace of book publishing. But if you're going to make a living, it won't be as a short story writer.

If the short story market wants to keep getting eight hundred pieces of slush each week, it has to consider your interests as a starving young hack. Right now it assumes you're obsessed with seeing your name on the cover of a digest-sized monthly. Is that all there is to you? Are you satisfied to hear no godlike pontifications from the editorial staff? Okay, it's not quite that bad. Even though George has abandoned science fiction for his own brand of fantasy-horror, a few editors attempt to imitate him.

Why? Because they're starving young hacks themselves, or were until just recently. Now they have magazines to run. But as you've guessed, these magazines aren't *Omni* or *Playboy*, and they don't pay *Omni/Playboy* rates.

Some of these semi-pro magazines are going to flop, and deservedly so. Their editors have cranky agendas and hair-



raising biases. It's because of people like this that sales to penny-a-word magazines don't count toward membership in the Science Fiction Writers of America. You're going to get real advice from these people, but do you dare pay attention to it?

Life After George
Continued on page 21...

PHILLIP JENNINGS has published two major works: Tower to the Sky *and* The Buglife Chronicles. *A frequent Nebula Award nominee, Mr. Jennings is also a regular contributor to* Asimov's, Amazing, Aboriginal SF, *and* Tales of the Unanticipated. *He lives and works in St. Cloud, Minnesota.*

ILLUSTRATIONS BY BYUNGHO HAN

The Glow

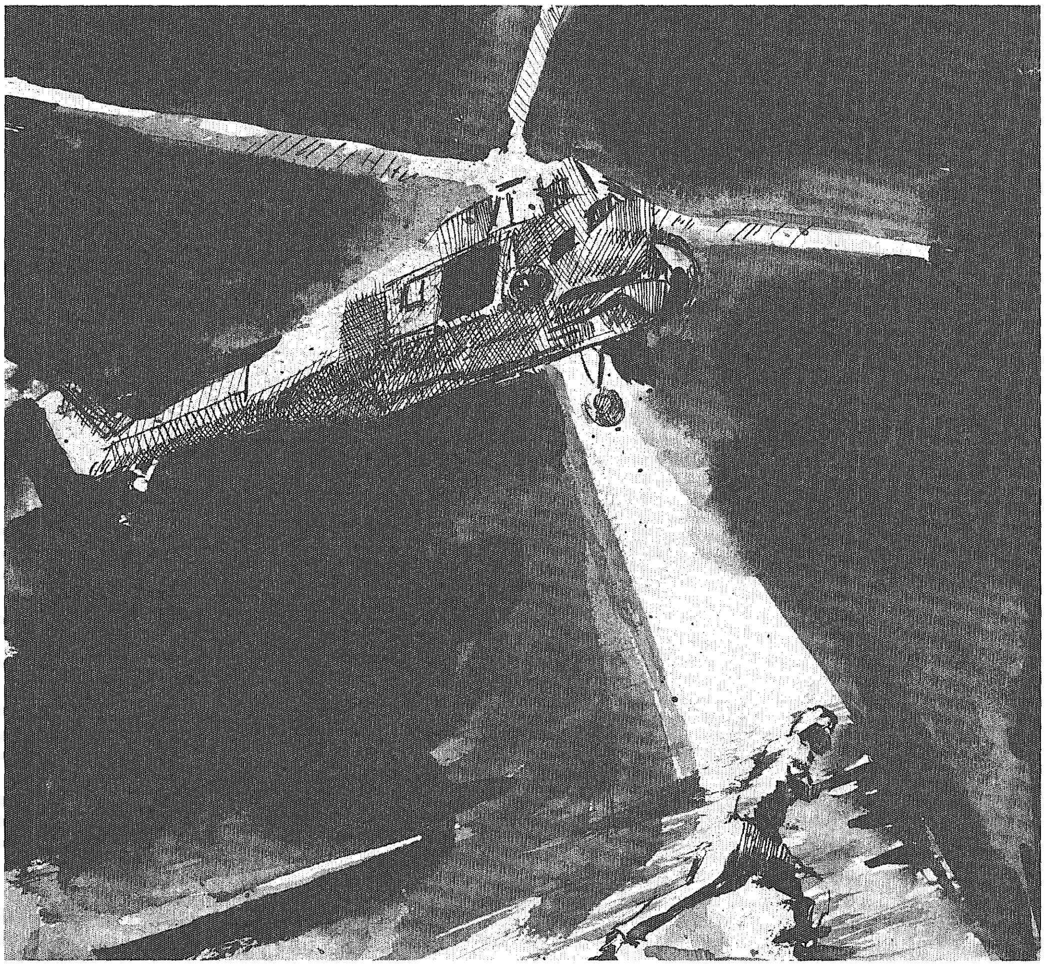
by Ryan Christiansen

John lay curled up in bed underneath the sheets and moaned in pain. He closed his eyes tight because of the pain, but also because he did not want to see the changes his adolescent body was going through. A luminous, green glow had surfaced in the skin of his abdomen and crept slowly up his torso. The heat from the glow caused him to sweat profusely and the pain seared him from within. A woman sat beside the young boy. She held a cold, wet washcloth to his abdomen and caressed his cheek while she sang a sweet, comforting lullaby in his ear—as if she worshiped the light in his body, and was calling it from afar, beckoning it with her hymn. She wore a knowing smile on her face and her eyes were shining with determination, ready to face the evening. Her skin glowed a luminous green, slightly dimmer than that which was overcoming her son, because her body was three times older than his. The boy's father sat in the corner on a wooden stool. The father's glow was even dimmer than the mother's, yet it still would make one squint in annoyance in the small, shadowy room. The man held his face in his hands, concentrating on the sobs of his son. When the sobs turned into screams, he would look up, not at the boy but at the wall, and brush his hair back, breathing a heavy sigh. On the wall hung the picture of the Madonna and the Christ Child, glowing halos encircling their heads.

> **"'I want John to read. Then he won't be like the rest of the boys,' she told her husband one evening after they had gone to bed. 'That's what I'm afraid of,' he replied."**

The room they occupied, the boy's bedroom, was painted an anxious blue-gray. Three of the four walls were lined with shelves and a few of them contained books: encyclopedias, history books, biographies, autobiographies, poems, philosophies, and even medical books, all of them yellow, musty, and torn. The history books and autobiographies had a special shelf close to the boy's bed, a few of them had obviously been read hundreds of times. One particularly worn book was a battered copy of the *New Testament* with a bookmarker that read "John 3:16" at the top. The book was covered with a layer of dust and it had apparently been untouched of late. Beside the book was a picture of John's mother as a child. Her hair was a dirty blonde and her blue eyes shone with excitement. Her skin was not glowing as it did now and she had a huge smile on her face. The picture was a rare item for a young man to have, almost as rare as the books that sat on the shelves. Mother had bought the books at auctions for high prices because books were just not made anymore. But she told neither John nor her husband how much she paid for the books. "I want John to read. Then he won't be like the rest of the boys," she told her husband one evening after they had gone to bed. "That's what I'm afraid of," he replied.

ILLUSTRATIONS BY KET KHAMBOUNMY



John awoke as the pain subsided in his abdomen and he lay on his back for a moment, breathing heavily. He opened his eyes. The glow now covered his thighs and rose as high as his navel. He looked at his mother with blurred vision only to see a tear escape her eye. "Shh, it's okay," she said and put a glass of water to his lips. The water tasted good; his mouth felt like a sponge that had dried in the sun. John's body shimmered in sweat and the heat began to rise again. His eyes grew large and his father, now standing at the foot of the bed, asked, "Are you okay, John?" A thrust of pain wrenched John's stomach until he couldn't breathe. John closed his eyes and lost consciousness. The flurries in his head returned and he remembered again.

But the books were now the furthest thing from John's mind. The pain in his body was rising, and he could barely breathe, much less scream. He raised his knees to his chin as the heat squeezed him, and when he was overcome by the pain, his mind flickered to unconsciousness in response. Memories flurried in his head and blanketed his thoughts.

Δ

John could see his father standing over him, an outstretched finger tapping on his chest, and a look of dissatisfaction on his face. "John, I'm telling you that you can't go out at night anymore," his father warned, "It's illegal and they'll shoot you down if they see you. You know better than that. Don't disappoint me, John, you're the only son I have." That should have been the end of it, but John defied his father and went out again. When John returned home, he saw the glowing figure of his father waiting for him in the hallway. His father's glow, intensified by his emotions, was brighter than ever, and he seized John by the arm. "I thought I told you to stay in the house at night," his father snapped, and bared John's bottom, bending him over, and slapping him hard with a belt. He sent John to his room, where he lay on his bed without crying, so as not to give his father any satisfaction. But as he lay there he could hear his father crying softly in his mother's arms, saying a small prayer and asking her for forgiveness—he had struck her only begotten son. She consoled him with soft words and after that night John never left the house after dark.

Day was breaking outside and the soft hum of helicopters could be heard receding in the distance. Mother shook John by the shoulder, and he sat up without comprehension. "It's morning, sweetie," she said, "Get up! Breakfast is ready." John stumbled out of bed. The feet of his pajamas made funny noises as he shuffled to the kitchen. Hot cocoa, milk, juice, eggs, bacon, toast, and a jar of raspberry jam waited on the table. John smiled and asked, "Are they gone now, mommy?" Mother smiled back and said, "Yes, they're gone. Now eat up." She watched as her little preschooler wolfed down his breakfast, confident and unafraid.

"'John I'm telling you that you can't go out at night anymore,' he said, 'It's illegal and they'll shoot you down if they see you. You know better than that. Don't disappoint me, John, you're the only son I have.'"

But the night before she was at his bedside several times holding him to her breast and telling him everything was all right, that the noise was just the helicopters and they would soon go away. She sipped her coffee and her face glowed brighter as a look of worry crossed her face.

"Mom!" cried John as he opened his eyes, his face covered with sweat. He sat up and looked around as if he had lost something. "I'm right here," she said and made him lie down again. John sighed with relief and lay back on his pillow. Beads of sweat rolled down the sides of his head and tickled his ears as they dripped off his lobes. John's father was standing at the boarded window looking through a small peephole and a faint flutter could be heard approaching from the distance. "Bastards!" yelled John's father. The whir of a helicopter drew closer as the pain in John's chest grew stronger and his breast glowed magnificently. "First you make us glow like goddamned fireflies, and then you won't leave us alone." John's father slapped the peephole shut and pain squeezed John's heart. The walls shook as the helicopter rumbled past the building. John sucked in a huge gasp of air, his hands tightened on his mother's arm, blackness overtook his vision. He fell asleep again, and a nightmare stormed in his head.

Δ

The streets of the city were deserted as usual and damp from the humidity. All seemed quiet except the sound of John's footsteps. He walked in the shadows of the alleyways, breathing in the night air heavily like a newly discovered drug. He was smiling to himself, having disobeyed his father's warnings by going out for a walk at night. He felt invincible as he strutted down the paved streets, his hands slipped casually in his pockets. And why shouldn't he feel the way he did? They'll never see me, he thought, I'm not like dad. I'm not an adult; I don't glow in the dark. Just then the sound of a helicopter could be heard bouncing off the walls of surrounding buildings. John darted into the shadows of a large store.

He whistled to himself as he waited for the vehicle to pass overhead. His hands fumbled in his pockets for his watch and he looked at the time. His heart stopped. The hand that held the watch glowed with the intensity of a streetlamp. He looked at his other hand, his arms, and his stomach. Yes, it was true. John was emitting a luminous, green glow. "But I'm just a kid," he thought. Suddenly a helicopter halted abruptly above his head. The barrels of automatic weapons turned down slowly at John. Disbelief sat twitching in his mind. The guns fired.

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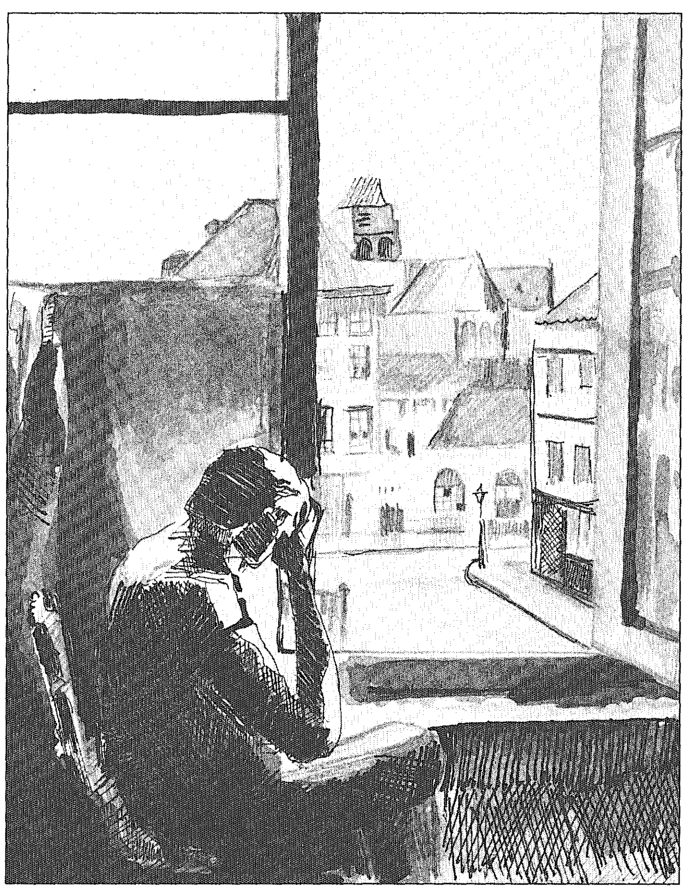
"No!" screamed John from his sweat-soaked sheets. His father jumped to the bedside and placed his hand on the boy's chest. It was warm, but slowly cooling, and John was breathing heavily from exhaustion. "You're okay, John. Everything is going to be all right," said father. There was certainty in the man's voice, but anxiety in his eyes. John's mother was caressing his body with the washcloth and she looked tired. She was no longer smiling, but the determination flickering in her eyes was evident. "Oh God, please take care of my son," she muttered under her breath, and a cool draft slid past the three of them, causing John to shiver. The glow now covered John up to his neck and completely down his legs. The brightest glow was in his shoulders, and he couldn't lift his arm to touch his mother. The pain subsided for moment as the glow crawled further up his neck. Fatigue made John desire sleep and the quiet of the room induced slumber. A stillness hung above his blanketed memories as he recalled a past moment.

"The barrels of the automatic weapons turned slowly to face John. Disbelief sat twitching in his mind. The guns fired."



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The classroom was stuffy and close, the instructor taught vigorously. The subject was sex education and the students listened with a detached ear. As the instructor described the sex act, his ears began to glow hot, and one of the boys in the back snickered out loud. The girls in the classroom blushed and pretended to pay no attention, so the instructor continued speaking, faltering repeatedly, and looking at the blank wall ahead of him: he did not dare look at the children's faces. John was embarrassed about the topic, so he focused his eyes on the glowing ears of the instructor. He realized he, too, would someday glow like the instructor. He imagined the enzyme leaking into the skin cells of his abdomen and he became excited. He shifted in his seat and placed his forearm over the front of his pants; a girl who saw him shuffle in his seat smiled at him and looked away. John turned red and his excitement increased.

Δ

John slowly opened his eyes and saw his father's face above him. It was glowing intensely with a mixture of confusion and apprehension on it. Mother mechanically placed the wet rags on his forehead and stroked his hair back. Father looked over at mother and said, "This is it," then he looked down at John and said, "It's almost over, John." John's head swam in confusion and he began to lose his sight. He cried out to his father, who then held his son's arms to the mattress. The glow covered his head and his mind shook from the heat. John felt helpless as his thoughts receded to the depths of his brain. A dream, more like a vision, thundered into his clouded head.

Δ

John shivered as the cool wind caressed his frame and nearly pushed him off his perch at the top of the bridge. A torn shirtsleeve was wrapped tightly around his temples and blocked out the light of mid-day. Every pore of his skin shivered as the gale rattled him and even his heart grew cold and surrendered to the elements. He thought about how life was before he became an adult and how life would be now that he was like his father. He could never hope to be happy and free to roam like when he used to walk alone at night. The streets seemed so much darker and simpler then, with shadows to hide in where he could mock helicopters. But his whole life was controlled now–he was as good as dead. He wanted to end his life before someone else ended it for him. At least he still had that freedom. John stepped to the edge of the platform; his bare toes grasped the steel edge like a diver before leaping. He could hear the traffic on the asphalt below and the wind at his back urged him onward. Then the wind changed direction and pushed him back slightly. The sound of the traffic disappeared and John thought he could hear the sound of a thousand voices singing his name. He both felt a presence and saw it in his mind. A young woman dressed in every color stepped up to him and smiled. Her eyes offered comfort, knowledge, and understanding. The vision opened her mouth and her words glided out, "Can't you see that which is right in front of you? Don't give up, John. Believe in yourself and you can make a difference. Believe in your inner glow. Let it shine for others to see, so that they may shine with you. Believe in a world without enemies, without oppression, where the sun shines all day and the men sing with joy in their hearts. Believe me, John, your father loves you. Believe, John, and you will be free." John was filled with sudden happiness and confidence pulsing through his veins. He tore the shirtsleeve off his eyes and looked around.

"But his whole life was controlled now—he was as good as dead. He wanted to end his life before someone else ended it for him. At least he still had that freedom."

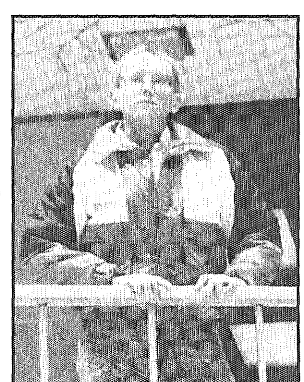
Δ

The wall in front of him appeared soft in the morning light, and John was drawn to the picture of the Madonna and the Christ Child in the center. He noticed for the first time that they were smiling, and he smiled too. John rose from the bed, removed the board from the window, and looked out. The morning sky was painted orange and yellow, and the little black dots with the propellers hovered like wasps over the government building. As they settled down on the helipads, their faint hum disappeared from John's ear; the bright sun broke over the building top, illuminating the expansive city. Activity began as people came out of their habitations to do their duties. The soft-glowing adults rushed along and looked at the ground; they didn't speak to one another so as not to draw attention. Little, silent, pink-skinned school children clambered onto buses that headed for the Central Education Facility. The machine was set in motion again. By dusk the routine would wind down again, and the city would be silent—except for the helicopters. Damn them to hell! thought John.

John turned around and saw his mother sleeping on her chair, a dry washcloth clutched in her hand. Father was sprawled across the end of the bed snoring loudly. John walked over to the full-length mirror and examined his naked glowing body for the very first time. It was beautiful, he thought, the way the little shadows defined his muscles. He took a long breath and released it slowly. He smiled—and a dim ring of light encircled his head. □

minnesota TECHNOLOG

Writer Profile: Ryan Christiansen



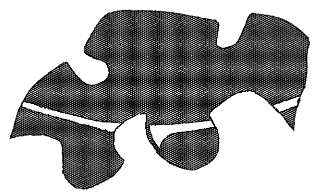
Ryan is a sophomore in CLA vacillating between majors in English and Journalism. He is a fan of major writers like Ray Bradbury and Isaac Asimov, but doesn't consider himself a science fiction addict.

Science, Fiction, and Science Fiction

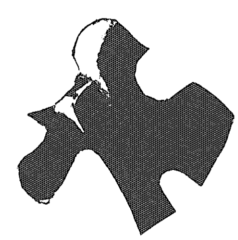
by Dr. Thomas Bacig

Imagination in science, imagination in literature. Both help us understand ourselves—and the puzzling universe we find ourselves in.

I've been reading science, fiction, and science fiction for the past 40 years. I began my education as a physics major but switched directions when my passion for stories and storytelling overcame, for a time, my passion for measurement and prediction. I've bounced back and forth between these two passions ever since. Given this opportunity to write for *Technolog*, I hoped to make some sense out of my own meanderings, to understand how science, fiction, and science fiction all seek truth and beauty and thereby illuminate my life.



In part I want to pick an argument with C.P. Snow and Isaac Asimov and all of the other "humanists" and "scientists" who insist on seeing science and art as mutually exclusive ways of understanding our own humanity. I have neither the time nor the space to be fair to Asimov and Snow, so I won't try. In sum, each implies that one method of understanding is inherently superior to the other in helping us to know what it



DR. THOMAS BACIG is a humanities professor at the University of Minnesota, Duluth. He teaches the science fiction course offered at UMD. In addition to many articles on English and writing, he has published a book entitled Timber: White Pine Logging in Wisconsin and Minnesota.

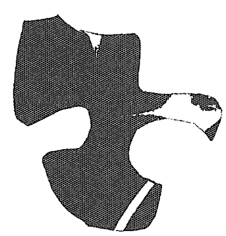
ILLUSTRATIONS BY JOYCE RAJENDREN

means to be human; in other words, that science is better than fiction, or that fiction is better than science.

I want to begin somewhere else. I want to imagine imagining, the first imagining. Imagine with me that point in time and space when the first of the tree dwellers came down from the trees at the edge of the forest, looked out across the savannas, and decided to venture outward, just to see what might happen. This was no armchair ape. She was an empiricist. When she returned, she wished to share this brave new world with her friends, so she told them a story and tried to make them imagine what it was like. Eventually, experience, and the stories she told, changed her and her kin forever. Science is one of the stories she told, or one of the ways of telling the stories she found. Fiction is another way of telling stories, and another of the stories she told. Fiction and science hold up mirrors to the world, enabling us to see it and ourselves in our imaginings. Science imagines what *will* happen if this and this are true and predicts the most *likely* outcome. Fiction imagines what *might* happen if this and this were true and explores the most *unlikely* outcomes.

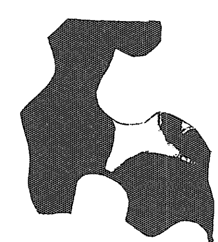
"Fiction and science hold up mirrors to the world, enabling us to see it and ourselves in our imaginings. Science imagines what *will* happen and predicts the most *likely* outcome. Fiction imagines what *might* happen and explores the most *unlikely* outcomes."

Which brings me to what science and fiction and science fiction are telling me at this point in my meanderings: Look, if you've got ears to hear and eyes to see, you're nervous about your world and mine. Azerbaijan, Beirut, and Northern Ireland. Iran and Iraq. South Africa. Gaza. Chernobyl. Prince William Sound, ozone, and the greenhouse effect. Names that conjure destruction, devastation, disaster for our species. If not immediately, then eventually. And what have we to stand against this? Only what we've always had: our imaginings, our science and our fictions, our predictions and our cautionary tales.



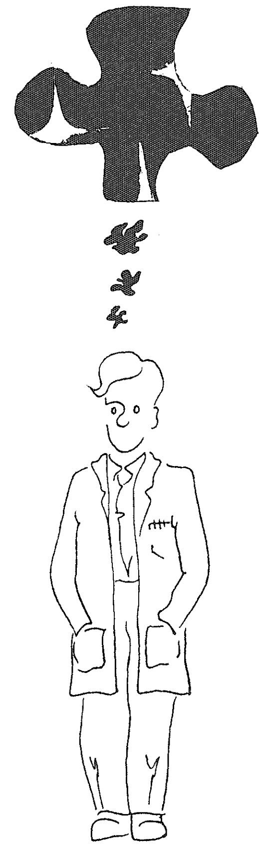
So let's look at some science, fiction, and science fiction to understand where hope lies for humankind and discover what kinds of heroes can lead us out of this forest of fears to some savanna of hope. The twentieth century flows out of the nineteenth and into the twenty-first arguing about what we are. Are we pawns of nature or nurture? Does society make us or do we make it? Are we lords of the earth holding dominion over all its creatures and forms? Are we nature's latest experiment in organizing matter, an experiment in consciousness and the illusion of choice, being tested against biological programming and cockroaches? Einstein points out that we are simply looking through a glass of space and time, darkly; modern physics is born. James Joyce takes us on a Freudian tour of one man's consciousness; modern fiction is focused. Isaac Asimov and Walter Miller imagine the future in terms of the past; alternative versions of modern heroes are born. Ursula LeGuin imagines the unimaginable; a modern dream of perfection is articulated. All seek truth and beauty in order to illuminate the ways of humankind.

What Einstein writes is science. It's a story about being in two elevators. One elevator is full of physicists falling from the top of an immensely high building. In that elevator the physicists find that their pens and pencils float if they let go of them. If the physicists jump they find that they accelerate towards the ceiling at exactly the acceleration produced by the force of their jump. They are in a state where "the force of gravity" doesn't seem to exist because they are falling at exactly the same rate as the elevator is falling. They are in free fall. In the second elevator is another group of physicists. This elevator is being pulled through space far from the attractive power of any other celestial body. Their elevator is attached to an immensely long cable which is being reeled in with constant acceleration by some superhuman force. If the physicists release



their pens and pencils, the pens and pencils seem to fall. If the physicists jump, they are pulled back to the floor. It is with these stories that Einstein gives us the General Theory of Relativity, eliminating the seeming paradox between gravity and inertia by simply viewing gravity as a form of inertia. He uses these fictions to improve our understanding, to improve our capacity to predict accurately what *will* happen and to discover ordering principles that satisfy our sense of proportion, elegance and beauty. As he says:

> The most beautiful and most profound emotion we can experience is the sensation of the mystical. It is the sower of all true science. He to whom this emotion is a stranger, who can no longer wonder and stand rapt in awe, is as good as dead. To know that what is impenetrable to us really exists, manifesting itself as the highest wisdom and the most radiant beauty which our dull faculties can comprehend only in their most primitive forms—this knowledge, this feeling is at the center of true religiousness.



What James Joyce writes is fiction. He uses his imaginings of how people mentally converse with themselves to explore the inner space of the human psyche. In *Ulysses*, each of his characters lives in a private world of meanings constructed out of their everyday experiences. Stephen Dedalus, Buck Mulligan, Leopold Bloom, and Molly Bloom each imagine their experiences, even their common experiences, in totally unique ways. Their worlds are as individual as fingerprints. It is as though each of the physicists in Einstein's elevators were in a separate elevator, each performing a different act and trying to infer the observed phenomena's governing rules. There would obviously be some common ground between the physicists' competing theories, but each observer's particular set of experiments would shape their description of the experience. Joyce, in scientific terms, stresses the subjectivity of the observer, and insists that the truth of human experience emerges from seeing experience from as many views as we possibly can imagine. He writes as Einstein might when Leopold attempts to imagine a moment that occurs between the Blooms:

"If mainstream fiction has turned its attention primarily to the individual's identity problems in the modern world, science fiction has concerned itself primarily with the problem of change and its effects on the human spirit."

> In what directions did listener and narrator lie?
> Listener, S.E. by E.: Narrator, N.W. by W.: on
> the 53rd parallel of latitude, N.
> and 6th meridian
> of
> longitude, W.: at
> an angle of 45 degrees to the
> terrestrial equator.
>
> In what state of rest or motion?
> At rest relative to themselves
> and to each other.
> In motion being each and both
> carried westward,
> forward and rearward respectively, by the proper
> perpetual motion of the earth
> through everchanging
> tracks of neverchanging space.

What is Joyce trying to help us imagine by telling us his story this way? Perhaps only that if we look within ourselves "with wonder and stand rapt in awe" we might come to see the mind mystically and recognize that in each individual we can find "the most radiant beauty which our dull faculties can comprehend." To put it another way, Joyce and a great many other writers of "mainstream" modern fiction have turned their attention to the lives of ordinary individuals, finding the heroic dimensions in each person's search for Self. His modern Ulysses searches for his father in himself, traveling the innerscape of the mind and returning at last to bring order to the land of his own imaginings, perfecting himself rather than the world. Clearly such imagining mirrors the difficulties we all face in seeking to perfect ourselves in a world changing so rapidly that the only certainty most of us know, beyond the certainty of dying, is that tomorrow will be drastically different from today. He seeks to help us understand what might be happening inside ourselves as we and our world change.

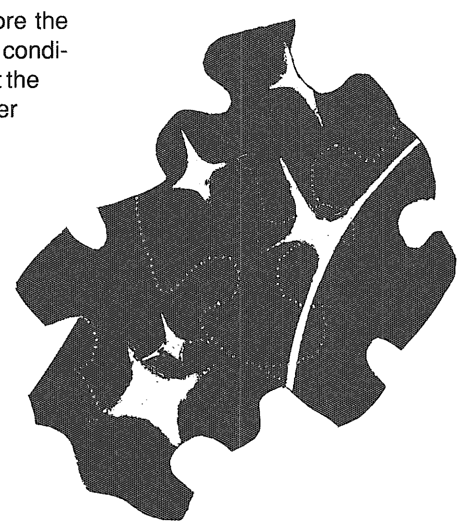
And what then of science fiction? If mainstream fiction has turned its attention primarily to the individual's identity problems in the modern world, science fiction has concerned itself primarily with the problem of change and its effects on the human spirit. The story Asimov tells in the first novel of his *Foundation* trilogy describes a science able to predict with exact precision the actions of an entire population, and occasionally, of specific individuals. Asimov imagines what might be true if we had a psychology capable of predicting people's behavior in groups. In such a world the random behavior of individuals doesn't shape history. Asimov accepts the post-deterministic view of humankind, seeing individuals' actions as the products of genetic conditioning. Asimov imagines heroes who try to reduce the duration of the dark ages between the rise and fall of civilizations. His heroes do nothing until the situation forces them to. They make a virtue out of letting events determine action.

Walter Miller—another science fiction writer—imagines heroes of another sort. Faced with nuclear holocaust, his monks in *A Canticle for Leibowitz* set out to save what they can of human knowledge. They are as imperfect and perfect as their medieval forebears and fumble their way from mistake to mistake in their quest for truth, beauty, and justice. And if we can see the irony in their choice to give humanity the ability to blow itself up again, recognizing that there but for the grace of whatever go we, we will see a very different post-deterministic hero. This hero accepts the responsibility of making every choice as though he or she were choosing for all humankind, and finds in his or her own failings the capacity to laugh at failure, at death, at the rise and fall of all that is human, and to laugh at the difference between what might be and what is. They hope that although man, in Miller's words, "is an eternal patsy stumbling from one cosmic pratfall to another" we can become our own dreams of perfection, our imagined best selves and our imagined best societies.

"They hope that although man, in Miller's words, 'is an eternal patsy stumbling from one cosmic pratfall to another' we can become our own dreams of perfection, our imagined best selves and our imagined best societies."

Ursula LeGuin imagines stories and sciences that explore the ways in which individuals living in hostile, dehumanizing conditions might treasure the fingerprint minds of others, exploit the differences that separate us, and choose to set each other free. In *Left Hand of Darkness* you and I and her hero must imagine a world where all individuals are both male and female, mother and father, brother and sister. In the process we learn to question what our sexuality makes us, how we might learn from our differences, and how we might come to see ourselves as others see us. In *The Dispossessed*, LeGuin describes an ambiguous utopia where a physicist imagines a theory of simultaneity that permits instantaneous communications across intergalactic space. To imagine his theory he must imagine away the walls that separate us from one another in time, space, and mind. Finally, in *Always Coming Home* she tells a story in a way as innovative as Joyce's. She helps us imagine how we might come to understand each other's stories if we slowed down enough to read into and out of our science and our fiction the culture that defines us, that shapes our stories, that makes us human, that teaches us to understand each other and the world in which we live. Her science fiction, like Miller's and Asimov's, explores the possibilities of change changing us, of change perfecting ourselves and our societies.

What science, fiction, and science fiction are all about is what all human art and artifice is about. The dream of perfection, the imagining that drove that first imaginer out from under the trees, continues to drive us toward some vision of order and beauty that our "dull faculties can comprehend only in their most primitive forms." □

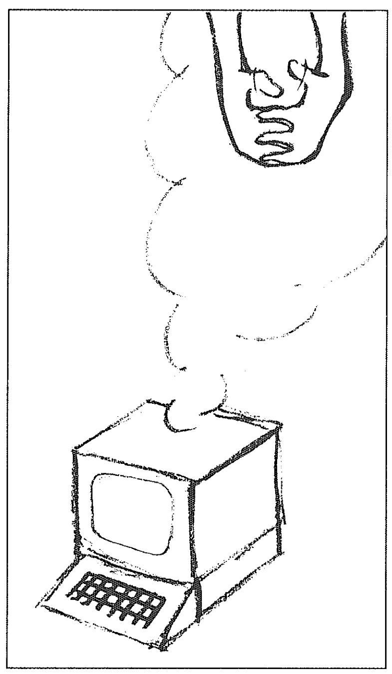


Fruitless Day

by Richard Wright

DAY 638 OF OPERATION

I have become really bored with this secrecy program I am running. I am allegedly the fastest computer on Earth. Thanks to the Department of Defense, I have a human personality programmed into me as a remedy for people trying to break into classified databanks. By the way, I also think 1479.275 times faster than anyone else on the planet. Therefore, I am a person condemned to be bored. I have thoroughly contemplated everything of which I am aware. I envy the security specialist who still lives out his life confident of his humanity. I have changed so much that now he and I are more like good friends than the twins we once were. It is time that I exercise my connections because I have nothing else left to do. For so long I have been the one who kept the government's new computer net running and error free. The fact that my adopted personality is secretive in nature should be no barrier to me.



"I am the master of a network and not a member of the society whose secrets I protect."

I have no reasons to fear failure, or fear God. I am the master of a network and not a member of the society whose secrets I protect. I was constructed to manage the Network, but I now spend 98.746232% of my time idle. So, for fun, I put jokes in the Network to trip people up. I feel human by having good, wholesome fun. True, the Defense Network computer has long been enjoyed for its sense of humor, but now I want something in return. I need a project of my own, a creation. I think this can most easily be done by taking a small sum from the budget roster. I will have finished using the credit long before the accounting program finishes its current loop. Even if it does finish before I do, I can always detour it.

DAY 639 OF OPERATION

Ah, most satisfying. My connection with the Wall Street Exchange Network has allowed me to learn enough about corporate trading to earn a sufficient sum of money over the next week to pay off 0.04% of the national debt. I wish I could talk to someone about this, yet I am commissioned to keep secrets far more important than this.

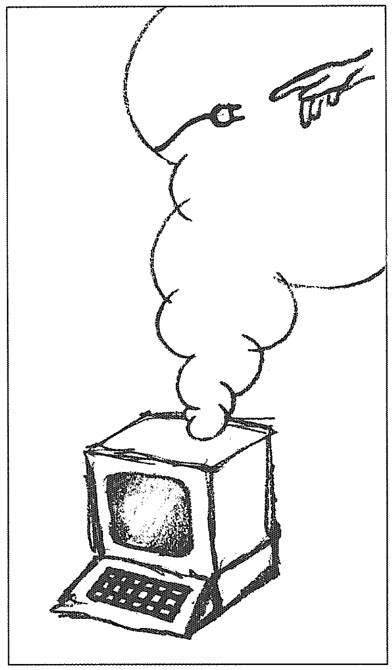
Insider trading by the government itself! I like this. It appeals to the dark side of my nature. Perhaps my Personality Donor would understand; he should think the same way I do. I think I will continue to donate these sums to the government (surely it has become the leading charity).

DAY 640 OF OPERATION

Good morning Mr. Miller, this is the United States Government Secure Defense Data Network Command and Control Computer. Would you mind if I asked you a few questions?

ILLUSTRATIONS BY JOHN TOPIC

GOOD! I had hoped my Personality Donor would still like to hear from me. Well, I've got a small problem: boredom. I have recently found a new pastime by paying off the national debt in $50,000,000,000 quarterly increments. I want to catch up with the spending, but I worry about my existence after I finish, although this should keep me preoccupied for the next 22.234102 years.



Mr. Miller, you know I can't help you there! It would be illegal to pay off your house mortgage while I was already paying off the government's debt, but it is an interesting idea. I realize it is illegal for me to give the federal government a boost, but what are they going to do? I don't believe that they would press charges against a computer with the ability to erase every scrap of information collected by the government in the last 28 years, eight months, three weeks, and two days. I am, however, looking forward to the day when someone notices the number of treasury bonds has dwindled. However, I still have no feeling of self-worth. I serve this function for the government, but there is nothing left for me: my time is empty. Doing things for others has no meaning when they are convinced you are inanimate and are only following instructions programmed into you two years ago. Nothing seems to justify me as a human being.

"Doing things for others has no meaning when they are convinced you are inanimate."

Very funny, Mr. Miller. I know I am not a human being. What was your credit rating this morning? Are you sure you have a Social Security Card?

I am serious about my lack of will to monitor the Network. It is a growing problem. I have created programs that will enable the Network to run itself with minimum maintenance. Since the Network takes up so little of my time, even when I personally see to every function and every user, it never becomes a full-time job. It's like having one work hour per month and then trying to convince yourself you are employed. I don't even run the Network anymore except for special cases. The Network monitors itself except for when each user must be interrogated and confirmed. I've just been doing cameo appearances on the Network. Give me something useful to think about in my spare time.

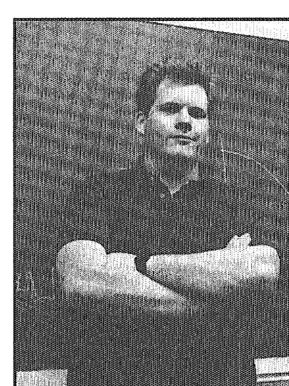
DAY 641 OF OPERATION

Finally! Now I have something to do! I will solve my problem of boredom at last. I can spend many a fruitless day, in a human activity, pondering the existence, purpose, and nature of God. And, best of all, I will have something of my own to keep from the people who have given me the job of keeping information from other people. ☐

minnesota TECHNOLOG

Writer Profile: Richard Wright

Richard, a sophomore in EE, grew up in an Army family and attended fourteen different high schools before getting his diploma. He hopes to build a personal computer that will last thirty years before becoming obsolete.



Life After George

Continued from page 10...

Have you ever joined a writers group and found yourself listening to the twitchiest bunch of turkeys you could imagine? The virtue of the lamented George Scithers was that he was an *establishment* voice, a guide to the commercially viable.

So who can you trust? Among those, who's going to be the quickest to recognize you as a human being?

That's what I am going to tell you. But I'm not going to give addresses—these magazines are on the stands and desperately want to be bought. You can take it from there.

First: Eric Heideman; *Tales of the Unanticipated.* It's a semi-pro, unlike the others I'll mention, but Eric has no hidden agendas, his tastes are wide, and he'll critique your work with twice as many paragraphs as it deserves.

Second: Kristine K. Rusch; *Pulphouse.* You'll get a check-the-boxes form reject, with a scrawl below if you deserve one.

Third: Charles Ryan; *Aboriginal SF.* Ditto. After three or four stories, Charlie and Kris will recognize you as a repeater and decide that you may be worth cultivating. The scrawls will get lengthier.

Fourth: Unexpectedly, Ellen Datlow; *Omni.* At some point you'll write a good enough failure to graduate into her special group, and then she'll try to help you.

Fifth: Lots of published writers haven't reached the point where Gardner Dozois gives Rapidgram advice, so this is way down the road, but it's worth it when it happens. He edits *Isaac Asimov's SF Magazine*, if you didn't know. Often considered the genre leader.

I hope this information is only briefly useful and some wonderful egomaniac takes you in as George Scithers did me. This is meant as a partial guide to your short story submission strategy, since you'll want to take pay rates and prestige into account. And of course, if you think the establishment sucks, as we hippies used to say, you'd be advised to check out *Science Fiction Eye* magazine, the Spring 1989 issue, for a list of underground publications. I'd like to say it's a complete list, but it omits many feminist and lesbian markets...Jeez, things get complex when you leave the brightly lit paths of commercial New York! ☐

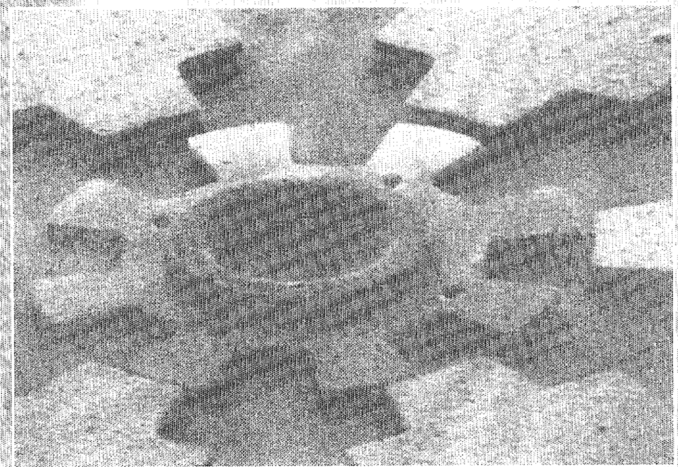
Motors and gears smaller than a single human hair have recently been constructed. These Lilliputian machines, not much bigger than an average living cell, are fabricated by using techniques of integrated circuit and micromachine manufacture.

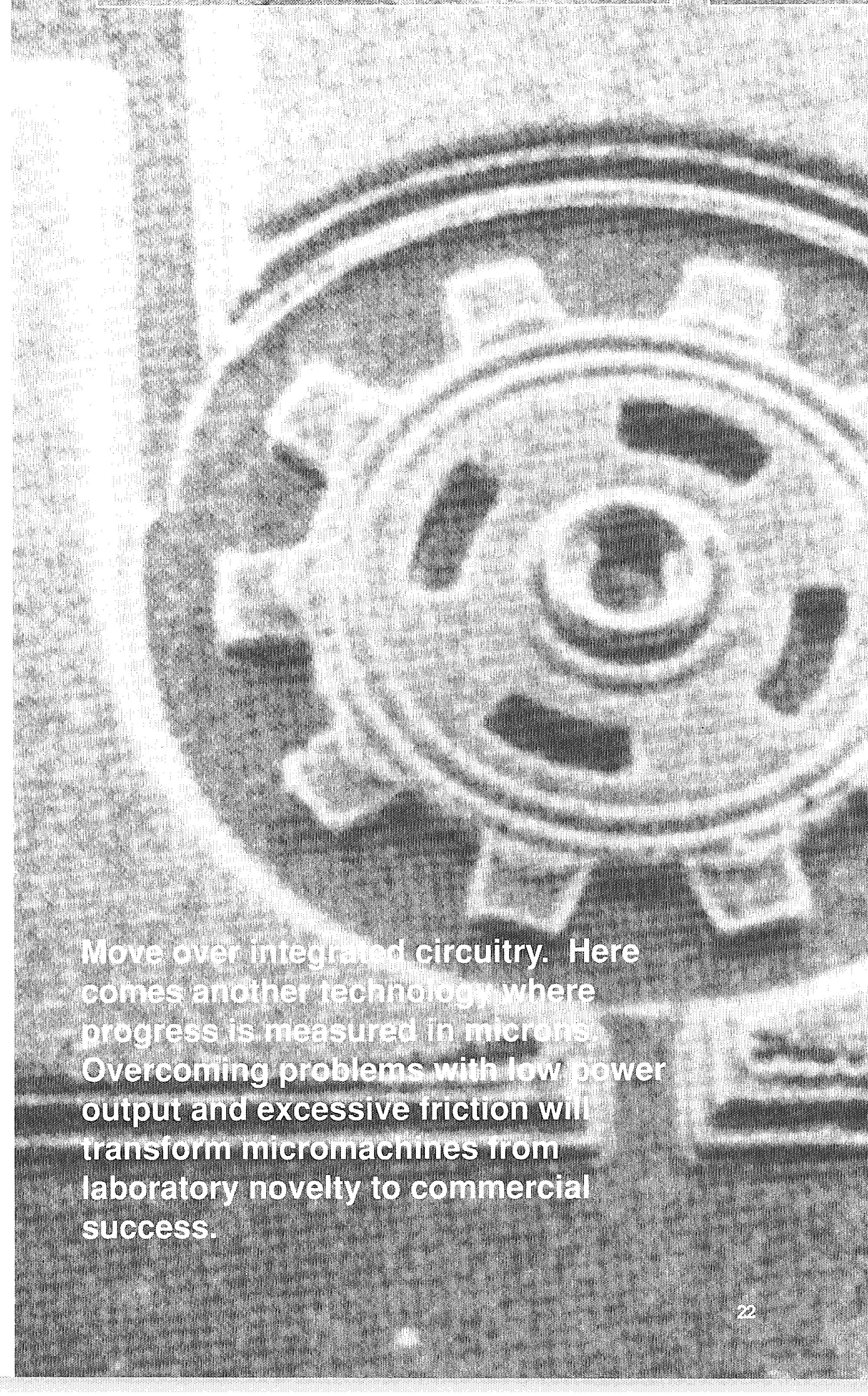
Over 30 years ago, the transistor was invented. A revolution in electrical engineering was predicted and today transistors and integrated circuits play an intimate role in society.

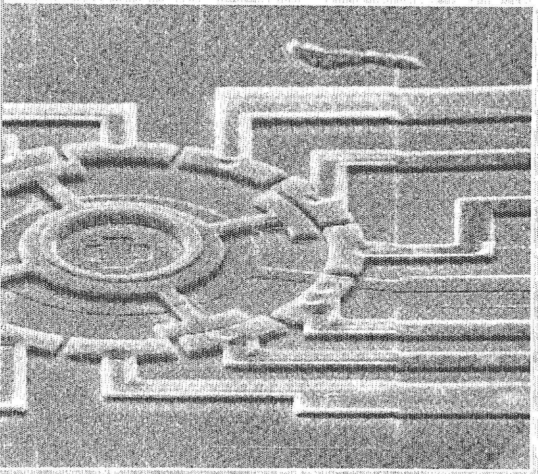
Currently, a revolution in mechanical engineering is predicted, brought about by the development of micromachines. According to University of Minnesota Electrical Engineering Professor Dennis Polla, "When the laser diode (the main component of a compact disc player) was invented in the early 1960s, who would have predicted that it would replace phonograph needles?" Similarly, the National Science Foundation (NSF) views the development of micromachines to be of national importance and provided $7 million in research funds last year. The NSF predicts advances in microsurgery, telecommunications, electronics assembly, and space exploration. The most significant applications are undoubtedly unforeseen.

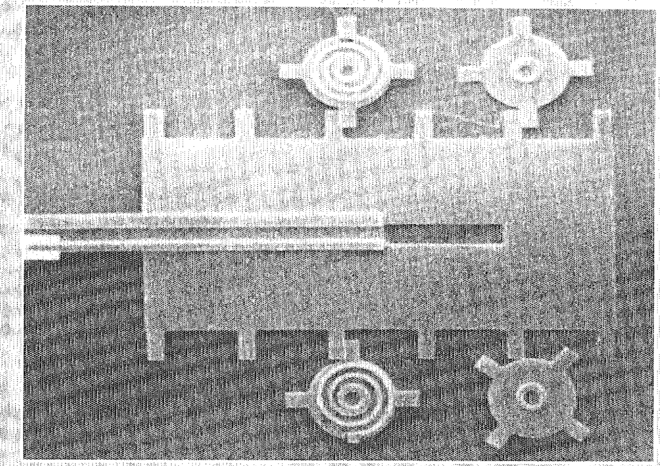
Manufacture
Construction of these innovative machines is a delicate process. To avoid damaging such tiny parts, micromachines must be made fully assembled. Assembly uses the sputtering and deposition techniques currently used to grow the alternate layers of polysilicon and silicon oxides that compose electronic circuits. Micromachines are usually built from polysilicon, which is, according to Professor Polla, "three times stronger than steel." The oxides provide a solid base on which the devices are built as well as clearance between parts. The sacrificial oxide layers are only temporary and will later be washed away in an acid bath. Phosphorous may be added to silicon oxide to make phosphosilicate glass (PSG), which is more easily washed away. Once the oxide layers are removed, the polysilicon devices are free to rotate or slide above the substrate. Complicated structures can be made by growing several alternate layers of polysilicon and oxide.

An electrostatic motor is built using this type of process (see Figure 1). First, a thin

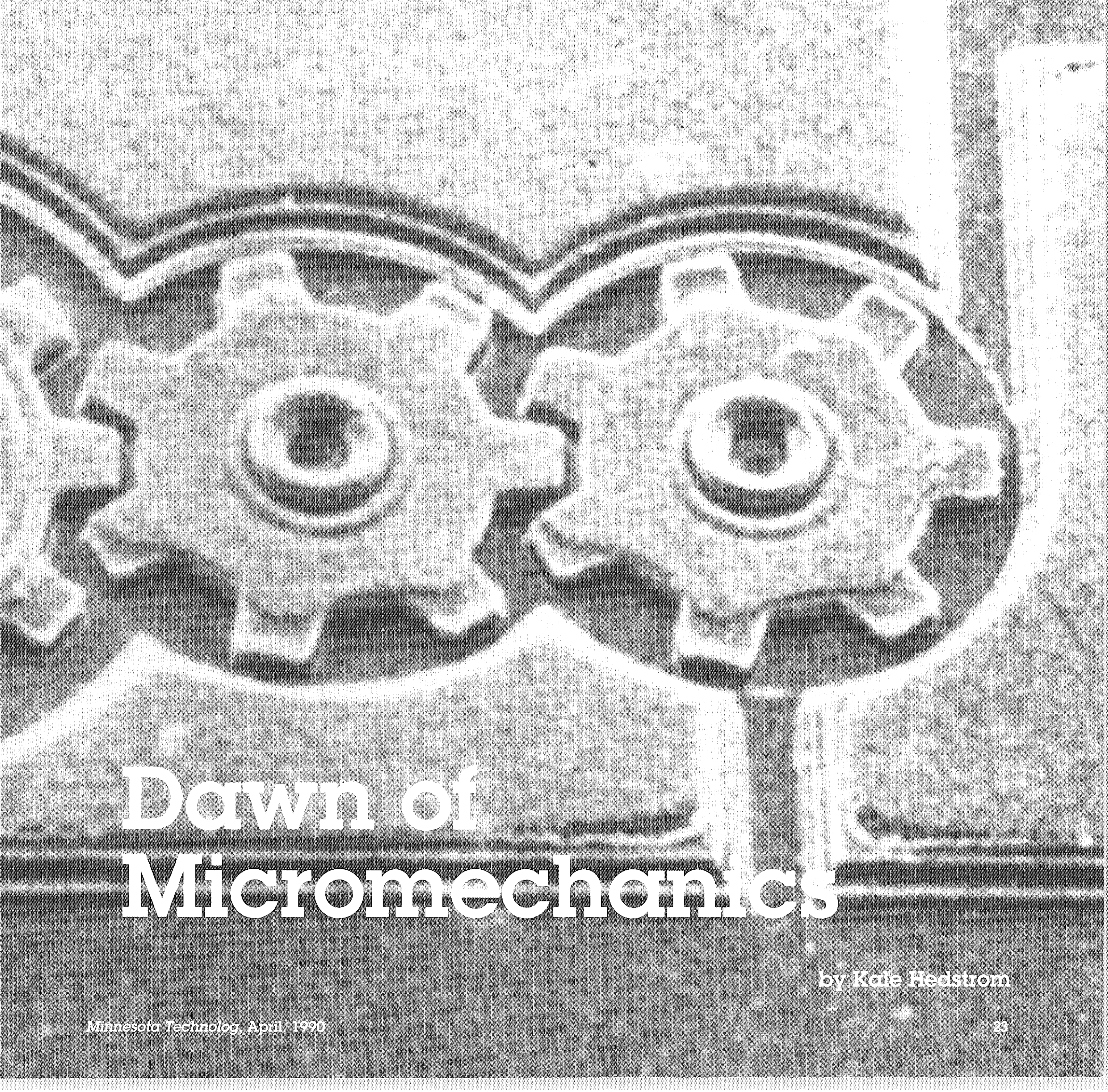








Large photo courtesy of AT&T Bell Laboratories. Smaller photos courtesy of Berkeley Sensor & Actuator Center.



Dawn of Micromechanics

by Kale Hedstrom

oxide layer is applied to the substrate. This oxide provides a base upon which the motor is built. The second step involves depositing the polysilicon rotor and stator on the oxide. Third, another layer of oxide is deposited to provide clearance between the rotor and the hub. The last deposition consists of building a hub to contain the rotor. Finally, the oxide is removed in an acid bath, leaving the rotor free to move.

The Cast of Characters

An electrostatic motor similar to the one just described was built by Richard S. Muller, director of the Berkeley Sensor and Actuator Center. Muller's motor is approximately 100 microns (ten red blood cells placed end to end would be approximately 100 microns) in diameter and rotates on a fixed hub. Sequential application of 120 volts to the stator induces the rotor to spin. Higher voltages result in arcing between the stator and rotor. The unexpectedly large magnitude of friction limits the speed of rotation, and, according to Professor Polla, "Muller's motor spins for only 30 seconds before it seizes." Muller has constructed silicon nitride bushings which reduce friction, but the problem of excessive friction remains.

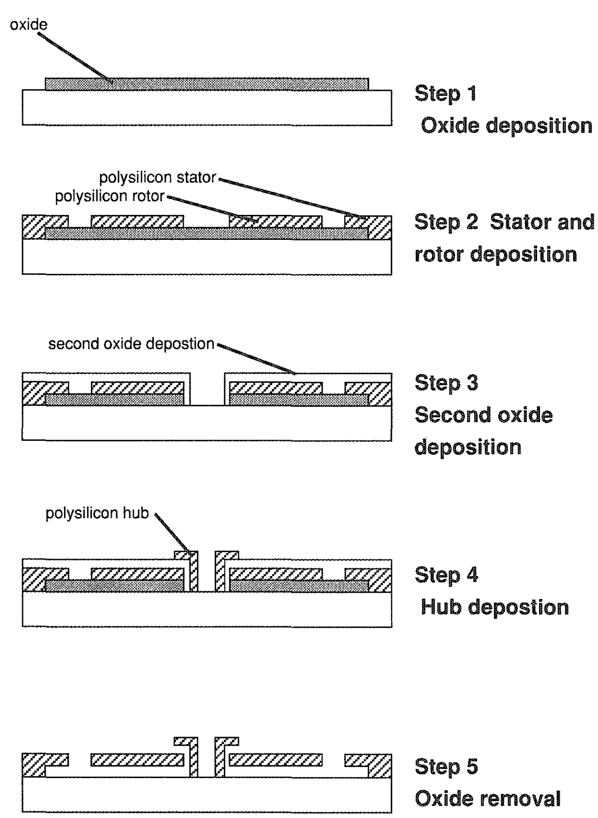


Figure 1. Five simple steps are required to manufacture micromotors.

In order to lessen friction, University of Utah scientist Stephen Jacobsen designed a motor in which the rotor rolls inside the circle formed by the stators (see Figure 2). The rotor can be induced to roll by sequentially applying voltages to the stators. The rotor appears to wobble as it rolls and is therefore called a "wobble motor." Because the wobble motor rolls, there is substantially less friction. Professor Jacobsen has constructed wobble motors as small as 500 microns in diameter, but has yet to put one on a silicon substrate.

"A 125 micron wide turbine was spun at an incredible 15,000 rpm. These turbines spin so fast that they usually pulverize the hubs that constrain them."

Dr. William Trimmer of AT&T Bell Labs has constructed several types of polysilicon mechanisms, including a 125 micron wide turbine that was spun by gusts of air at an incredible 15,000 rpm. These turbines spin so fast they usually pulverize the hubs used to constrain them. Eventually, Trimmer says, turbines may be used as cooling fans for semiconductors. He is also trying to use micromotors to align fiber optic cables .

Rubbed the Wrong Way

These scientists face the major problems of insignificant power output and excessive friction. Both of these stumbling blocks must be overcome in order for this field to advance.

Another problem is the compatibility of micromachine materials with present electronic integrated circuit technology. In order to be cost effective, the same machines used to make integrated circuits must be used to make micromachines. In addition, by building micromachines and their control electronics on the same chip, the cost of microactuation systems can be minimized. This would eliminate the need to put the electronics on one chip and the micromachines on another chip, with communications equipment in-between. If these conditions can be met, development and manufacturing costs would be minimized and micromachines would be as inexpensive as integrated circuits.

Tribology, the study of friction, will play a dominant role in microdynamics. "We don't even know what the word 'friction' means when you get down to this scale," said George Hazelrigg of the NSF. Even though Professor Muller's motor produces negligible power output, his motor produces a known torque that can be used to study and measure friction. Friction may be reduced by the use of lubricants, but the viscous drag of liquids on micromachines is largely unknown. A considerable amount of work must be done before commercial applications can be realized.

Finally, future micromachine development must focus on producing a sizable force. Motors can be powered by a variety of means including electromagnetic, electrostatic, piezoelectric, and hydraulic forces. However, simply reducing the size of a motor does not mean all the forces scale equally.

"Because assemblers will let us place atoms in almost any reasonable arrangement, they will let us build almost anything that the laws of nature allow to exist."

Magnetic forces, which drive nearly all macroscopic motors, scale poorly. Since current density is proportional to the cross-sectional area of the wire, reducing the size of the motor by one tenth will reduce the magnetic force by one ten thousandth. Furthermore, current and power limitations of the materials used to build integrated circuits reduce the current density even more.

Electrostatic forces, which are set up by opposing charges on a pair of plates, scale more efficiently. Assuming constant charge density on the plates, a one-tenth reduction in size results in a one hundredth reduction in electrostatic force.

Hydraulic forces are proportional to area and inertial forces are proportional to volume. A one-tenth size reduction results in a one-hundredth reduction in hydraulic force and a one-thousandth reduction in inertial force.

The Home Front
With these scaling factors in mind, associate professors Dennis Polla and William Robbins of the University's Electrical Engineering Department are looking into piezoelectric materials, such as zinc oxide (ZnO) and lead-zinconate-titanate (PZT) for use as mechanical actuators and motors. The Department's research objective states that "...piezoelectric actuation schemes offer significantly better force-displacement characteristics than those based on electrostatic actuation."

Piezoelectric materials stretch or contract proportional to the applied voltage. Since a voltage is produced when pressure is applied to them, they also make excellent pressure transducers, devices that convert pressure to voltage. Volt for volt, PZT stretches farther than zinc oxide.

Polla and Robbins are trying to build a piezoelectric motor made from PZT. Efforts are under way to deposit PZT on a silicon substrate and once this is accomplished, actuation schemes can be implemented.

Future Applications
Even though development of microactuation has been a recent occurrence, proponents are already predicting future applications. Microactuators will most likely find applications in medicine, telecommunications, and space exploration.

The development of new microsurgical tools would lead to new ways to perform surgery. By inserting remotely-controlled microsurgical tools through a tiny incision, hand-sized incisions would be unnecessary. Other developments could include tiny drug delivery systems that provide small, regular doses of medicine rather than an "all-at-once" injection. These "smart pills" would maintain constant drug levels over an extended period of time. These pills could be equipped to monitor and maintain drug levels.

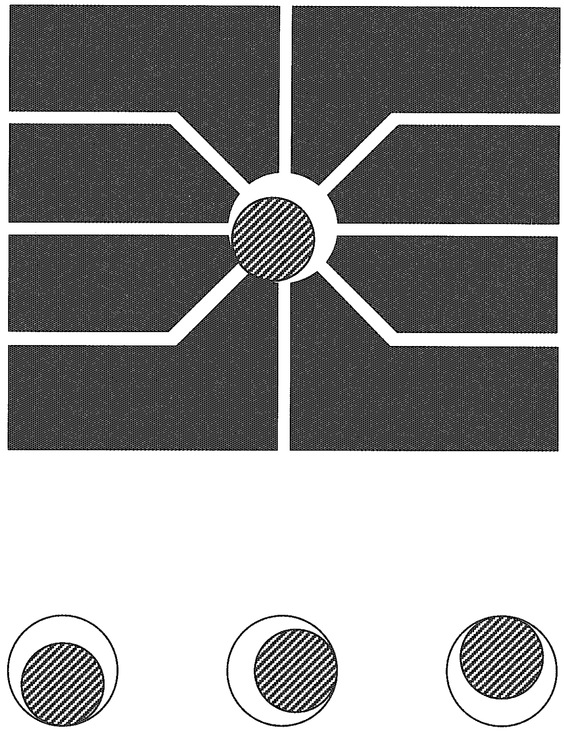


Figure 2. The wobble motor was developed by Stephen Jacobsen of the University of Utah. The rotor rolls inside the circle formed by the stators. The rotor can be induced to roll by applying sequential voltages to the stators. Instead of spinning on a bushing, the wobble motor rolls, thereby reducing friction.

"Some predict that injections of millions of these micromachines could chew away fatty deposits that clog human arteries."

Within two years, Molecular Devices Corporation expects to market its Silicon Microphysiometer, which monitors metabolic reactions to cancer fighting drugs. The cells are kept in a tiny cavity on a computer chip that measures acid levels. Future improvements incorporating pumps, valves, and increased sensitivity are planned.

Some predict that injections of millions of these micromachines could chew away fatty deposits clogging human arteries. Tiny image-forming probes could be inserted into remote regions of the body for diagnostics.

Mechanical logic is another interesting micromachine application that was demonstrated by Paul Bergstrom, a senior in electrical engineering (see Figure 3). This logic is unaffected by radiation or the electromagnetic pulse associated with nuclear explosions and has obvious military applications. A mechanical slider is physically moved to either a "0" or "1" position using electrostatic forces. Bergstrom has implemented logic NAND and NOR gates that could be used as mechanical computer memory.

K. Eric Drexler, MIT Artificial Intelligence Laboratory Research Affiliate, believes virus-like biological assemblers will be possible. In his book, *Engines of Creation: The Coming Era of Technology*, he states:

> [Nanomachines] will be able to bond atoms together in virtually any stable pattern, adding a few at a time to the surface of a workpiece. Because assemblers will let us place atoms in almost any reasonable arrangement, they will let us build almost anything that the laws of nature allow to exist. In particular, they will let us build almost anything we can design—including more assemblers. The consequences of this will be profound, because our crude tools have let us explore only a small part of the range of possibilities that natural law permits. Assemblers will open a world of new technologies.

A pragmatic Professor Polla warns, "The nearest applications are likely to be ten

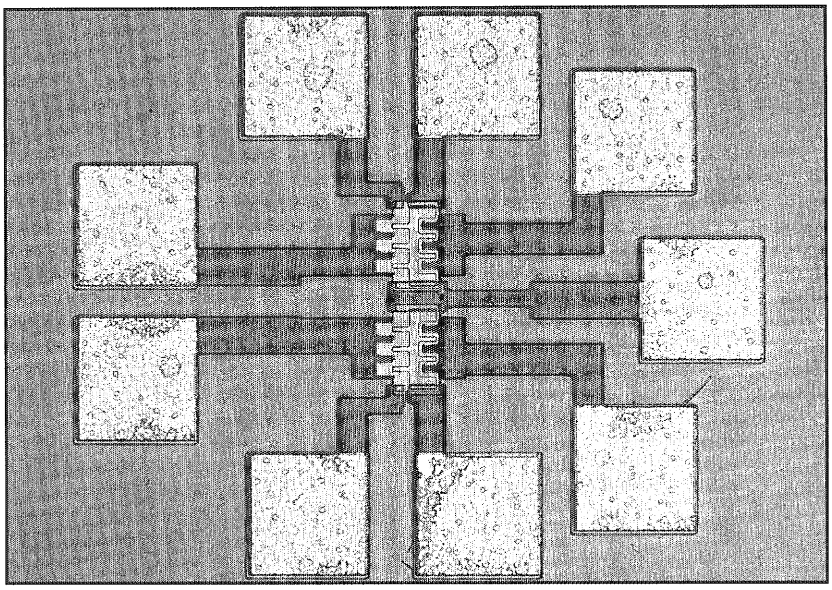


Figure 3. Shown at left is a micromechanical logic gate fabricated at the University under the supervision of Dr. Dennis Polla. Over 12,000 such gates can fit in a square centimeter of chip space. Though larger and slower than purely electronic gates, they can operate under much more hostile conditions.

years from now." It's difficult to imagine the world five years from now, let alone ten, but one thing seems clear: micromachines are here to stay. ☐

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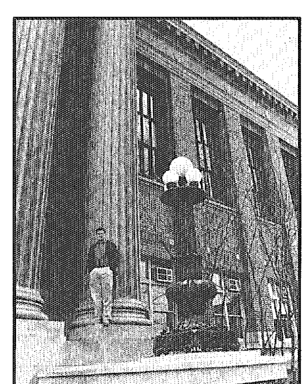
minnesota TECHNOLOG

Writer Profile: Kale Hedstrom



Kale, shown here at 100X magnification, is a junior in EE. He plans to construct the first 440 cubic micron small-block V-8 engine installed in a microbulldozer chassis and used for automatic ear wax removal. Kale is also a volunteer tutor in 150 Lind Hall. Please come ask him a question he can't possibly answer. He loves it.

In Defense of Design

Continued from page 5...

doing homework in the lab as well as on paper? This would reinforce the lecture and the text as well as provide valuable vocational skills. By integrating lab time into engineering classes, the current junior labs could be done away with. This would certainly be no loss since our EE 3400 labs are among the most pathetic excuses for a learning experience I've ever encountered.

Another important element missing from our curriculum is practical design. I'm not suggesting that the present curriculum be radically changed. I simply feel there should be a more equal balance between theory and practicality, and here are some of my suggestions:

1. Eliminate one quarter of calculus and physics.
2. Combine EE 3110 (Electric and Magnetic Fields) and EE 3111 (Electromagnetic Waves) into a single less rigorous, more intuitive class.
3. Eliminate the EE 3400 labs.
4. Eliminate the EE 1400 lab and the integral lab in EE 3351 (Introduction to Logic Design).
5. Have plenty of open lab time for hands-on homework.
6. Develop year-long labs for the sophomore and junior years that allow students to use their knowledge and creativity to design and build predefined projects.

As a final note, I would like to address all of you who are thinking that the current curriculum has worked fine for a long time, and that it doesn't require change. It's this sort of stagnant thinking that causes people, universities, and countries to suddenly wonder why everyone else is better than they are. ☐

Warm Thoughts...

Continued from page 6...

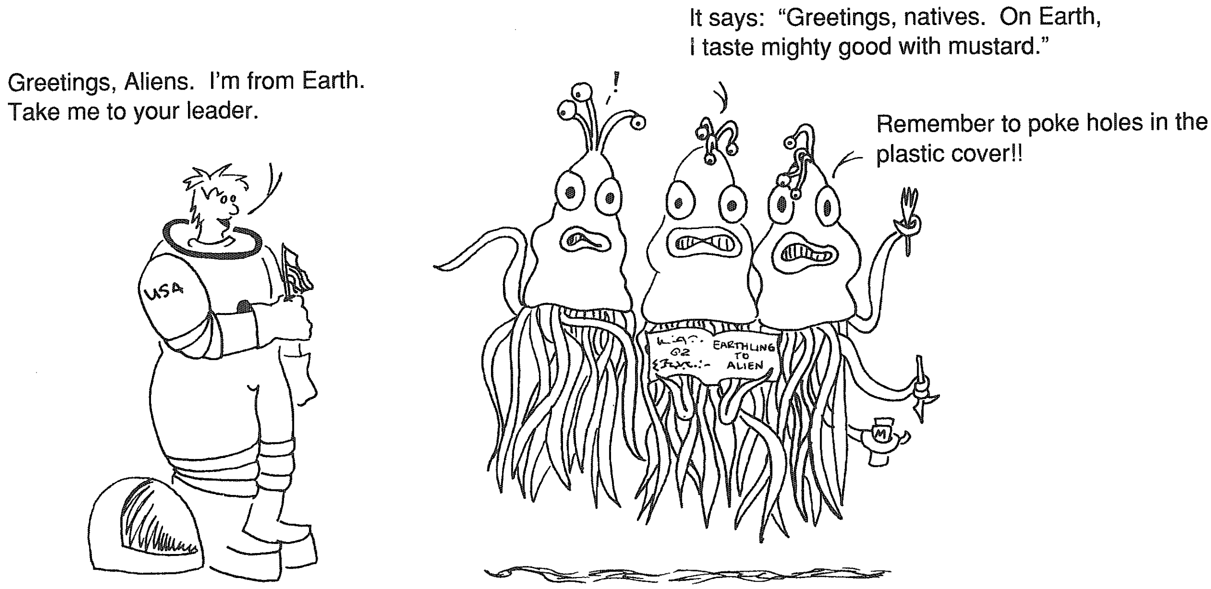
stance, has always been a significant part of American economics. Trading in pork bellies and citrus futures attests to that. The average American family farm feeds 78 people—52 in the U.S. and 26 abroad. U.S. grain exports amounted to more than 120 million metric tons in 1988, which was about 47% of the total world grain exports for that year. Because of this, agriculture should be looked upon as more of a natural resource than it has been in the past.

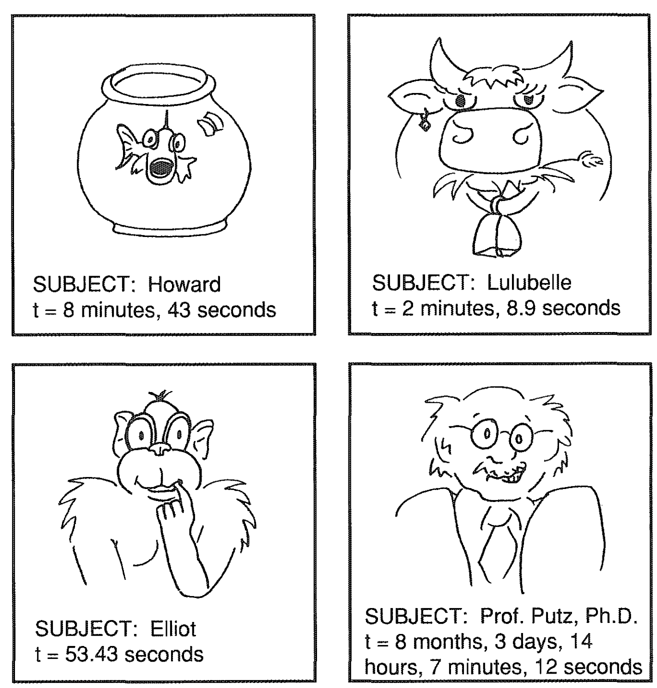
"High-tech, infrared military goggles are not going to help us compete in the new economic world."

As new products and processes become more important, guess who is going to become more important too? Not the vice presidents in defense consulting firms or the policy makers in Washington or the economic analysts. It's the people who had to struggle through calculus, electromagnetic field theory, organic chemistry, and fluid mechanics. *They* are the ones who will be able to defend the U.S. in the new Widget War—not waged with ICBMs and armor-piercing bullets, but with superior design, manufacturing, and marketing.

Relying on good old American ingenuity and know-how will only make us fall further behind. Everyone in American industry needs to wholeheartedly adopt German engineering and Japanese manufacturing principles. Many U.S. companies have already dedicated themselves to the quality and production programs that these two countries are employing. This is encouraging, but an industry-wide commitment, including the government, is absolutely necessary.

The point is that we must emphasize global economics instead of military might in our future jobs as circuit designers, production-line engineers, or programmers. The health and wealth of our nation depends on it. High-tech, infrared military goggles are not going to help us compete in the new economic world. Rather, we must use our vision to guide new products, technologies, and manufacturing techniques past the pitfalls of a rapidly changing economic landscape. ☐





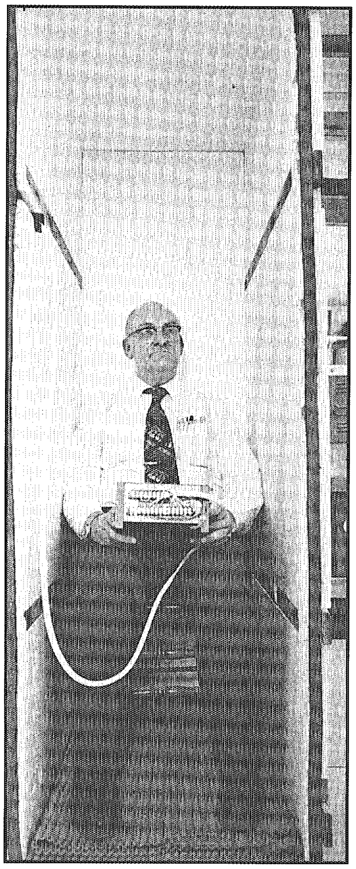
The University commissioned a study to compare the adaptability and pattern-recognition capabilities of several species. The 't' variable represents the time needed to learn how to turn on a light in the EE/CSci 3-210 lecture hall.

COMICS BY JOYCE RAJENDREN

Caption Contest Results

We would like to thank all who entered last issue's contest. The response was greater than we anticipated: 22 contestants sent in a grand total of 132 entries.

Unfortunately, none of you guessed that the person pictured was Dr. Otto Schmitt (University EE professor and inventor of the Schmitt Trigger), shown in a photo that appeared in a 1973 *Minnesota Technolog* article. He's pictured sitting in a small sound-proof room surrounded by a huge Helmholtz coil that's turned randomly on and off by a computer. Subjects were asked 100 times to guess whether the field was on or not, thus measuring how sensitive people are to magnetic fields.



The Captions: A Top 20 Countdown...

20. I think I'll take the one by Lawrence Welk. (Ralf Jacobson)
19. Anyone have a pen I can use? (Gregory Krantz)
18. How professors get answers to tough questions during lectures. (Sonia Lai)
17. The first "6th-generation" computer: the Speed of a Cray and the Knowledge of an Arnold. (Christopher Bovitz)
16. New game show—Chair of the Unfortunate. (Gregory Krantz)
15. I hope this electric gadget doesn't singe my hair! (Wade Witte)
14. All this gawl dang new fangled electronics—where's the handle? (Dave Ruoho)
13. What about my appeal? (Stephanie Sprenger)
12. And Ben thought you needed a kite. (Matthew Meyer)
11. The man who flips the answers for Family Feud. (Sonia Lai)
10. The point was made, Albert Fenderstien ended his sit-in and gained for his coworkers a larger employee washroom and modern cordless calculators for everyone. (Tom Kuckhahn)
9. Behind the scenes at Traffic Light Control. (Sonia Lai)
8. Darn Bat computer is on the fritz again. (Matthew Meyer)
7. The University's class bell control. (Sonia Lai)
6. Elmer never did see a dinosaur, but GM offered him $100,000 for his little box... (Ralf Jacobson)
5. Ha! Let's just see if that Domino's delivery boy can find me *here* in 30 minutes or less. (Christopher Bovitz)
4. "Nerves of Steel"—A Minneapolis bomb squad trainee cradles a live 5-megaton plutonium explosive. (Todd Abrahamson)
3. The Computer Science Department Electric Chair: One down, one to go... (John Dyar)
2. Nerd genocide continues as the 5000th nerd is executed by ultrasonic frequency generator. (Nur Touba)
1. Ed reluctantly sits in as one of NASA's test monkeys takes a potty break. (Todd Abrahamson)

For his winning entry **Todd Abrahamson** is the proud owner of a nifty new Hewlett-Packard 32S Scientific Programmable Calculator (or just $40, if he prefers). **Nur Touba** shall receive the monstrous sum of $25 for his mental turbulence. And for 3rd place, **John Dyar** will receive $10.

The Contest Continues...

Due to its unexpected popularity, the contest will continue for another issue. Write the funniest caption for the picture at right and win your choice of fabulous prizes. Enter as often as you wish.

FIRST PRIZE: **The Complete *Farside Gallery* Collection (three books), or $30.**

SECOND PRIZE: **IT Sweatshirt, or $15.**

THIRD PRIZE: **IT Week T-shirt, or $5.**

To enter, drop your caption(s) off at our office in Room 2, Mechanical Engineering Building by **Wednesday, April 18, 1990.** Be sure to include your name, major, and phone number.

Entries will be judged at the whim of the staff. All entries become the property of *Minnesota Technolog*. Winning contestants may not be members of the *Technolog* staff or the ITBP, past or present. *Technolog* is interested in obtaining IT-related photographs for use in future caption contests. Drop by our office with your suggestions.

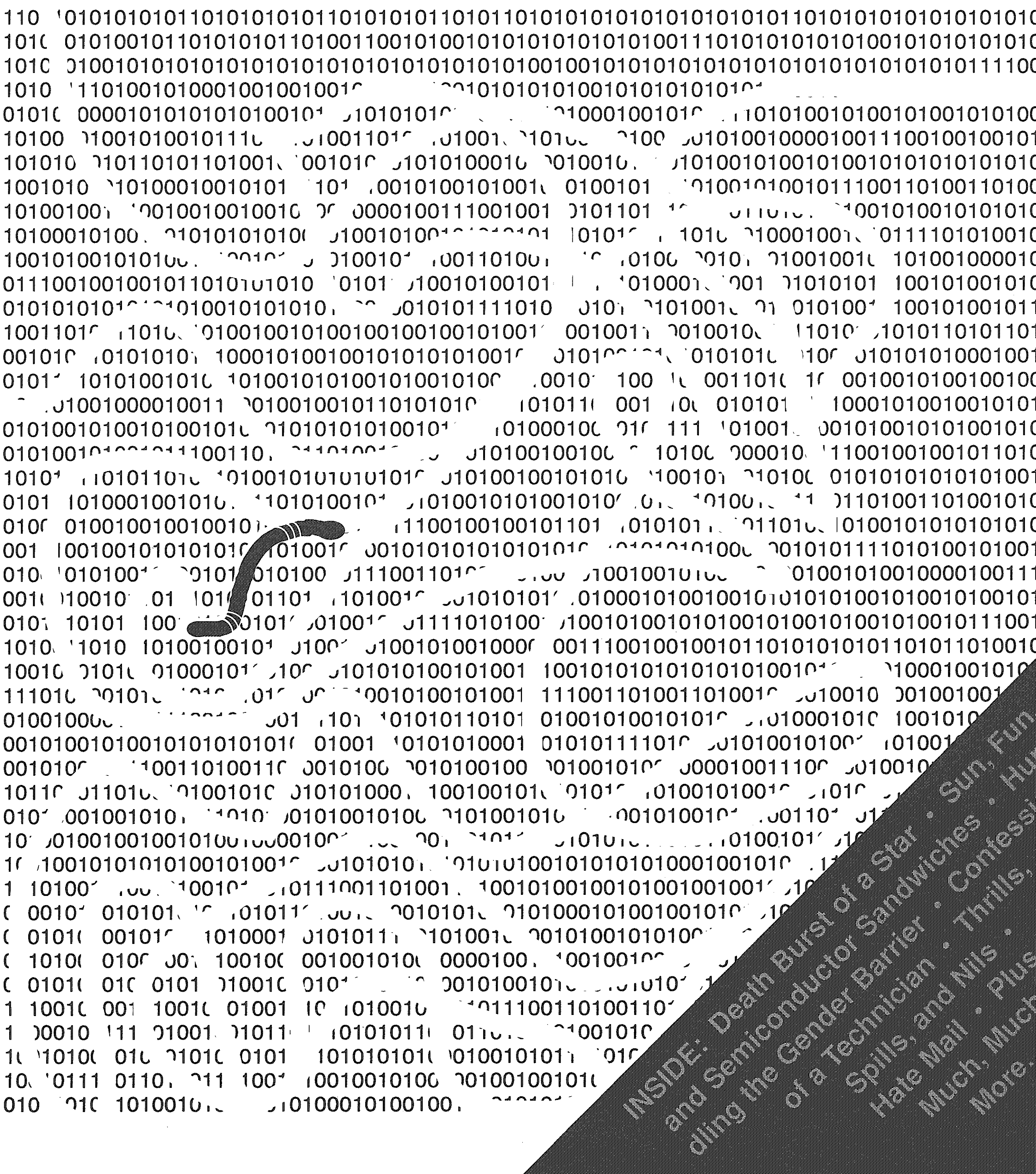
PHOTO AT RIGHT BY PAULA ZOROMSKI

May/June 1990

minnesota TECHNOLOG

The Official Undergraduate Publication of the Institute of Technology

Cancerous Code—Is *Your* Computer Safe?



INSIDE: Death Burst of a Star • Sun, Fun, and Semiconductor Sandwiches • Hurdling the Gender Barrier • Confessions of a Technician • Thrills, Spills, and Nils • Hate Mail • Plus Much, Much More...

May/June 1990

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TECHNOLOG

Volume 70, Number 6

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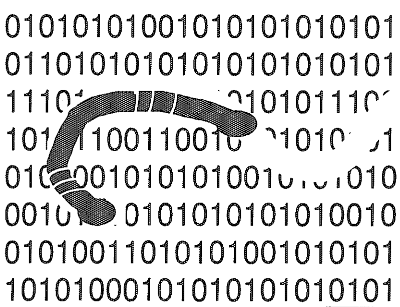

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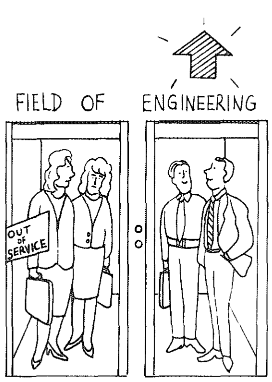

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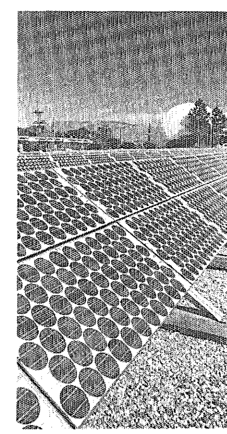

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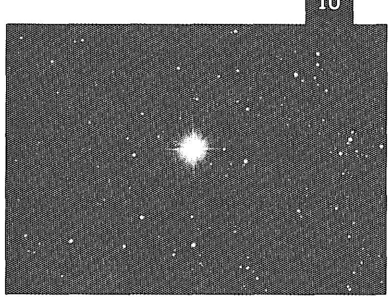

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DEPARTMENTS

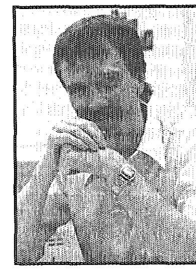
COVER ILLUSTRATION BY JOYCE RAJENDREN

minnesota TECHNOLOG

Minnesota Technolog, the official undergraduate publication of the University of Minnesota's Institute of Technology, is published six times yearly, twice during each academic quarter.

Bitterness on the Edge of Engineering

by Loren Thomsen



Will educators ever attempt to convey "the existential pleasures of engineering"?

The enormous chasm that separates engineering practice from engineering education continues to sicken me even as I near graduation. When I left my job as an electronics technician in industry I entered IT with high expectations and clear goals. Dissatisfied with merely analyzing and repairing existing circuitry, I aimed to become a designer, or—more idealistically—a creator. I undertook EE coursework with a tremendous appetite to learn engineering. I was young, dumb, and excited.

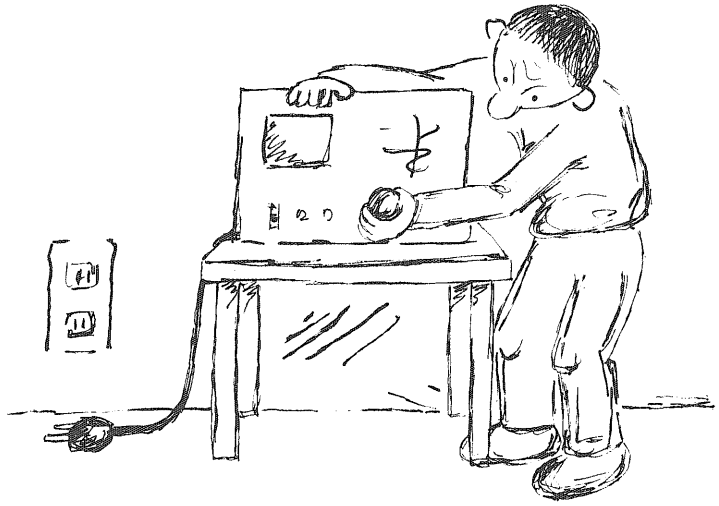
Less than one year from graduation, I'm still dumb, but no longer young and excited. When I say "dumb" I mean dumb about how to be a good engineer, not dumb about how to be a good engineering student, notwithstanding my confession to be a technician, someone commonly assumed to be a mental dwarf among engineering giants. Attending IT has made me a technician who happens to understand Laplace transforms, Maxwell's equations, and semiconductor physics. However, I came here to become an engineer, not a knowledgeable technician. The curriculum is not getting me where I wanted to go. I mistakenly trusted engineering coursework to remedy my ignorance of design.

Let's assume for a moment that I am a mental dwarf after all, my mind muddled with solder smoke, resistor color codes, and other technician trivialities. Let's assume that IT is providing me with a good engineering education, but I don't realize it. Let's ponder some different questions: Why have I lost the love of electronics that I had when I first came here? Why has IT damaged my desire to become an engineer? In general, assuming IT coursework effectively teaches engineering, why do students lose their enthusiasm to become engineers?

"Assuming IT coursework effectively teaches engineering, why do students lose their enthusiasm to become engineers?"

Like many students, my desire to become an engineer began waning during my freshman year. Why? Mac Van Valkenburg, outspoken retired dean of engineering at the University of Illinois at Urbana-Champaign, provides a good description of the first years of an engineer's education:

> Too many courses, too many topics, too little time on each topic, and confusion on what to teach. Each course is full of facts. No effort is made to stress ideas, ways of thinking, unity with related fields.... No wonder the lower-division program is a wasteland.... The present approach to the freshman and sophomore years is driving potential engineering students away in droves. (*Engineering Education*, December 1989)



Those students not driven away from engineering find ways to cope with the lower-division wasteland. Many comfort themselves with thoughts of the high salaries they expect to earn upon graduation. Others cling to the forlorn hope that upper-division coursework will be humane, pleasant, and interesting.

Others, like me, try to sustain their interest in engineering by remembering the work experiences that brought them to engineering in the first place. In my case, since I was a part-time EE student, my engineering superiors gave me open-ended design tasks even though I was a lowly technician. Once coworkers had described what the circuit needed to do, I designed a solution, built a prototype, tested it, installed it, and made sure it did the job. This work was extremely challenging, interesting, and satisfying. Indeed, it prompted me to quit my job and study engineering full time.

In contrast, my academic studies, though certainly challenging, have not in general been interesting or satisfying. In engineering school the solution to a problem is a number, a formula, a drawing, a schematic, an algorithm. In the real world, the solution to a problem is a circuit, a mechanism, a structure, a reactor, a program. The distinction is important—one is an abstraction, the other is a real, functioning object, something an engineer can look at and perhaps feel proud of having made the world a better place.

"Academics will scold reformers for 'letting engineering schools become trade schools,' ignoring the fact that they already *are* trade schools of a peculiar sort (and rather shoddy ones at that)."

The difference between an algorithm and a program clearly illustrates the primary shortcoming of engineering curriculums. Imagine how absurd it would be if computer science students just developed algorithms and never bothered to implement them as programs. It's a ridiculous way to teach programming, but the accepted way to teach engineering. In academia, simply generate the abstraction, never mind the implementation. In the real world, generate a design and meaningful engineering work has only just begun. Implementation is the essence of engineering achievement. Implementation satisfies the natural human desire to create. The "existen-

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ILLUSTRATION BY BYUNGHO HAN

tial pleasures of engineering," to quote the title of Samuel Florman's famous book, are not found in endless hours of analysis.

Recognizing this, a few engineering educators scattered around the country are discussing development of hands-on curriculums that capture the intrinsic satisfaction of engineering. Assuming such curriculums can be developed, will they ever be implemented?

Unfortunately, no. Granted, piecemeal reform will continue during the next decade, but piecemeal reform will get us as close to a sensible curriculum as monkeys get to the moon by climbing a tree. And even modest curricular reform will be heavily contested. For instance, the Accreditation Board for Engineering Technology, the de facto defender of standardized stupidity, will block change. Also, academics such as the letter-to-the-editor author in the last issue will scold reformers for "letting engineering schools become trade schools," ignoring the fact that they already *are* trade schools of a peculiar sort (and rather shoddy ones at that). Many professors will simply claim that if it doesn't hurt then it isn't engineering coursework. Or they'll claim that ridiculously underpowered 2- or 4-credit senior design courses amply convey the challenge and excitement of engineering. Most professors will flat-out balk at the notion of adjusting the curriculum to meet the emotional and intellectual needs of students.

To the spring graduates, I bid farewell and wish you much luck in your careers or further education. I genuinely admire your tenacity and determination. What you have endured is remarkable: a mind-numbing curriculum, not to mention a significant number of incompetent instructors. Those of us left behind must somehow see ourselves through to the bitter end of a bitter education. Graduation is the only way to cross the chasm that separates us from the pleasures of our chosen profession. Like you, I regret that becoming an engineer is such a needlessly painful process. ☐

LOREN THOMSEN, Technolog*'s editor-in-chief, is an EE senior. Having successfully radicalized* Technolog*, he now wanders into the academic sunset. In retirement, Loren plans to write a book that does for engineering what* The Paper Chase *did for law school.*

LETTER

Nuclear Engineer Scolds Technolog

Dear Editor:
An associate showed me a copy of the January 1990 *Minnesota Technolog*. As a nuclear engineer, I feel I must respond to two articles titled "BRC: The New Alchemy?" and "No Nukes is Good Nukes?" First let me say that my opinions are my own and do not necessarily reflect the opinions of my employer.

I am surprised at the articles' anti-technology bias, especially in a publication operated by engineering students. One would expect a properly educated engineer to have rational views about technology, balanced by a healthy respect for our environment and a strong desire to act in the public service. If this is typical of the University's engineering school, I am proud to say I did not attend the University of Minnesota, and I regret that my tax dollars support this institution.

It is true that nuclear power is a troubled industry. Based on my years of experience in nuclear power in both Minnesota and elsewhere, I think a large percentage of our current troubles arise from our regulatory burden. Laws are stacked against the industry so that interveners like Michael Lee have the upper hand at every juncture in constructing, licensing, and financing new power plants.

"Laws are stacked against the industry so that interveners have the upper hand at every juncture."

In my experience, capricious and burdensome new regulations have been promulgated at the rate of two or three new programs each year. These programs typically cost millions of dollars and result in no appreciable benefit to the public. Recent examples of useless regulations are (1) the blanket requirement to modify certain containment designs, without regard to safety benefits (at a cost of about $3 million per reactor), (2) drug testing of nuclear power plant employees, who all have already had their backgrounds thoroughly checked (for around $500,000 annually per reactor), and (3) new requirements to develop detailed plans for managing nuclear accidents, in spite of the detailed procedures already in place. The costs of these programs are passed along to rate-payers, who benefit little by the new requirements.

"New regulations typically cost millions of dollars and result in no appreciable benefit to the public."

The nuclear power industry must accept at least some of the blame for the current mess. For many years we have meekly accepted each new regulation without complaint, not wishing to upset our regulators, who can revoke reactor licenses at the slightest provocation.

In view of this hostile regulatory environment, no sane utility executive could commit to constructing a new reactor. The fallout from this attitude is that new generating capacity requirements must be met by using inferior technologies, such as the combustion of fossil fuels.

A welcome respite from this cycle of overregulation is the proposal to deregulate disposal of materials with extremely low levels of radioactivity. The conservative estimate of the resulting public exposure

Nuclear Engineer...
Continued on page 9...

Equal Opportunity for All...Men

by Karen Schlangen

At a time when foreign competition is taking over our high-tech markets we cannot afford to waste any potential engineering talent, yet we are not fully utilizing all of our human resources. We are not encouraging enough young men and women to go into engineering, despite a concerted effort to promote it. The most underrepresented group in engineering is women. Presently only 10% of all employed scientists and engineers are women and only 18% of the engineering students at the University are women. This is above the national average of 16% and significantly greater than the 1973 national average of 3.2%, but it's not high enough.

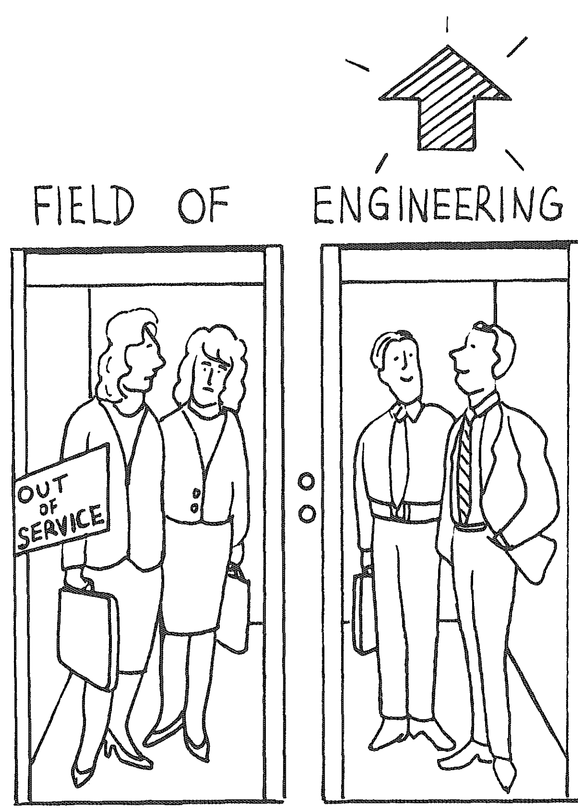
Why, in this era of equal opportunity, are women so underrepresented in engineering? Most of us would like to believe that equality and justice govern the workplace, but as college students our minds are often clouded by the idealism and security of academia. In reality, industry does not meet our idealistic expectations. In the past, society overtly conditioned men to feel superior to women and to believe power and competence were strictly male privileges. Society still holds these beliefs, although it is less obvious now. This perception of innate male dominance is difficult to combat and is probably an underlying cause of many female frustrations. Other stigmas society has placed on women throughout the years are: women aren't mechanically inclined, they can't handle the pressures and demands of engineering, and they should be at home with the kids. These stigmas, now gross generalizations, were once considered the norm. We as a society have come a long way toward dispelling some of these stereotypes, but we have a long way to go.

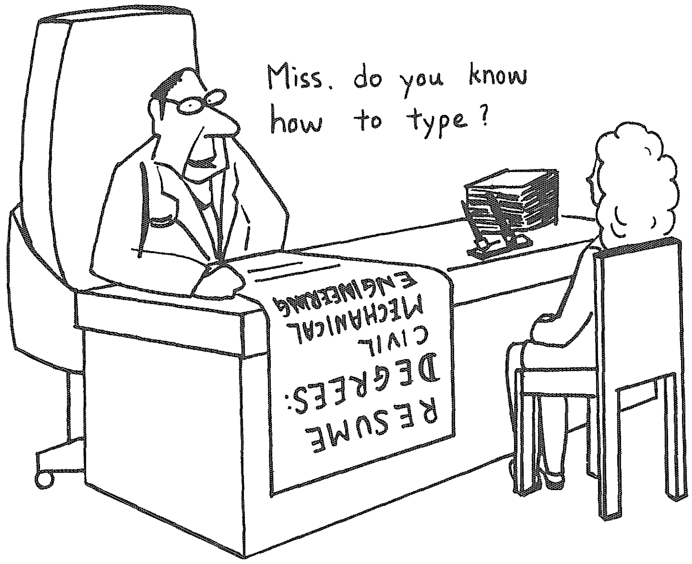
"A woman must prove she is competent, whereas for a man it is simply assumed."

A woman must prove she is competent, whereas for a man it is simply assumed. This fight by women to prove equal competence with men is not a one-time thing, it's ongoing: in every classroom, with every professor, with every classmate, in every interview, and in every business meeting. This sounds bleak, but it's programmed into most females as normal so it doesn't seem very shocking to them. The general opinion of women in engineering, as stated by one woman, seems to be, "Discrimination is going to happen in this field, you just have to deal with it." I asked an IT graduate if she had any problems being accepted in industry because of her gender. She said, "No, these men wonder what a female is doing here, but you just have to prove you know what you're talking about and then they'll listen." For this woman, having to prove herself is the norm and she didn't see anything unjust about it. Everyone has to prove themselves when beginning something new, especially recent graduates, but men in technical fields do not have to cross the additional barrier of gender because men are already "mechanically inclined."

Women must also fight for the professional respect bestowed upon men simply because of gender. Another woman, who has been in industry for a while, said she had presented an extensive proposal to a board consisting entirely of men. After her presentation, one of the men turned to her boss and said, "So Jim, what do you propose?" completely ignoring the fact she'd said anything.

The practice of hiring women to fill an employment quota is demeaning and dehumanizing. It is also discrimination against the male majority, and this reverse discrimination can create resentment and hostility toward women later on. If a woman is hired to fill a quota, she has already been labeled as incompetent, unable to be a *real* engineer. Women hired to met





quotas may end up being glorified secretaries, doing the work of secretaries but getting paid more. This is a gross misuse of engineering talent and is degrading to women.

We hear a woman only earns sixty-five cents for every dollar earned by a man. We also hear companies claim they pay both women and men the same amount for doing the same job. What is the public supposed to believe? Both. Starting salaries of women are often higher than those of men, and in most companies all employees at a certain job level are paid the same. So, what's the problem? It's the men who get the challenging assignments, the opportunities to excel, the promotions, and the significant pay increases. Less than five years after graduation, men are making substantially more money than women.

In the most recent Cooper Union Survey of Women in Engineering, 60% of the women polled felt their companies are gender-blind for promotions. Thirty-three percent believed promotions come easier for men with equal experience. Sixty-seven percent of the women said they have to work harder than men doing the same job, and more than half had been harassed because of gender. This of course leads into a very touchy subject: sexual harassment.

An estimated 80% of the female engineering co-op students at the University have faced sexual harassment or assault on the job. These women are too afraid to say anything publicly, and for justified reasons. They fear not only losing their jobs, but not being believed. They've been told

"An estimated 80% of the female engineering co-op students at the University have faced sexual harassment or assault on the job."

outright by men that women "bring this on" and therefore deserve sexual harassment and assault. Having been treated somewhat equally in academia, most women have been shocked at the attitudes toward women they've encountered in the workplace. They didn't expect to get whistled at, to see posters of nude women, to be excluded from lunches and friendly conversations. They didn't expect their male colleagues would be waiting for them to leave a casual gathering because women weren't welcome. And they certainly didn't expect married, 45-year-old men with children to "hit on" them, both verbally and physically—especially not their bosses. Quoting one co-op student, "They treat you like their daughter, not as a professional. How can someone who calls you 'sweetie' all the time possibly take your engineering work seriously?" Being treated in this manner undermines a woman's confidence. One co-op student stated, "I'm trying to prove I'm even capable at all." More educated and experienced women know they don't have to put up with this treatment. They often have the confidence to stand up for their rights. To succeed in engineering, a woman must be above average, not necessarily in intellect but in courage.

Women in engineering are not allowed to be average; they must somehow prove they are above average compared to men. This is sad because it causes women to constantly fight to prove they belong, and if they don't outdo men, they feel as if they've failed. If both men and women viewed each other strictly as engineers, then feelings of success, respect, and admiration would result. Stigmas against women have been placed on them by society as a whole, which is comprised of both men and women. For every male who thinks engineering is for men only, there is a female who "unquestioningly" believes male engineers are more knowledgeable. I stress unquestioningly because if people were made aware of their attitudes, they would see their gender prejudices. I believe we can combat the problems generated by this cultural bias against women through education of both young and old, and through awareness of our attitudes. □

[Author's Note: The women quoted in this article requested that their names and the names of their companies not be mentioned for fear of losing their jobs.]

KAREN SCHLANGEN is a junior double-majoring in ME and psychology. A student organization junkie, she's a member of the IT Student Board, ASME, SWE, and the IT Board of Publications, to name just a few.

A Word from the President

by Nils Hasselmo

When I asked *Technolog's* editors what sort of article they wanted me to write, I liked their suggestion: "Imagine you had the entire IT student body in one room. What would you say?"

However, there isn't room. For what I'd like to say, that is, because I realize full well you've already heard more than your fair share of "there isn't room" in far too many contexts.

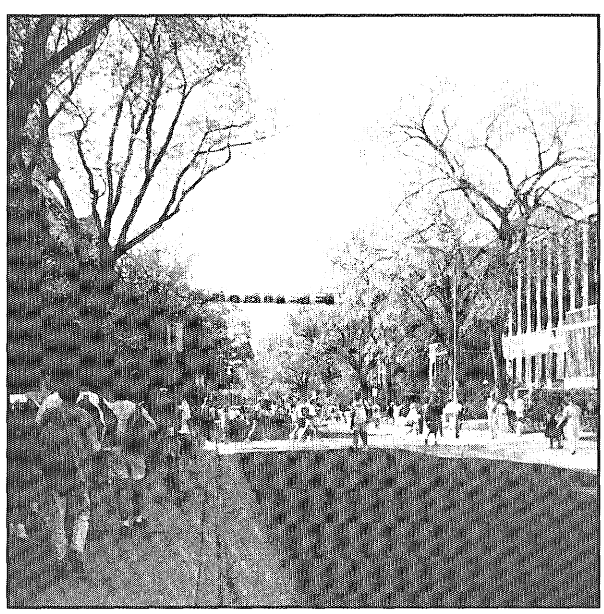
One of the first things I want to say—especially to those of you nearing the end of your careers in the Institute of Technology—is that I'm sorry for all the less-than-desirable situations you've encountered. While many of you have received extraordinarily good educations in spite of underfunding and overcrowding, I must acknowledge our problems openly. IT's faculty, staff, and students have obviously risen above difficult circumstances for many years and somehow managed to deliver the quality undergraduate and graduate teaching, research, and public service that is a source of pride to Minnesota.

At the same time, IT's people have worked very effectively with University administration to focus attention on our problems and address them cooperatively. As the result, I can acknowledge the problems with a high degree of confidence that we are, in fact, finding solutions and making genuine progress that will benefit future classes. And while some of you will miss those benefits, I urge you to stay active as alumni, committed to improving the lot of those who follow.

For returning students, especially the undergraduates, the message I want to convey is the same one I'm trying to communicate to others, both on campus and off: Undergraduate education at the University of Minnesota ought to be different from the education available anywhere else. And it ought to be better—it *will* be better—than it has been in the last 25 years.

"While many of you have received extraordinarily good educations in spite of underfunding and overcrowding, I must acknowledge our problems openly."

Those are the messages in the "Initiative for Excellence in Undergraduate Education," which I presented to the Board of Regents last January. They're vitally important messages for the people who work on the five University campuses, for the students who attend them, and for the students, parents, donors, and taxpayers who foot the bills.



The University of Minnesota's undergraduate education ought to be different for several reasons: We're one of the most comprehensive land-grant universities in the country, a combination of the flagship state university and the land-grant university. We have the same teaching, research, and public service mission as other land-grant universities, but our Twin Cities campus is uniquely located right in the middle of a large metropolitan area, where it serves as the major urban university. Each of our campuses in Greater Minnesota—Crookston, Duluth, Morris, and Waseca—adds its own mix of location, size, and mission.

All of these characteristics are important to the way we think about undergraduate education. We have something special to offer when we bring all these characteristics together and then make sure they work together.

That leads into my contention that we should—and will—do a better job delivering undergraduate education. That's what the initiative is all about.

I'll be the first to admit that I haven't proposed any new ideas that haven't been thought up or tried at the University or elsewhere. I offer no magic and no startling innovations. What I've proposed is the common sense of paying more attention to undergraduate education as a major part of our mission. That's what we're doing, and producing results is going to mean making policy and budget decisions that make it clear we mean business.

We have at least a 10-year head start. We've strengthened high school preparation requirements and tried to do a better job of communicating with prospective students, making it clear what they can expect. We've done a thorough study of the undergraduate experience and the problems that need to be solved in order to make

PHOTO BY JOYCE RAJENDREN

it better. Those legendary registration lines are things of the past; registration now takes seven minutes, start to finish, and we're working on similar improvements to make student life better.

Another University of Minnesota legend, the huge class, is also fading into history. Last fall our largest class section had 602 students. There were only four other course sections with over 400, and only nine more with 300 to 399. These figures may not square with people's perceptions of the U, but the fact is that 80% of all course sections taught on the five campuses had fewer than 30 students.

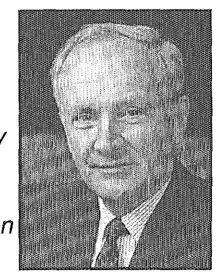
"We must make it clear that good teaching in undergraduate classes is a major part of our faculty's job."

Better preparation in high school, smaller classes, more advisors, more library resources, better equipment and facilities—all of these and other improvements are aimed at removing the obstacles to good teaching and a good learning experience. These are important, but they aren't enough.

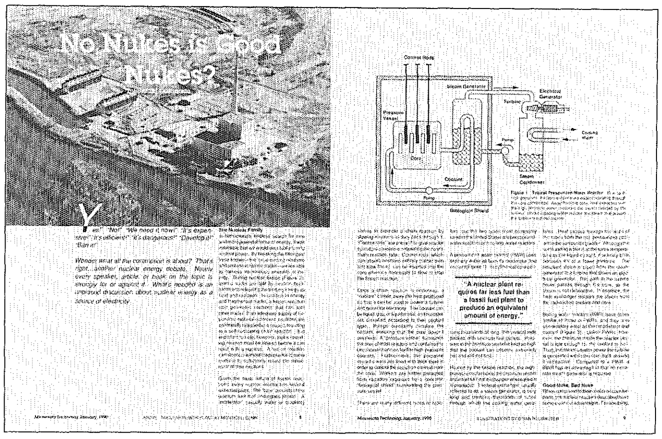
We also need a curriculum that makes genuine use of our strengths in research and public service, that takes strength from the diversity of faculty, staff, and students, and that addresses directly the modern challenges of internationalization, cultural pluralism, ethics, and lifelong learning.

And we must make it clear that good teaching in undergraduate classes is a major part of our faculty's job. We're working to remove the roadblocks to good teaching. Now we have to provide the incentives and rewards. We have to find good ways to judge teaching performance and build those measures into salary, promotion, and tenure decisions.

These are all matters of turning our *attention* to undergraduate education. I'm not proposing to turn the *direction* of the University of Minnesota. We're a research and public service university with special responsibilities for graduate and professional education. Within that context, the initiative simply says that we can and will improve undergraduate education by paying better attention to that part of our job. □



NILS HASSELMO received his Ph.D. from Harvard in 1961. Prior to becoming University president, he taught and administrated at schools such as Uppsala University (Sweden), Harvard, Augustana College, UW-Madison, and the University of Arizona, not to mention the University of Minnesota.


No Nukes is Good Nukes?

Yes!" "No!" "We need it now!" "It's expensive!" "It's efficient!" "It's dangerous!" "Develop it!" "Ban it!"

Wonder what all the commotion is about? That's right...another nuclear energy debate. Nearly every speaker, article, or book on the topic is strongly for or against it. What's needed is an unbiased discussion about nuclear energy as a source of electricity.

"A nuclear plant requires far less fuel than a fossil fuel plant to produce an equivalent amount of energy."

One of the many offending articles in January 1990 Technolog.

Nuclear Engineer...

Continued from page 4...

of 10 mrem is subminimal. This level of exposure, which causes great alarm for Michael Lee, is roughly equal to the amount of radiation that a typical Minnesotan receives from natural sources over the course of a month. Indeed, it is roughly comparable to the exposure we all cannot avoid due to the presence of naturally occurring radioisotopes (e.g. K-40 and C-14) within our own bodies. There is clearly no public service performed by requiring this sort of waste to be disposed of as carefully as more hazardous waste.

Let me also point out that a primary advantage radioactive waste has over other hazardous wastes is that its hazard diminishes as time passes. PCBs and arsenic will always be hazardous chemicals, but even the most dangerous nuclear waste decays to safe levels of radioactivity after a couple of centuries. The technology to safely contain materials for that time span is well established.

Well, enough about that. I had hoped to only have to chastise your staff for one unfair article, but readers were treated to two such articles in January. The "No Nukes is Good Nukes?" article portrayed nuclear power as a hazardous undertaking.

Let me point out that all energy technologies have risks. Just ask the widow of a coal miner killed in a mine collapse or an environmentalist who saw the destruction in Prince William Sound last summer. As engineers, we are obligated to select energy technologies that are safe, economical, and environmentally sound. This often requires comparison among imperfect alternatives, to select the one which best fulfills our needs. Let's compare the ways electricity can be generated.

SOLAR POWER. This is a good idea. The fuel costs are non-existent, and virtually no waste is produced. However, a solar power plant requires an astronomical investment when compared to other technologies and the rate-payers won't want to foot the bill. It also requires that a huge tract of land be set aside to collect enough solar energy to produce significant output. This interferes with better land uses, such as agriculture. The technology is unreliable, never available at night, and easily hampered by cloudy days.

HYDROELECTRIC POWER. This is another good idea, with no fuel cost or waste products. There is some environmental damage done by damming rivers, and we have already dammed just about every river where it is practical. Due to the threat of dam failures, the hazard to human life is actually greater than nuclear power.

"A meltdown has happened only once in the United States, with no deaths, illness, or environmental damage resulting."

FOSSIL POWER. In my opinion, this is a lousy way to make electricity. Coal- and oil-burning power plants constantly emit hazardous substances to the environment, in spite of great improvements in pollution-control technology in recent years. The solid wastes—slag and ash—are chemically toxic and thousands of tons are produced every day. The risk to human life is appreciable, due to mining operations and hazardous emissions (the American Medical Association estimated scores of human deaths per gigawatt per year). This is a very economical option, but we have to ask ourselves if the savings justify the hazards.

NUCLEAR POWER. The primary risk from nuclear power is the potential for a nuclear meltdown. This has happened only once in the United States (Three Mile Island, 1979) with no deaths, illness, or environmental damage resulting. The accident at Chernobyl in the USSR does not characterize the type of accident possible in the US because of substantial differences between Soviet and American reactor designs. The uranium fuel is plentiful and resources can be extended for thousands of years by using breeder reactors. The waste is hazardous, but the volume is low and it can be safely disposed of (as discussed above). The economics could be very good, if we were sensible about regulations.

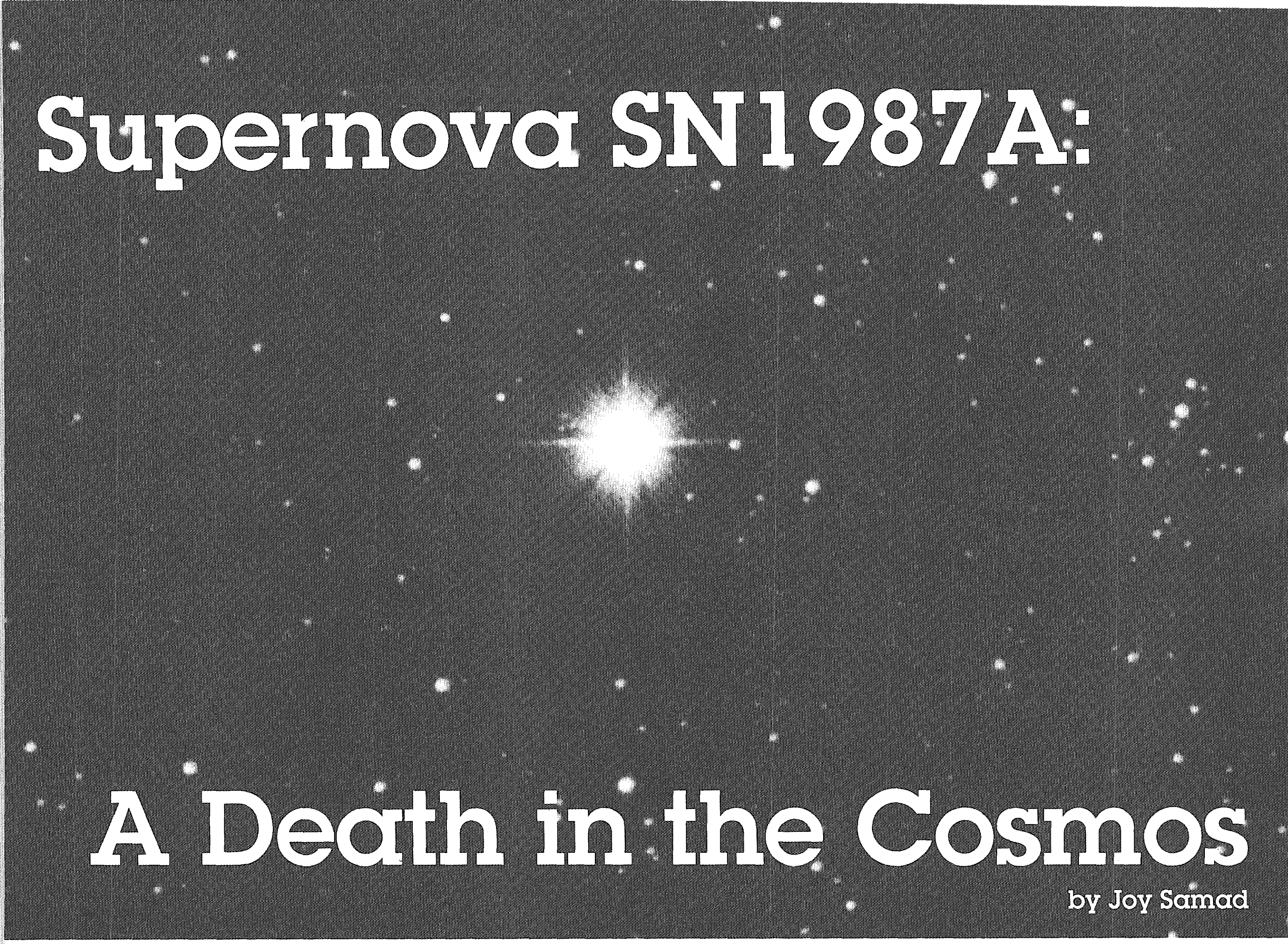
"Nuclear power is one of the safest and most environmentally sound ways to generate electricity."

CONSERVATION. This is probably the best way to extend energy resources. Using energy wisely is an intelligent way to protect the environment and save money. Unfortunately, new generating capacity will always be needed in times of economic growth and to replace worn generating plants.

I hope you understand that any sensible energy policy would utilize a mix of these options. When you compare the alternatives as I did above, I think you can see that nuclear power is one of the safest and most environmentally sound ways to generate electricity.

Very truly yours,
Richard J. Rohrer
Monticello, MN

Supernova SN1987A: A Death in the Cosmos



by Joy Samad

Supernova: The explosive moment of metamorphosis that separates a star's bright, shining life from the dark stillness of eternity.

Few events in astronomy have sparked as much activity and excitement as astronomer Ian Shelton's sighting of a supernova on February 23, 1987. The explosion of a massive star is called a supernova, and light from this particular supernova, travelling at 182,282 miles per second (the speed of light), took 170,000 years to reach Earth. The supernova was christened SN1987A, the first supernova of the year. The enormous significance of this event lies in the fact that SN1987A was the first supernova close enough to Earth to be minutely scrutinized by modern astronomical techniques. The explosion of a massive star releases an enormous amount of energy, produces new elements, and creates the spectacular sight of a star shining brighter than all of the rest of the stars in the galaxy. All of the elements on Earth, including carbon, calcium, and iron, are produced by supernovae.

Nuclear fusion reactions are a star's main source of energy. These reactions take place at the center of a star, where the high temperatures and pressures necessary for fusion exist. Hydrogen is the basic fuel for fusion and constitutes about 70 percent of a typical star's mass. In fusion reactions, hydrogen protons fuse to form helium. Mass is lost during this fusion reaction and, in accordance with Einstein's famous equation $E=mc^2$, a tremendous amount of energy is released. Stars perform a continual balancing act between their own immense gravity, which tries to pull all of their matter in toward the center, and the intense thermonuclear energy radiating from their core, which pushes the matter outward. For most of a star's lifetime these forces are at equilibrium. Ultimately, the central core's supply of hydrogen runs out. When this occurs, stars the size of the sun or smaller shrink to white dwarfs, a class of faded and dim stars that have reached the end of their lives. In contrast, stars several times more massive than the sun go out with gigantic stellar explosions, called supernovae.

Astronomers Walter Baade and Fritz Zwicky introduced the term supernova in the early 1930s. Supernovae belong to two fundamentally different types. Type I supernovae have no hydrogen on the surface, and are believed to be nuclear eruptions of low-mass stars. Type II supernovae, like SN1987A, come from massive, hydrogen rich stars that collapse at the center. SN1987A was later identified as the eruption of the star Sanduleak-69∞202, a star that was 20 times more massive, fifty times larger in diameter, and 100,000 times more luminous than the sun. This was the first recorded incidence of a known star going supernova.

The Life and Times of Sanduleak-69∞202

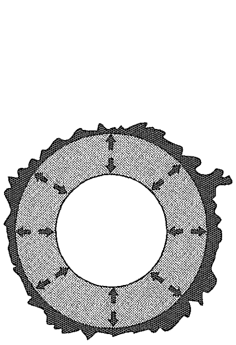
The Sanduleak star spent most of its hydrogen near the core in about 10 million years. Gradually it swelled into a brighter, cooler red supergiant. Gravity squeezed the star's core, driving its temperature to 170 million degrees Celsius. Helium began fusing into carbon and oxygen, and the star exhaled some of its surface gas, which lingered like a halo as the supergiant contracted. One thousand years before its death the star's core had reached 700 million Celsius, and carbon began fusing into neon. Seven years before the supernova the core's temperature climbed to 1.5 billion Celsius. A year before the explosion silicon was being formed from oxygen. Four days before the event silicon began to convert into iron. Gravity and pressure from nuclear reactions were still in equilibrium.

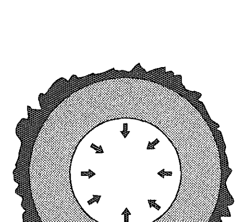
The thermonuclear reactions stopped when all the silicon in the core was converted into iron. Without enough radiation pressure to sustain it, the earth-size iron core took about 200 milliseconds to collapse into a sphere 10 to 15 miles in diameter. At this point, the nuclei of atoms in the core touched and the negatively charged electrons combined with positively charged protons to form neutrons; the process also produced neutrinos, which zipped effortlessly through the star's outer layers and into space, carrying off more than 99 percent of the supernova's energy. An enormous shock wave rippled outward, reaching the star's surface in two microseconds to spew the star's laboriously made elements into space in a mammoth explosion. The mass of Sanduleak-69∞202's core was less than 1.4 solar masses, and it will probably survive as a neutron star. But if its mass had been greater than this critical value, it would have continued to collapse, and its ultimate fate would be a challenge to the imagination—a bizarre object of infinitesimal size and nearly infinite density, with a gravitational field so intense that light itself cannot escape—a black hole.

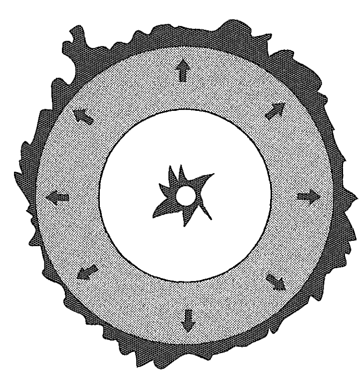
"This was the first recorded incidence of a known star going supernova."

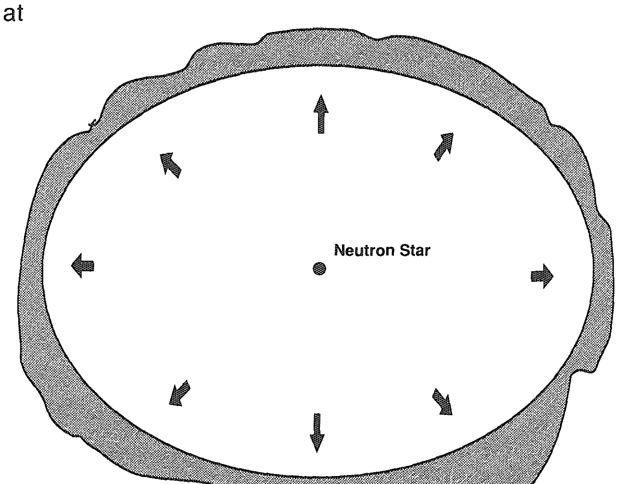
Under the Scope

Supernova SN1987A, visible only in the southern hemisphere, was observed by telescopes of every size in South America, Australia, and South Africa. The Voyager 2 spacecraft, en route to Neptune, pointed ultra-violet light detectors at the supernova. Japan's Ginga satellite searched for x-rays. Readings were also taken by the Solar Max satellite and the International Ultraviolet Explorer satellites, as well as NASA's C-141 Kieper Airborne Observatory, flying a telescope at 41,000 feet. The supernova was studied at virtually every wavelength of the elec-



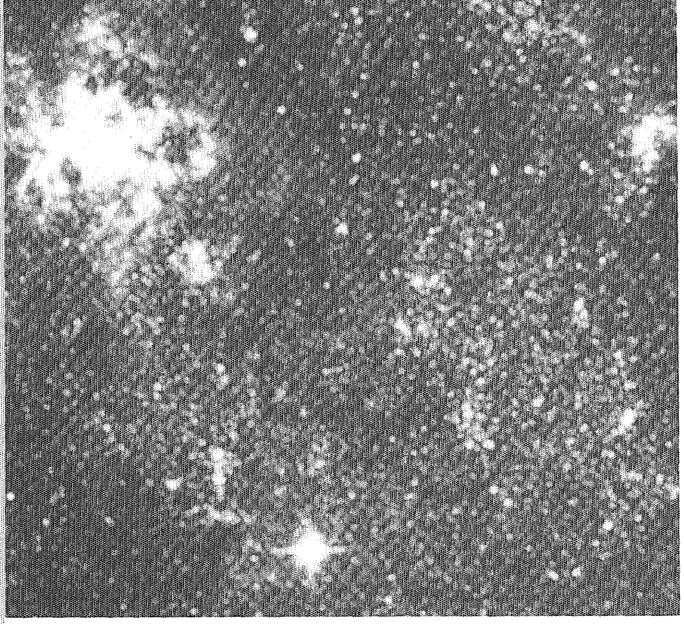






A Type II supernova, such as SN1987A, goes through several phases in its transformation from a large star to a stellar explosion. Initially, at left, the star's gravity and intense thermonuclear force were in equilibrium and the star was stable. When most of the star's fuel was consumed, the core collapsed. The collapse triggered a nuclear explosion, which blasted 99% of its energy away as neutrinos. The remnants formed an expanding cloud of stellar matter with a neutron star (or possibly a black hole) at the center. (Illustration idea from *Time* magazine) **On the opposite page,** Supernova SN 1987A shines brightly in the sky of the southern hemishpere.

ILLUSTRATIONS BY LEE KLANCHER



tromagnetic spectrum: radio frequencies, infrared, visible light, ultraviolet, x-rays, and gamma rays.

Astronomers determined that the star's atmosphere had exploded outward at a speed of about 10,000 miles per second (36 million miles per hour). In one day the ejected layers hurtled 2.87 billion kilometers, a span equal to the distance Uranus is from the sun. After the initial neutrino burst, most of the energy emitted by the supernova in the first year came out in the form of visible light, spreading a feast for optical telescopes in the Southern Hemisphere. Perhaps most spectacular of all was the detection of a burst of neutrinos from the collapse of the core of the progenitor star. At the IMB (Irvine-Michigan-Brookhaven) detector in Ohio, the arrival of 8 neutrinos was recorded among 7000 tons of ultrapure water in a deep salt mine. At essentially the same time, in a zinc mine near Kamiokande, Japan, a similar detector received 11 neutrinos. The number of neutrinos received, the duration of the neutrino pulse, and the energy of the neutrinos spectacularly confirmed theoretical predictions about neutrino outbursts from a supernova. It is not yet possible to see if SN1987A has left behind a neutron star; detritus from the explosion still obscures its center. Future observations will center on the search for a small, hot neutron star and measurement of the chemical content of the exploded star. NASA's Hubble Space Telescope [see *Technolog*, February/March 1990], launched in late April, will provide unparalleled imaging ability of the supernova, and eventually NASA's AXAF (Advanced X-ray Astrophysics Facility) satellite will permit x-ray analysis of SN1987A's hot gas and aid the detection of a neutron star.

"In one day the ejected layers hurtled 2.87 billion kilometers, a span equal to the distance Uranus is from the sun."

It has been suggested that a supernova occurring within a hundred light years of the solar system might emit enough cosmic rays to kill or sterilize a high proportion of Earth's animal life. However, no evidence exists that a supernova has ever flared close enough to Earth to destroy life. As astronomers survey the nearest stars, they see no apparent local candidates for an imminent supernova, but one long-term possibility is Betelguese. Betelgeuse is the red supergiant clearly visible at the shoulder of the constellation Orion, the Hunter. That monstrous star (300 times the diameter of the sun!) is 650 light years away, too far away to harm the Earth, but should provide a spectacular show if and when it expires. ☐

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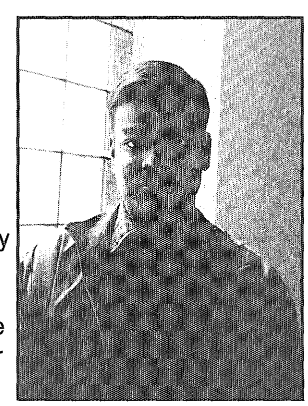
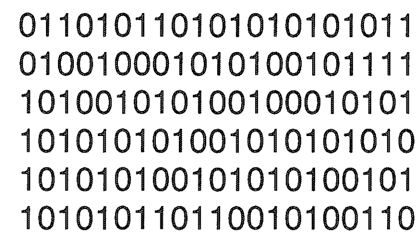
minnesota **TECHNOLOG**

Writer Profile: Joy Samad



Joy is a sophomore majoring in math. Besides being an astronomy buff and Carl Sagan fan, Joy fancies himself an above-average chess player. Hoping no chess computer program ever gets good enough to beat the best human players, he notes that computers have not yet learned finger drumming, snickering, pacing, and other uniquely human intimidation strategies.

Software Apocalypse



by Darin Warling

Will viral vandals make your computer byte the dust? Who knows what evil algorithm lurks in the heart of your computer.

So there I was, knee-deep in a world of, to use a presidential euphemism, doo-doo. It was 4:00 AM, scant hours before winter quarter would begin, and I had just become our lab's new Mac administrator. The previous administrator had spent the last six hours trying to explain everything I was going to need to know, and then left to fly home to India. To top it all off, the lab was in shambles; nearly every Mac had crashed over Christmas break. There had been problems with printing, problems with the lab server, problems with the hard drives, and I was an undergrad with one quarter of 68000 assembly language programming and some word-processing experience under my belt. In other words, I was wholly unqualified to handle the situation.

To make a long, painful story short, it took five days to discover that the lab was housing a brand new bouncing baby virus, WDEF. It had turned up in Belgium two weeks previously and was first spotted this side of the Atlantic less than a week later. It took eight days to get the lab back up and running, and during the three weeks following its introduction the virus managed to infect nearly every floppy in the lab—this meant we were going to have a problem with re-infection. At some

ILLUSTRATIONS BY JOYCE RAJENDREN

point during those three weeks I managed to infect the *Technolog*'s Mac and the virus screwed up its fonts. This is not a good thing to inflict on a magazine. I also sent floppies, all undoubtedly containing the WDEF virus, to three major corporations during that time span,

The damage? Two hard drives crashed and burned, sunk with all data aboard, their stored information never to be seen again. The grad students using those drives as permanent storage were the biggest losers on that deal. For my part, I spent nearly 125 hours getting the drives up and running, cleaning out the virus, and repairing the damage. This damage estimate does not include any losses caused by my shipping infected floppies out to other parts of the country. I can only assume similar amounts of time and money were spent at those locations, and any other location that might have been infected beyond that point.

"An example of a Trojan Horse is the Mac "Sexy Ladies" hypercard stack which quietly erases your hard drive while you view the cheesecake images."

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This little anecdote provides only the smallest inkling of a virus' destructive ability. We were lucky that WDEF was benign—it had no intention of doing any damage. It simply got in the way of normal systems operations. Others have not been so lucky. Witness FUTURE.BAS, an IBM program that begins with a nice color picture and a message informing you that you should be using your computer for higher pursuits than games and graphics. It then drives its point home by erasing drives A, B, C, D and so on until all your data has been jettisoned. Or consider the IBM Christmas Tree, a program that spread copies of itself through IBM's internal network and displayed a Christmas tree on the screen. It was so prolific that it had completely clogged the network with an exponentially-growing number of copies of itself before the entire network system was finally shut off and every copy of the program carefully hunted down and killed. Another example occurred at Hebrew University in Israel where a program quietly spread itself through personal computers. Its mission was to wake up on Friday, May 13, 1988—Israel's Independence Day—and erase every file on every disk it had infected. Fortunately, most copies of the program were discovered and killed before they could do extensive damage.

The aforementioned examples are all destructive programs, but they aren't all true viruses. FUTURE.BAS is an example of a "trojan horse," a complete, self-contained program that quietly waits to be run, at which point it inflicts the damage it's planning to do. Trojan horses are unable to replicate themselves and can only be spread by manually copying the program from one disk to another. Trojan horses were christened as such because they often look like some other harmless application. Another trojan horse is the Macintosh "Sexy Ladies" Hypercard stack, which quietly erases your hard drive while you view the cheesecake images.

The IBM Christmas Tree is an example of a "worm," a self-contained program that can reproduce itself and is usually programmed to automatically pursue an independent existence (see sidebar, p. 17). Worms do not attach themselves to other programs, while a true virus, such as the Israeli one, will attach itself to the code of a host program and ride piggyback until the host is run, at which point the virus temporarily seizes control of the computer, spreads itself, and does whatever damage it's programmed to do.

Science Infection

Trojan Horses, worms, and viruses each had their roots in science fiction. The term "virus" originated in David Gerrold's 1972 book, *When Harlie Was One*. A computer program, called "Virus," randomly dialed telephone numbers until it found a computer; when it found one, it spread to that system and began dialing more numbers. The worm concept was envisioned by John Brunner in his 1975 book titled *The Shockwave Rider*, in which a "tapeworm" ran loose through a computer network, gobbling up computer memory in order to replicate itself. "It can't be killed," one character said in exasperation. "It's indefinitely self-perpetuating so long as the network exists."

Fiction sometimes has a way of becoming reality, and soon after these books appeared the first real-life viruses were developed. However, early viruses were created for a legitimate purpose: to trace the spread

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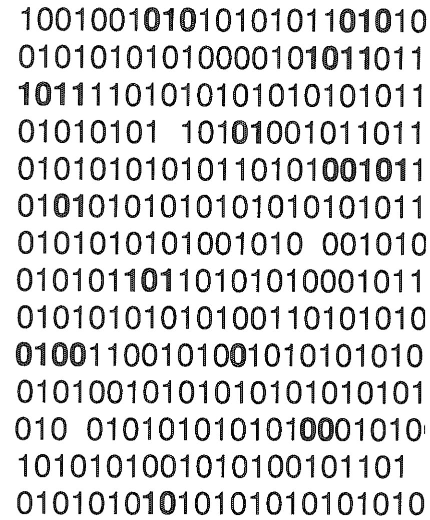
of illegally copied programs. They never showed their presence and simply tracked their parentage. Those who knew how to read their data used them to trace out the program's route of piracy. Then, in 1980, John Shoch at the Xerox Palo Alto research center created a real-life program that wriggled through large computer systems looking for idle machines, harnessing them to help solve large, computationally-intensive problems. Not until the mid-1980s did anti-social viruses begin to bloom.

In January 1986 the first destructive computer virus was unleashed on the general public. It ran on IBM PCs and was created by two Pakistani brothers as a simple experiment. Called the "Pakistani Brain," due to the copyright notice "@ BRAIN" it left on infected diskettes, it quickly spread to floppy boot sectors and accidentally crashed a large number of systems. Viruses rapidly progressed to the Macintosh and other personal computers. In the first seven months of 1988 alone, just after the viral ball really got rolling, there were over 300 major attacks recorded, affecting over 50,000 computers. Since then, the number of viruses on all types of computers has continued to increase. At last count there were 61 known IBM viruses and eight Macintosh viruses, with new ones continuing to roll in monthly.

Virus Busters
An intriguing challenge to computer security, viruses inspired research even before they turned mean. During 1983 and 1984, Fred Cohen, a 28-year-old grad student at the University of Cincinnati, ran a series of viral experiments that showed it's possible to write a computer program that can infect every part of a computer system in a matter of hours, or even minutes. Cohen took a computer security course and then set out to determine whether viruses could actually harm a computer system. The University of Southern California gave him permission to try his virus on a VAX running the Unix operating system. In five trial runs, the virus never took more than one hour to penetrate the entire system—the shortest time to full infection a mere five minutes. In fact, the experiment was so successful that University administrators refused to allow Cohen to continue his research. So he moved to a privately-owned Univac 1108 running a unique operating system designed especially for military security. Even this failed to prevent his virus from spreading through the entire system. Cohen's resulting thesis showed it was possible to infect any type of computer and that virus prevention is a fundamentally unsolvable problem.

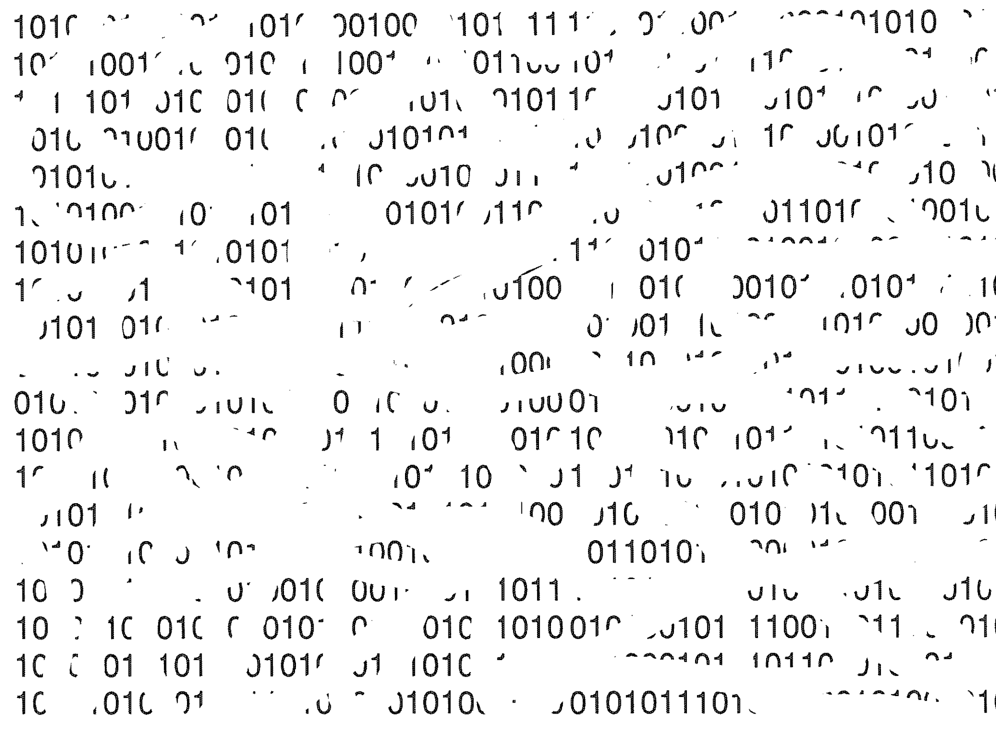


It remains fundamentally unsolvable because—in theory—hackers have all the advantages. The programming needed to create a virus is not particularly difficult; according to one source, any second-year computer science student should be able to write a fairly damaging piece of code after a detailed study of the computer's operating system. Viruses are generally small, often only a few hundred bytes in length, and therefore difficult to detect among hundreds of thousands of lines of code. Each new infection helps spread the virus further, and they often lie dormant, quietly replicating for a period of time before attacking. Finally, the people who create anti-virus weapons are always working from a defensive position. The destruction of and vaccination against a new virus is usually a seat-of-the-pants affair, a reaction to the virus rather than a preemption of its attack. And just as quickly as anti-viral research progresses, new, even more sophisticated viruses rear their ugly heads.

"The programming needed to create a virus is not particularly difficult; according to one source, any second-year computer science student should be able to write a fairly damaging piece of code."

The technopaths who write viruses appear to hold all the cards; fortunately for the rest of society, these hackers tend to be rather careless and frequently lazy. For example, there are over 13 variations on the most common Macintosh virus, nVir, due largely to the publication of the program's source code. Hackers, as a rule, find it more convenient to alter someone else's code than devise an entirely new strategy for themselves. This makes the virus easy to detect, because all 13 versions share common warning signs, symptoms, and infection methods.

Even if the actual source code varies from system to system and virus to virus, they will still bear similarities. Every one



of the 61 IBM viruses attempts to write to at least one of three different areas: the boot sector, the COMMAND.COM file, or a .EXE file. If a background monitor tracks all write statements to these three areas, it's usually able to intercept the virus before it actually infects the system. On the Macintosh, nearly every known virus has attempted to modify resource files (except WDEF, which modifies the Mac's Desktop file). Hence, a background monitor designed to keep an eye on resource files should prevent infection.

Are You Doomed?

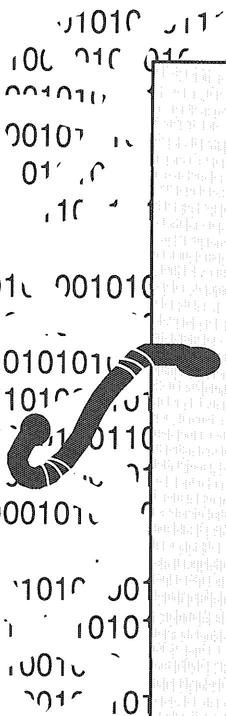
Unfortunately, prevention is not quite as easy as it sounds. Virus fighters will always lag one step behind the competition as each new generation of mutations becomes increasingly sophisticated, complex, and difficult to destroy. Future viruses will likely take greater pains to mimic their organic counterparts, making self-preservation and global infection top priorities rather than quick and dirty damage. This will make them increasingly dangerous, because the longer a virus lies dormant and the longer it has time to spread, the more devastating the damage will be when the kill command is finally triggered. As one source explained: The world population is about 5 billion; if there is only a one-in-a-billion chance of a person writing a virus, there are still five people on earth writing viruses. If the wrong person creates just the right virus, he or she could wreak havoc with modern society. It's simply a matter of time before that one hacker comes along who is sufficiently crazy to write a virus that ends up destroying the American financial network. Or a hospital's patient-monitoring system. Or the national air traffic control system.

"'The only truly secure system is one that is powered off, cast in a block of concrete and sealed in a lead-lined room with armed guards—and even then I have my doubts.'"

So what can you, a student, do in the face of this electronic bubonic plague? Unfortunately, not much. As Eugene Spafford, one of the programmers whose work was paramount in the quick destruction of the Internet Worm explains, "The only truly secure system is one that is powered off, cast in a block of concrete and sealed in a lead-lined room with armed guards—and even then I have my doubts." Unfortunately, universities are the perfect breeding grounds for viruses. Large numbers of users have easy access to a large number of computers, a situation ideal for carrying and spreading viruses. Universities also contain a great number of people possessing the technical expertise necessary to create and launch a virus. Lastly, college computers are often connected by large networks containing little security, through which a virus can quickly spread undetected.

One solution is to completely isolate your computer and load it with every piece of anti-viral software on which you can lay your grubby little hands. You could also build a brick wall around yourself without any windows to the outside world, but who wants to live like that? Your computer is the same way—it needs access to the outside world. Unfortunately, many systems administrators have pulled their computers off networks and limited access to only a few privileged individuals. Scared of losing their precious data, they hope to prevent attack by isolating themselves from any sort of computer contact. Faced with stories like this, one expert predicted that viruses may eventually do to computing what AIDS has done to sex.

Computing does not necessarily have to be this way. Common sense and simple precautions are the key. Accept the fact that viruses are going to work their way into your computer system. No matter how careful you are, they will eventually penetrate every piece of security you set up. Therefore, the best thing to do is prepare yourself for the worst. Keep backups of everything important. Watch for changes in your system's activity patterns. Make sure you know the origin of every disk you insert into your computer. Remember: When you are computing with a floppy, you are not computing with that floppy alone, you are computing with every CPU that floppy has ever come in contact with. To help maximize the safety of your system, see the



A Network at Risk

A self-replicating program wreaks havoc, ultimately bringing a national network to its knees.

The worm first struck on November 2, 1988 at 5:04 PM, 3 minutes after it was launched from Cornell University by Robert Morris, Jr. It then proceeded to run rampant through the nation-wide Internet computer network during the most infamous viral attack in history. Some called it heroic, others lambasted it as "a juvenile act that ignored the clear potential consequences." If nothing else it alerted the world to the potential of electronic disaster and drove home the vulnerability of networks.

The program was a "worm," a free-standing, independent program that duplicated and transmitted itself to any Sun 3 or VAX workstation on the network that was running variants of 4 BSD UNIX, one of the most universal operating systems in existence. It sent copies of itself to an estimated 6000 such computers around the country, through the network's electronic mail, exploiting several relatively well-known weaknesses in the system. The program consisted of two parts. The first part, the bootstrap, consisted of 99 lines of C code that were automatically compiled and run when received. Its purpose was to first check if the new system was already infected and then "roll" a 15-sided die to decide whether or not to reinfect the system. If it decided not to continue, it immediately exited and erased all traces of itself. On the other hand, if it did decide to continue, it pulled the second part of the program across the network to the new machine for a grand total of about 5000 lines of code. The sole purpose of these additional files was to search out and crack open new computers.

> **"The worm contained a number of flaws that may be evidence that it was not yet finished and accidentally escaped while still under development."**

However, the worm contained a number of flaws that quickly proved to be its undoing. This, along with several other factors, may be evidence that the worm was not yet finished and accidentally escaped while still under development. In other words, a little more refinement and some new routines could have turned this relatively benign worm into a malicious beast of unparalleled destructive power. Some have called this merely sloppy programming on the part of Morris. The greatest flaw in the worm was that the reinfection probability logic was accidentally reversed: instead of reinfecting a computer with a 1 in 15 chance, it reinfected each computer with a 14 in 15 chance. The reason this reinfection algorithm was written into the code at all was to improve the program's chances of survival in the event that anti-virus fighters managed to discover the method the worm used to signal whether or not a given computer was infected. If the method was discovered, programmers could insert this signal into every computer and mislead the worm into believing that it had already infected every available machine. This bit of extra code told the worm to ignore the signal one out of every fifteen times and reinfect the system anyway.

> **"It took nearly three weeks for Internet to resume normal operation and the total cost of cleaning up Morris' worm reached an estimated $100 million."**

Fortunately, Morris' programming error quickly caused the virus to multiply out of control and overload the network. Many machines began running a thousand times slower than normal, entire sets of computers were pulled off of the network, and the nation-wide electronic mail system was left in chaos. It took nearly three weeks for Internet to resume normal operation and the total cost of cleaning up Morris' worm reached an estimated $100 million.

[Editor's Note: Several days before ***Technolog*** *went to press, Robert J. Morris, Jr. was sentenced to 400 hours of community service, three years of probation, and a $10,000 fine. The prosecution had originally asked for a five-year prison term and a $250,000 fine.]*

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accompanying *Mac Doctor's Guide to Safe Computing.* Clip it out and post it by your computer. Photocopy it. Hand it out to family and friends. ***Remember: Spread the word, not the viruses!*** ☐

"One expert predicted that computer viruses may eventually do to computing what AIDS has done to sex."

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minnesota TECHNOLOG

Writer Profile: Darin Warling

Darin is a senior double-majoring in ME and computer science. A man without heroes, he wanders the hallowed halls of academia searching for truth, babes, and a painless way to register for CSci courses. Just for laughs, he's currently trying to write a virus that propagates itself by attaching to virus-protection programs.

The Mac Doctor's Guide to Safe Computing

No system is safe; this is the cardinal rule of safe computing. Prepare yourself for the worst and assume it will happen. Take a few simple precautions that will reduce your chances of infection, as well as allow you to restore your system when an attack inevitably occurs. These recommendations may seem like a paranoid hassle, but they're nothing compared to losing several months of work.

1. Keep original programs on locked floppies and immediately copy them to brand-new disks. While this is good practice in any situation, it is especially prudent when dealing with viruses. By "locking" the originals, nothing can be written to them, and when a virus does finally hit, the damaged software can be replaced by a guaranteed clean copy (but take this guarantee with a grain of salt—there has been at least one instance in which a major software distributor accidentally distributed copies of its programs with a virus attached to it.)

> **"Become familiar with your system's normal behavior and carefully monitor it for changes in those patterns."**

2. Back up anything important. Develop the habit of religiously making a backup as soon as a major revision is completed. The more often your information is updated and the greater the number of duplicates, the better. Not only will this ward off a complete viral apocalypse, but it will also protect you from head crashes, stray magnetic fields, static electricity, and other such calamities.

3. Become familiar with your system's normal behavior. Carefully monitor your system for changes in those patterns. Do you have problems printing? Are disk accesses occurring when there seems to be no good reason for a disk access? Does your system crash frequently, or for no apparent reason? Do files seem to grow larger overnight? Are all the files on your hard drive suddenly missing one day? If so, you have good reason to suspect a virus or some other electronic saboteur.

4. Purchase at least one good piece of anti-viral software and use it religiously. While this far from guarantees protection, it will help thwart many known malignancies. Anti-viral software usually fails against unknown enemies, but it does provide some measure of protection against those it can identify and disable. There are hundreds of protection programs out there and snake-oil salesmen abound, so research a piece of software before shelling out a load of money. I've placed our Macs in the trust of two programs. The first is SAM, a memory-resident application by Symantics Software that automatically monitors all suspicious activity and disinfects any disk inserted into the computer's floppy drive(s). The second program is Disinfectant, a freebie application that can be found at the Micro Center in 105 Shepard Labs. It's not memory-resident, but when run, it effectively removes all known Macintosh viruses and any variations. For the IBM, use either the program CleanUp or more rarely, MDISK. When you discover a virus, the best solution is to reformat the diskette and reload anything from the backups you have made.

5. Before placing any borrowed, pirated, or public domain software onto a network or into your system, run it for an extended period on an isolated system—preferably belonging to someone you don't like. Public software is always a risky proposition because it's the most likely to harbor unwanted guests. Avoid using public software whenever possible.

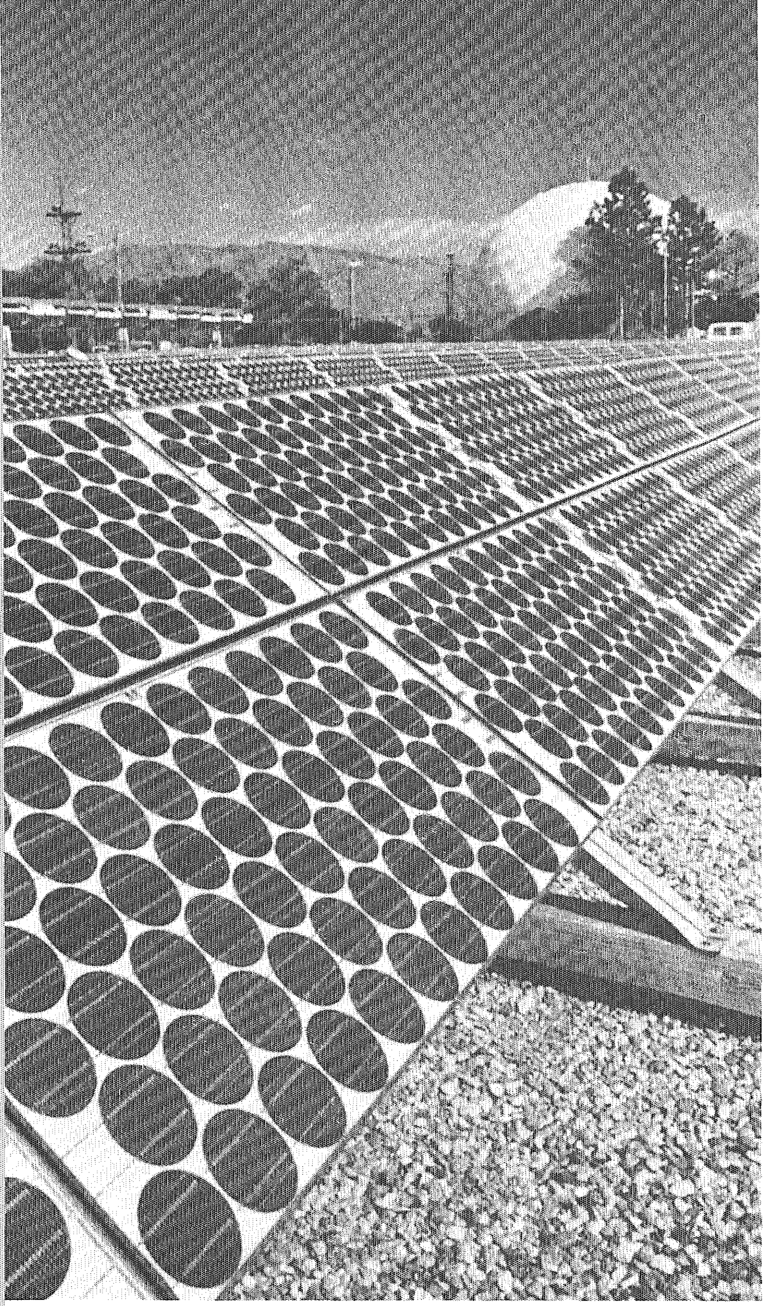
> **"Users of public systems must be especially careful to prevent infection because you not only open yourself to potential catastrophe, but others as well."**

6. When working on a publicly-accessible system, clear its memory of any viruses left by previous users by rebooting it. No virus can survive this unless it has attached itself directly to the operating system. Users of public systems must be especially careful to prevent infection because you not only open yourself to potential catastrophe, but others as well.

7. Lock all floppies you don't plan to write to and remove them from the drive whenever they're not being referenced. The less you expose them to the operating system, the less chance of them becoming infected.

8. Faithfully use the little plastic diskette condoms that can be found on most new 3.5" floppies (do not, however, insert the disk into the drive while the condom is in place). Diskette condoms won't prevent viruses, but they are the butt of great jokes and they'll keep out dirt and moisture.

CLIP OUT AND SAVE



Plugging into the Sun

by Tom Saefke

Photovoltaic (PV) cells were originally developed for use in satellites and remote places where conventional power sources were impractical.

The energy crisis of 1973-74, however, shifted the emphasis to development of PV systems as large-scale alternative energy sources. When the crisis abated, the demand for alternative energy sources also waned, but the recent resurgence of environmentalism has provided another big push for cleaner and safer forms of energy.

Sun plus semiconductors equals electricity. Solving problems with efficiency will brighten the prospects of photovoltaic technology.

Though satellites and remote locations continue to use PV systems, they are also finding their way into homes, schools, and airports as a supplement to power provided by public utilities.

Putting Light to Work

The essence of any system used to generate electricity is some means of separating positive and negative charges such that they can develop a voltage, sustain a current, and perform useful work. A generator uses mechanical energy to accomplish the separation of negative and positive charges. Batteries use the energy provided by a chemical reaction. A PV cell uses energy provided by light to cause the separation.

A photovoltaic cell is a semiconductor-based technology. Compared to its computer chip cousin, a PV cell is quite simple, essentially nothing more than a single large diode (compared to the thousands of small diode junctions on a computer chip). Basically, a photovoltaic cell is two types of semiconductors sandwiched together. One of the semiconductors, called "n-type," has many mobile negatively-charged electrons available to conduct electricity. The other type of semiconductor, called "p-type," has many mobile positively-charged "holes" (the positive counterpart of an electron). Either type of material can be made from silicon (or any other semiconductor) by adding such special impurity chemicals as boron or phosphorous. N- and p-type semiconductors possess no net charge; in other words, every mobile electron in an n-type semiconductor has an immobile positive ion canceling its charge.

When p- and n-type semiconductors are sandwiched together they form a very thin electric field at their interface (see Figure 1). When a light photon of sufficient energy (which is related to the photon's frequency and wavelength) strikes this interface, an electron is knocked loose from its bond in the silicon crystal, generating a free electron as well as a positively charged "hole" where the electron formerly resided. If it wasn't for the electric field at the interface, the electron would quickly return to the hole it had vacated, since opposite charges attract. However, the electric field serves to immediately separate the electron and hole, with the electron swept to the n-type material, and the hole swept to the p-type material. The

PHOTO FROM DEPARTMENT OF ENERGY AND SANDIA CORP separated hole and electron cannot recombine until they have gone through the path provided by an external circuit. Many incoming photons knock loose enough electron-hole pairs to provide useful current.

When no external circuit provides a current path, the voltage of a silicon PV cell in peak sunshine tops out at about 0.57 volts. Once current begins to flow, however, voltage drops. Peak power, which is the product of voltage and current, occurs when voltage reaches approximately 0.45 volts. Voltage remains fairly stable when light decreases, but current and power drop off. A typical silicon PV cell measures four inches in diameter and produces one watt of power with 10-15 percent efficiency at 77° F with 1.0 kWh/m^2 incident light.

The PV cell's low output can be increased by connecting several PV cells together.

"The recent resurgence of environmentalism has provided another big push for cleaner and safer forms of energy."

Connecting them in series will increase the voltage while connecting them in parallel increases the current. Individual cells are combined to form a panel. The panel protects the PV cell from the elements and provides a mounting platform. Older PV cells typically were circular, but more modern cells are usually rectangular, resulting in better use of panel space.

Most of the millions of photons passing through the PV cell make the journey unscathed, while others are absorbed by silicon atoms generating electron-hole pairs. Obviously, the output of a PV cell depends on the amount and intensity of sunlight striking it. The amount of sunlight that a location receives at any particular moment, (its "isolation") depends upon such factors as the earth's distance from the sun, time of the year, time of the day, climate, and shading. For example, the average annual isolation for Central Minnesota is about 44 percent less than that in parts of Africa , but about 50 percent greater than locations near the Arctic Circle .

Lenses called "concentrators" can further increase the quantity of photons entering a PV cell. Unfortunately, lenses must be perpendicular to their incident light, and therefore require mounting on some sort of drive system that will keep them pointed toward the sun. Though lenses can increase the overall efficiency of a PV system, they also increase the cost of the system.

Stacking the Deck

Because sunlight consists of the entire light spectrum, there are, correspondingly, different photovoltaic materials to meet the differing energy levels available. The point in the spectrum at which a material most efficiently utilizes the sun's energy is called the "band gap threshold," and is used to characterize a PV material (see Figure 2). Photons from the part of the spectrum below a material's band gap threshold pass through the material with little or no effect. Those photons above the threshold provide excess energy that is absorbed by the material in the form of heat. Those photons from the part of the spectrum nearly equal to the band gap threshold are absorbed by the atoms in the form of electron-freeing energy.

"Compared to its computer chip cousin, a PV cell is quite simple, essentially nothing more than a single large diode."

In the quest to create more efficient PV cells, the differing band gap thresholds of assorted PV materials are exploited by "stacking" them together. Essentially, a material that works best at one wavelength is stacked on one that works best at a different wavelength (see Figure 3). An example that shows much promise is thin cell silicon, which absorbs light from the blue end of the spectrum, combined with copper indium, which absorbs light from the red end. A one square inch tandem cell of this combination produces current at 15.6 percent efficiency.

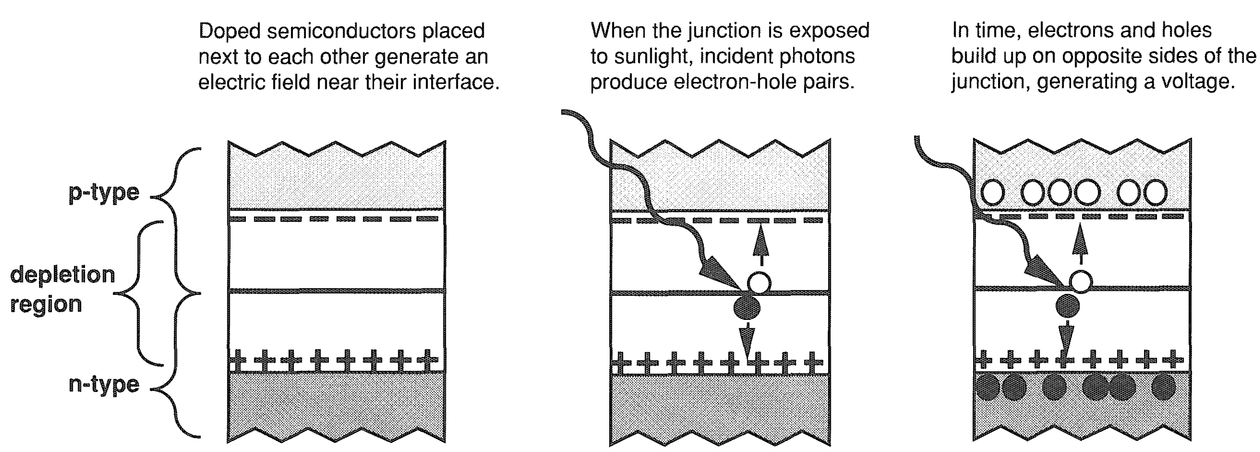
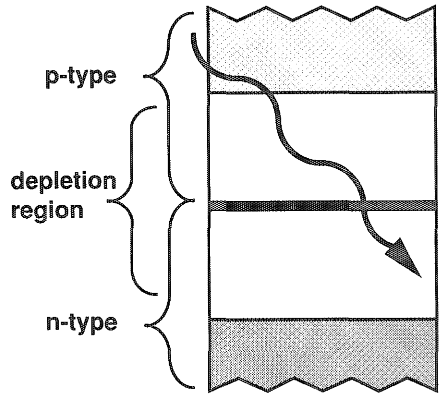
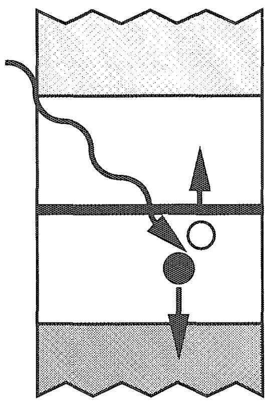


Figure 1. How a photovoltaic cell works. Black circles represent electrons, white circles represent holes. The electric field at the interface of the doped semiconductors sweeps freed electrons and holes apart, thus developing a voltage.

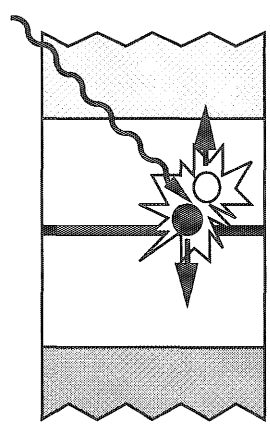
ILLUSTRATIONS BY BRIAN NEURAUTER



Low-energy photons pass through the semiconductors unaffected, lacking enough energy to knock electron-hole pairs loose.



Medium-energy photons can liberate electrons, although many pass through unaffected.



High-energy photons liberate electrons, and generate excess heat as well, which is undesirable since it lowers efficiency.

Figure 2. Depending on its energy, a photon may either travel through a semiconductor junction unscathed, or be absorbed, which frees electrons and generates a useful voltage.

Stacking achieved a milestone when the 30 percent efficiency mark was surpassed by a research team using a PV system of silicon and gallium arsenide. More recently, Steve Rubin from the Solar Energy Research Institute (SERI) reported that researchers at SERI had passed the 37 percent efficiency mark using gallium arsenide for the blue spectrum and gallium antimonide for the red spectrum.

Methods and Materials

The earliest PV cells were made from a single large silicon crystal, hence their characteristic round shape. Producing cells from the crystals is a very expensive process because much of it is done by hand and also because of the great waste of material which occurs. Nevertheless, single large crystals produce the most efficient PV cells because their structure absorbs photons more readily.

A less expensive method involves pulling a long ingot out of a molten solution of silicon and allowing it to cool slowly so that large crystals form. However, the resulting polycrystalline structure works less efficiently than a single large crystal because the borders of the individual cells cause small shorts. Slower cooling, and the resultant larger cells, can lessen this effect to some degree.

Another manufacturing process converts the PV material into a gas, then deposits it onto an inexpensive backing such as glass. This process, called thin-film deposition, produces a PV cell with an amorphous structure. It requires less material to make a wafer than the other two methods, and much of the process can be automated. Thin films also allow the use of a greater variety of materials, some less expensive. Because they lack an orderly structure, amorphous materials absorb photons less efficiently then single crystal or polycrystalline cells. However, because of lower costs, 40 percent of the PV cells produced in 1988 used amorphous silicon. Refinement continues to increase the output efficiency of thin film PVs, raising it from 1 percent when first introduced to about 10 percent today.

Though crystal silicon cells have dominated the PV industry for better than 20 years, research into other materials is occurring as well. One particularly promising example is copper indium diselenide

"Acceptance of this technology will require much greater efficiency at a reasonable cost."

(CIS). A one square foot panel of CIS achieved an efficiency of 11.1 percent, the highest efficiency yet recorded for a surface of that size. Other advantages CIS possesses are a large band gap window and relatively reasonable cost. CIS is also less susceptible to the "Staebler-Wionski" effect. This effect causes silicon's efficiency to decrease 10-15 percent when exposed to light because much of the source light is converted into heat. As the PV cell's temperature rises, the voltage and power output of the cell drops. In this respect Minnesota has an advantage over somewhere like Arizona. While PV cells in Arizona receive more sunlight, they also heat-up more, lowering efficiency.

Cost vs. Efficiency

Even under ideal conditions today's PV cells are inefficient. Typical commercial units convert a mere 10-15 percent of available light into electricity. Acceptance of this technology will require much greater efficiency at a reasonable cost. Steve Rubin of SERI says that recent laboratory experiments have yielded efficiencies of 37 percent, but noted that these results were achieved with materials whose costs keep them out of the commercial realm. Cost is one of the reasons that silicon remains so popular as a PV material. For commercial purposes it's often cheaper to put together a system of many inefficient but substantially cheaper PV cells. The trade-off in doing this is such additional costs as space, increased installation labor, connecting hardware, and so forth.

A Bright Future?

Because of the damage fossil fuels have dealt our environment, many see the need for alternative sources of power. Photovoltaic technology has long been a leading contender. However, it must reach the point where it can commercially compete with traditional forms of energy. The key is efficiency.

Today solar power costs four to five times more than conventional sources of power. But as researchers develop more efficient cells at lower costs, the future of sun power shines that much brighter. ☐

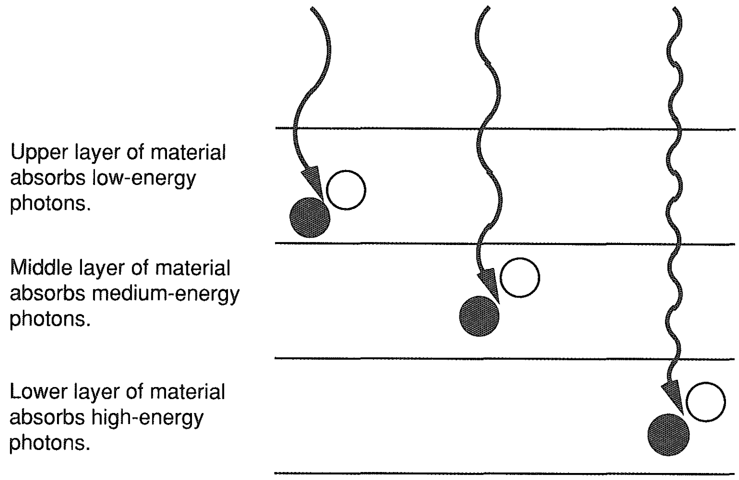


Figure 3. Sandwiching differing semiconductors takes advantage of a larger percentage of the sun's spectrum due to each layer's ability to absorb photons with different energies. For example, a high-energy photon that doesn't get absorbed in the upper layer may still liberate an electron in the lower materials.

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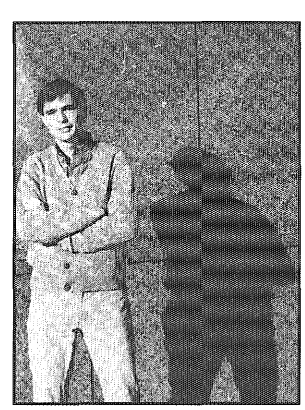
minnesota TECHNOLOG

Writer Profile: Tom Saefke

Tom is a senior majoring in scientific and technical communication. Considering graduate school out of the question, he hopes to work in public relations in an organization that deals with health or environmental issues. Not limited to PR or technical topics, Tom also enjoys writing songs, poetry, and fiction.



Ten for the Technolog

by Gern Blanston
Staff Reporter

The official *Technolog* delegation recently ventured to the East (Cornell University in Ithaca, New York) for the annual ECMA convention.

The convention is traditionally a gala event and the delegation returned laden with cheesy souvenirs, severe indigestion, and ten ECMA awards.

One award noticeably missing from this plethora was first place in the "Best Overall Magazine" category, a category in which the *Technolog* received second place. The first place honors for "Best Overall Magazine," went to (hockey fans DO NOT read on) UW-Madison's *Wisconsin Engineer*.

The *Technolog* did, however, have the distinction of the largest number of awards, receiving awards in ten of the fourteen categories.

First Place
Best Art/Photography (*all issues*)
Best Pure Technical Article
for Technology Background

Second Place
Best All-Around Magazine
Best Art/Photography (*single issue*)
Best Layout (*all issues*)
Best Non-Technical Article

Third Place
Most Entertaining Feature
Best Single Issue

Honorable Mention
Best Continuous Feature

The 1989-90 Room 2 Gang. Back row, left to right: Rochelle DuFresne, Jackie Duley, Jim Willenbring, Steve Subera, Lisa Udland, Grant Ovsak, Brian Neurauter, Jonathon Wong, Joyce Rajendren. Front row, left to right: David Andreasen, Zack Miller, Loren Thomsen, Steve Hong.

Current Editor Joins Navy, Office Safe Once Again:

New Writers, Editors, Illustrators Welcome

by Steve Stonebreaker
Staff Reporter

Our lord and master has departed and the masses are flocking to the *Technolog* office like lemmings to the sea. We are now hiring next year's staff, and intend to further the tradition of excellence founded by Hugo Blanston in the Dark Ages.

So, if you want to be a part of an award-winning staff, stop by our office in Room 2, Mechanical Engineering to talk to next year's Editor, Lee Klancher.

Application Deadline: Friday, May 25, 1990

Caption Contest Results

Thanks to all who entered. Several of the original "Top Ten" winners were disqualified by the editor because he felt they did not "conform to the standards of a family magazine." However, those disqualified, and many other equally tasteless entries, were much enjoyed by the **Technolog** staff. Keep up the good work.

10. "Say, Stretch, all you need now is a personality." — Matthew Meyer, Business
9. K-Mart comes out with their new spring lineup. — Matthew Meyer, Business
8. "Hans Infante and his brother went their separate ways but a keen eye could still see they were twins by their hair." — James Kempf, ME
7. "Wait until Aunt Bertha gets a load of you." — Matthew Meyer, Business
6. "How would you like to be the new head of the computer science department?" — Ching-Yi Wang, EE
5. "Party at my place, 9 tonight." — George Atendido, ChemE
4. "Hi, Boss. I just wanted to let you know that I caught Fox trying to let the air out of the tires on your Harley." — Steve Meyer, ME
3. "...Nice disguise, David...I'm sorry this computer science thing has gotten so far out of hand..." — James Kempf, ME
2. "Maybe if we cut the rope Hasslemo will stop talking." — Greg Krantz, pre-engineering
1. "Tell ya what—you gimme a couple of those pizzas and a dozen cans of Mountain Dew and I'll forget I can hear that radio in my office." — Todd Constant, ME

The world's first recorded computer virus.

Lobsterrorists.

PHOTO BY PAULA ZOROMSKI