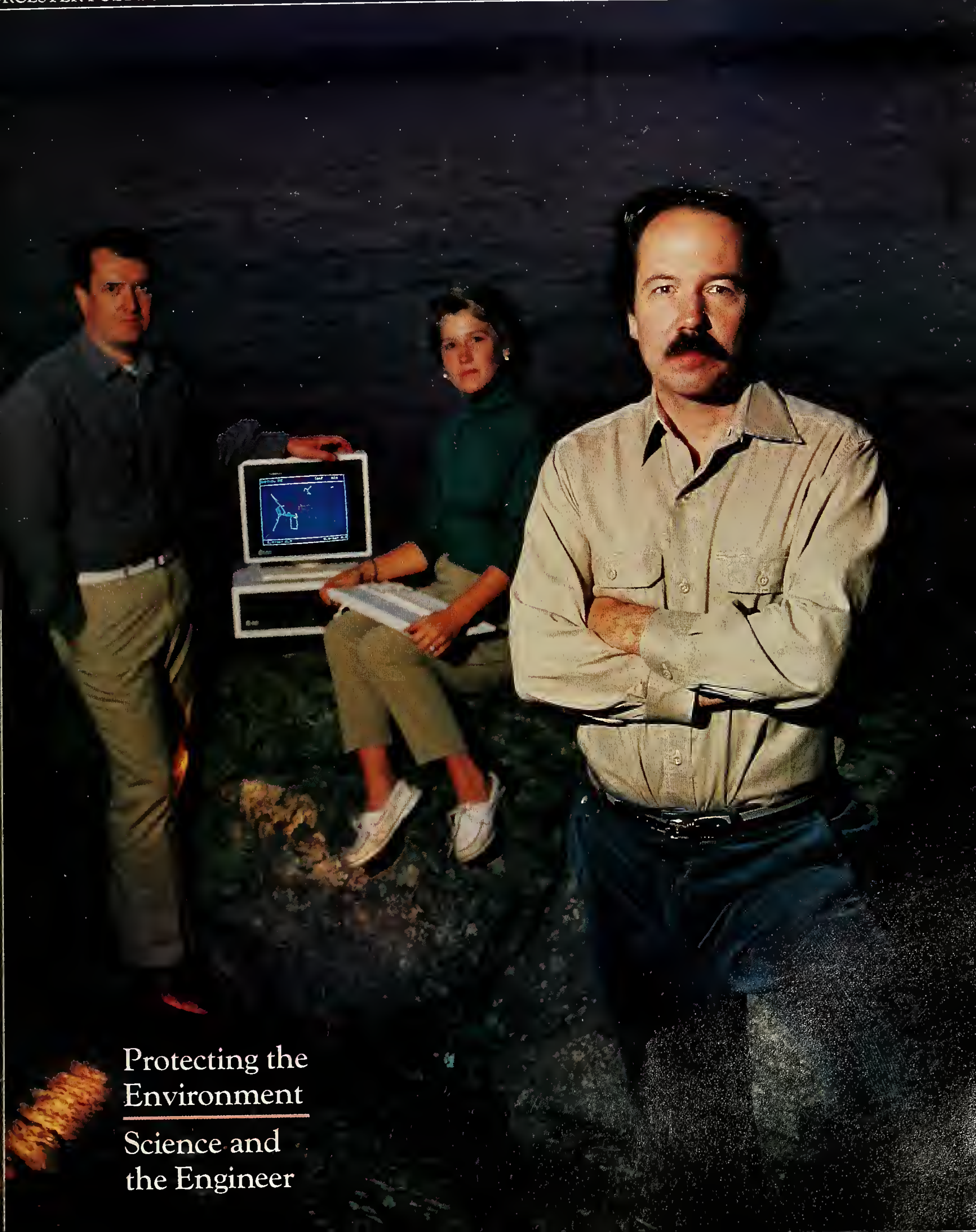
WPI Journal

WORCESTER POLYTECHNIC INSTITUTE

AUTUMN 1987



Protecting the Environment

Science and the Engineer

Brian J. Savilonis '72, associate
sor of mechanical engineering a
women's cross-country coach, w
out with his '87 recruits. Photo b
Michael Carroll.

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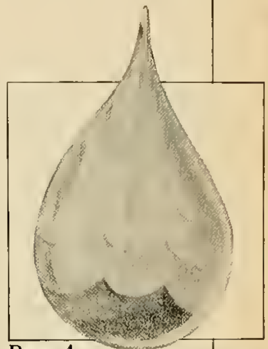
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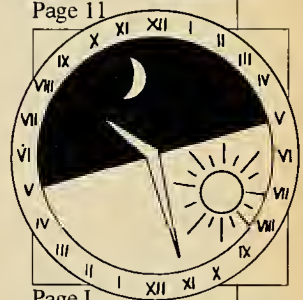
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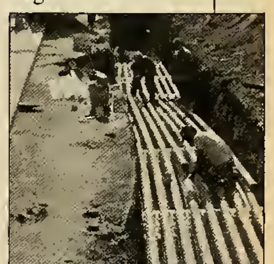
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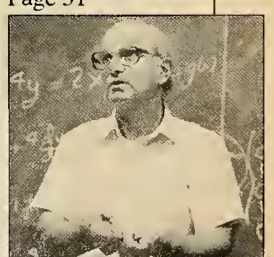
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Cover: Dr. Frederick Hart, associate professor of civil engineering (right) and graduate students Wayne Wheeler and Suzanne Lewis, standing on the shores of Wachusett Reservoir, work to meet environmental challenges through advanced technologies. Story on page 4. Photo by Michael Carroll.

Accreditation: Why All the Fuss?

By Dr. Richard H. Gallagher

One of the feature stories in this issue of the *WPI Journal* discusses the role of basic science courses in the education of engineers. Although the article amply justifies instruction in these courses, it notes at the outset that the accrediting agency for WPI's engineering programs, the Accreditation Board for Engineering and Technology (ABET), has insisted on the presence of these courses in the curriculum.

Just who is ABET? you may wonder. What other conditions do they place upon programs seeking their imprimatur? How do they go about measuring institutional compliance with their criteria? In view of the fact that WPI is being visited by a team from ABET in 1987-88, it seems appropriate to discuss these and other related questions.

ABET was created some 55 years ago by action of the major engineering societies operating under the umbrella of the Engineers' Joint Council, with the support and encouragement of the engineering education community. It was known then as the Engineers' Council for Professional Development, but it has since changed its name to its current, more descriptive appellation. The term "technology" stems from the fact that ABET also serves to accredit institutions that offer programs leading to the bachelor of technology degree, which is more oriented toward "hands on" practice than the baccalaureate degree.

It is important to observe that ABET accredits *programs*, rather than institutions, and that accreditation, once it has been awarded, has a specified, limited life—generally three or six years. WPI might wish to refer to itself as being accredited in engineering because *all* of the programs for which it has sought accreditation are successful in that respect. However, in accordance with ABET policies, WPI must refer specifically to each program that is accredited. If one such program were to be denied accreditation, however, it would no longer be accurate for WPI to describe itself as "ABET accredited."

Michael Carroll

The engineering accreditation process has been a strong factor in building the stature of U.S. education in the profession.

When an institution's accreditation is up for renewal, an ABET visiting team pays a two-day visit to the campus. The team consists of a chairman and one visitor for each program, and occasionally visitors-in-training, as well as observers assigned by such organizations as the state professional engineering society and the state board of technical registration. A team of 15 or more in not uncommon at large universities. For WPI, with four programs (chemical, civil, electrical and mechanical engineering) seven to ten individuals might constitute the team.

When only one program is scheduled for a visit, the team might consist of just two persons—the team chairman and the visitor to the program being reviewed. This reminds me of a story associated with the legendary American Indian athlete Jim Thorpe. Someone assigned by the organizers of a major track and field meet to greet visiting teams was surprised when just two persons from the Carlisle Indian School stepped off the train. He asked if there were only two people representing the school. Thorpe replied, no, there was just one: "My companion is the team manager." Thorpe went on to win most of the events.

ABET's criteria for accreditation are both general and specific to the program being reviewed; the latter originate with the relevant major technical societies, such as the American Society of Mechanical Engineers. Looking at the total four-year undergraduate experience as eight semesters, ABET requires one semester of mathematics, one semester of science, two semesters of engineering science, one semester of design, and a semester of humanities and social sciences. Fully three-quarters of the curriculum is affected!

In addition, there are detailed requirements, bearing upon computing, writing, and communication. Certain students carry special obligations, such as ROTC. This helps to explain why a curriculum

that would span more than four years is widely discussed, and why suggestions for the inclusion of other, seemingly appetizing course requirements Shouldn't they learn to speak Japanese and grapple with ledgers like a veteran CPA?) fail to elicit much enthusiasm.

A visiting team also takes a careful look at institutional budgets, salary scales, faculty biographies, advising mechanisms, placement services, computing facilities, and laboratories and classrooms, among other things. They visit the library and supporting academic departments such as the sciences, humanities, and social sciences. They study the textbook used, the homework assignments, the examinations and grading policies, and talk to the students, faculty, and administration.

My own policy, in a seven-year stint as visitor to civil engineering programs, included visiting classes and holding discussions with the students present. Although an institution might view a visit with apprehension—and there is certainly a great deal of background work to be done before the team arrives—the visit itself is truly a grueling experience for those who conduct it.

Visits occur in the fall semester. The report of the team members passes through many hands and committees within ABET, emerging officially in the following June or July. Along the way, the colleges being examined are permitted to review and respond to preliminary versions of the report. In recent years, the criteria have been stringently applied. Of almost 300 programs visited in 1985-86, only 28 percent were awarded the maximum (six-year) term of accreditation. This was down from a high of 58 percent eight years earlier.

On the other hand, many observers argue that these statistics indicate an erosion of the quality of engineering education in the past decade, brought about by faculty shortages, inadequate equipment, and the striking rise in undergraduate enrollment. The number of graduates of accredited engineering programs has more than doubled in the past ten years, to approximately 80,000 annually.

Others believe, to the contrary, that there has been an escalation in the rigor with which the criteria are applied—otherwise known as "bean counting." Today, more facets of the engineering educational process are being looked at, and higher standards are being set. Some observers feel that the menu of requirements exceeds that which is actually essential for a good education in engineering. There is concern that this trend has worked to the detriment of innovative curricula, such as the WPI Plan, or of even less venturesome efforts.

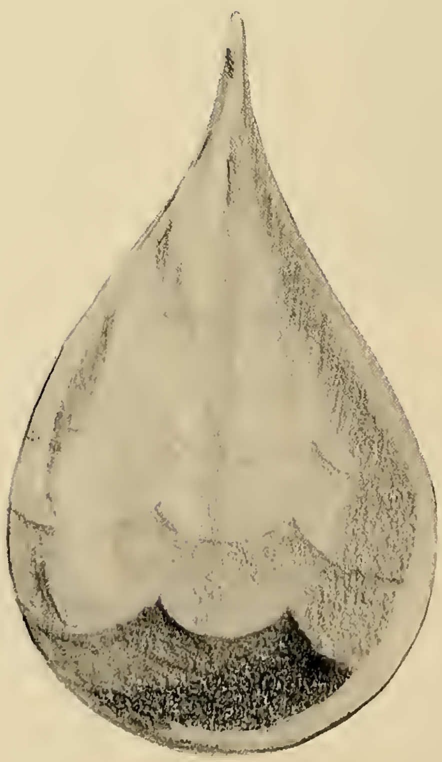
Pressure is growing for a more flexible interpretation of accreditation criteria, but at the same time there are standards to be set and met. If anything, the recent years have seen the expansion of diploma mills and commercial educational operations that seek to short-circuit the educational experience needed for a professional career.

In my view, the engineering accreditation process has been a strong factor in building the stature of U.S. education in the profession. It has been singled out for praise in a Carnegie Foundation study of such processes, which was otherwise critical of other disciplines, and it increasingly serves as a model for programs elsewhere in the world.

Richard H. Gallagher is provost and vice president for academic affairs.

But One Environment

Despite cutbacks in funding to protect the earth's environment, the need to safeguard our air, water, and soil has never been greater, as a growing number of WPI researchers are finding.



By Evelyn Herwitz
Photos by Michael Carroll

A long, cool drink after a workout, a steaming cup of coffee on a brisk morning, a base for soups and gravies, a bath for vegetables, a rinse for toothpaste—drinking water is so much a part of our daily lives that we barely notice it.

But the apparent simplicity of water belies the complex chemistry of its production and distribution, particularly for large populations. In a city like Worcester, which draws most of its drinking water from a series of 10 reservoirs in surrounding towns, the risk of bacterial contamination is an ever-present concern.

Like many public water supplies, Worcester uses chlorine as its only line of defense. But knowing how much chlorine to add, and when and where in the distribution system to add it, is a mixture of art and science. Too little chlorine increases public health risks from water-borne pathogens; too much chlorine can foment the creation of carcinogenic organic compounds, trihalomethanes (THMs). Factors include not just the volume of water to be treated, but also the age of the distribution network and the degree to which pipes are clogged by decades of tuberculation—black goo that interferes with the chlorination process.

Finding a way to help municipalities solve the chlorine dilemma has been a major concern of Frederick L. Hart, associate professor of civil engineering. Working with undergraduate and graduate students for the past two years, including John L. Meader '86 and Shih-Ming Chiang, Hart has developed a tool that he believes can enable public water supply operators to fine-tune their chlorination process.

Called CLNET, the computer model simulates the decay of chlorine throughout a given distribution system. The information enables the operator to know where to put secondary chlorinators and how much chemical to use in order to maintain proper chlorine residual levels throughout the system.

Divided into an input processor (designed by Susanne Lewis '87 and Steven Woodard '87 under the supervision of Grace Crooker Levergood), a simulator (coded by Chiang and Meader), and an output processor (coded by Margaret Blastien '87, James Connell '87, and Russell Houde '87), the user-friendly program helps operators to create a data file tailored to their systems. Parameters include flow rates, diameters, and length of pipes. Results from the initial simulation, he adds, are compared with field observations, and the data file calibrated to improve accuracy of future simulations. Output is displayed in colored graphs and tables to make the information easy to read and interpret.

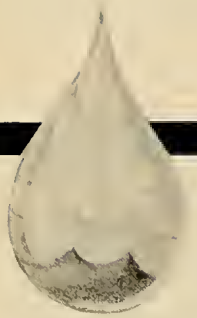
Requiring a 32-bit processor to handle all the data during the simulation, CLNET has been developed at a time when proposed federal regulations may tighten already tough standards on THMs. "A lot of water companies are having trouble maintaining the current standards," says Hart. "And the upcoming

to Protect—Forever

regulations are even more stringent. Municipalities will have an extra impetus to regulate chlorine use.

Hart is one of a handful of WPI faculty engaged in environmental research, an area that has experienced tremendous swings in funding support and student interest over the past two decades. Although the field is no longer as trendy as it was in the late 1960s, research into environmental problems is, at the same time, no less critical to world survival. And despite cutbacks in government-funded research, issues like hazardous waste disposal and groundwater contamination present some of the toughest and most important scientific and engineering challenges to be faced in contemporary life.

"Urban improvements are often made without thinking that water has to go someplace," says Dr. Malcolm S. FitzPatrick, shown here with two Major Qualifying Project students. An associate professor of urban and environmental planning, FitzPatrick describes urban planning and environmental planning as "two sides of the same coin."



Wetland protection and soil erosion control have been the focus of several student projects. Three students are laying the groundwork for an open space and recreation plan for the nearby town of Spencer. Of concern is the adequacy and location of the town's groundwater supply and drainage system. Another student project involves studying the impact of water contaminated by heavy metals on fish in the Nashua River.

Because the issues are so significant, Professor of Civil Engineering Kris Keshavan believes environmental research and the field of environmental engineering are beginning to experience renewed interest.

"Environmental concerns are coming back," asserts Keshavan, "but not at the fanatical, frenzied level of the late '60s and early '70s, which I think probably hurt efforts more than it helped."

Head of Civil Engineering from 1976 to 1986, Keshavan recalls the environmental movement's heyday as a period when "many articles were written and papers published without much understanding of the problems." It was also a time, he says, when "everyone wanted to be an environmental engineer." Department enrollment swelled to 120 students, making civil engineering the second largest department on campus.

But following the Vietnam War, the lure of lucrative high-tech jobs began to draw students in new directions. "Everyone drifted to electrical engineering, and our enrollments plummeted to a third of what we'd had before," says Keshavan. Though the energy crunch sparked some renewed interest in the field, he notes, the prospect of somewhat lower salaries compared with "higher tech" industry discouraged many students from pursuing a career in environmental engineering.

In a dynamic economy, however, things are bound to shift again. And Keshavan sees evidence that the pendulum has begun to swing back in his direction. "Jobs are going begging for graduates and salaries have increased," he observes. "Students getting into environmental engineering now are doing themselves a favor."

Once again pursuing his own research, Keshavan has turned his attention toward developing and perfecting innovative technologies for wastewater treatment.

Many modern municipal sewage treatment plants currently employ traditional sludge treatment processes such as sludge digestion, sludge dewatering, and incineration. Another sludge treatment process used in several cities is the Zimmerman process, which involves oxidizing wet sludge under high temperature and pressure. These well-developed technologies, Keshavan says, require significant energy levels and space. Their by-products include odor-causing compounds, which can make life unpleasant for those unfortunate enough to live down wind.

A new, alternative approach is the deep-shaft wet well oxidation process. As its name implies, this method of treating wastewater sludge involves drilling a foot-wide, mile-deep hole, which is then cased with stainless steel. When liquid sludge is pushed through the tube, the pressure at the bottom rises significantly. Once the oxidation process is started, Keshavan says, the temperature will remain high enough for the system to be essentially self-sustaining. Energy requirements are negligible, and this wet incineration process creates no air pollution.

"It's a very attractive system for locations like Deer Island [in Boston Harbor], where there is little space," says Keshavan.

Sewage treatment is also a research priority for Keshavan's successor, department head James C. O'Shaughnessy. Coming to WPI from Northeastern University's civil engineering department, O'Shaughnessy says he plans to involve undergraduate and graduate students in studies of advanced wastewater treatment processes.

"We'll be looking at ways to remove nitrogen from wastewater prior to its discharge into the groundwater. The methods we're investigating require few modifications or additions to wastewater treatment plants," says O'Shaughnessy, who also specializes in treatment methods for industrial wastewater and hazardous wastes.

O'Shaughnessy will be sharing this fall's project work with Fred Hart, who, in addition to developing CLNET, has involved students in another kind of wastewater research. Working with Kristin Nygard '87 on a project begun when Hart worked for a Wellesley engineering firm, he has calibrated a computer model of groundwater flows and pollutant transport beneath Barnstable, Mass., on Cape Cod.

The problem, in this case, stems from the fact that Barnstable, like many Cape communities, is experiencing rapid growth but uses its underground aquifer as its sole water supply source *and* as a wastewater disposal sink. Homes depend on septic systems for wastewater disposal, while the town operates a municipal secondary wastewater treatment facility which discharges about one million gallons of effluent directly into a sand bed. Though the sand acts as a natural filter, Hart says, the town has become concerned that increased municipal wastewater may cause a plume of nitrate contaminants to flow underground into the town's nearby wellfields.

To study the plume's movement, Hart and Nygard used a

"We'll be looking at ways to remove nitrogen from wastewater prior to its discharge into groundwater," says Dr. James C. O'Shaughnessy (left), head of the Civil Engineering Department, who plans to get students involved in studying advanced wastewater treatment processes. O'Shaughnessy and a student created a computer model of groundwater flow in a growing Cape Cod community that uses its underground aquifer as its water supply—and its waste disposal system. After finding that plumes of waste were drifting toward municipal wells, O'Shaughnessy recommended building sewers to limit the use of septic tanks.

three-dimensional, computer-generated contour map of the town's water table. Bumps in the contour map indicate the plume's location, while dimples show where wells are drawing groundwater.

Projections based on population growth and discharge data revealed that the plume is traveling toward the south and southeast, potentially affecting several municipal wells. Nygard notes that Barnstable's options include building sewers in the southern area of the town to limit the addition of septic tank wastes to the plume, and more extensive treatment of effluents.

That kind of interaction and conflict between economic development and the environment is one of Malcolm FitzPatrick's primary concerns. An associate professor of urban and environmental planning in the Civil Engineering Department, FitzPatrick describes urban planning and environmental planning as "two sides of the same coin."

To illustrate his point, FitzPatrick cites the problems that development creates for soil erosion, particularly in wetland areas. "Urban improvements are often made without thinking that water has to go someplace," he observes. "Subdivision developers cut down trees and build roads, while ignoring the fact that trees and other vegetation help to hold water and put it into the ground. As a result, you get increased flooding and erosion downstream."

Wetland protection and soil erosion control have been the focus of several student projects supervised by FitzPatrick. In one ongoing project, Mark Nelson '89, Valentino Tocci '89, and Mark Czerepuszko '89 are laying the groundwork for an open space and recreation plan for the nearby town of Spencer. Among the topics being researched are the location and adequacy of the town's groundwater supply and natural drainage system.

"The drainage system is the basis of forming an environmental plan," explains FitzPatrick. "By protecting that, you pro-

vide open space and protect the town's water resources."

Other student projects have included a study of the environmental impact of cluster subdivisions for the Nashua River Watershed Association (NRWA).

The NRWA also has benefited from student project work supervised by another environmentalist on the WPI faculty. Robert Wagner, professor of chemical engineering and a member of the Institute's faculty since 1949, has been an enthusiastic proponent and advisor for student projects dealing with the environment.

Officially retired from WPI last December, Wagner—known fondly to his students as "Daddy Wags"—remains on campus this fall to supervise the department's unit operations lab. An avid mountain climber who scaled his first peak at age 44, Wagner has linked his love of nature with his work, both through founding and guiding WPI's Outing Club and through a vast array of student projects.

For the NRWA, one of Wagner's frequent project clients, student research has ranged from developing a canoe guide to a study of tumors found in some of the river's fish.

The latter project, which Wagner co-advised with Daniel Gibson, assistant professor of biology and biotechnology, drew on the resources of state environmental officials as well as the Smithsonian Institution.

The research problem, explains Wagner, stemmed from a discovery of heavy metals in river sediments. "We were concerned as to whether the heavy metals were causing cancerous tumors in fish," he says. With the help of state fish and wildlife authorities, fish were procured from those sections of the Nashua where sediments were known to be most contaminated.

Examining tissue segments in the laboratory, students Eileen Brown, Neil Garnache, and Musfik Konuk found "many tumors" on the lips and livers of the fish. But the question remained as to whether the tumors were malignant. "The kids

Head of Civil Engineering from 1976 to 1986, Dr. Kris Keshavan (left) recalls the environmental movement's heyday as a period when "many articles were written and papers published without much understanding of problems." It was also a time, he says, when "everyone wanted to be an environmental engineer." But following the Vietnam War, the lure of lucrative high-tech jobs began to draw students in new directions. "Everyone drifted to electrical engineering, and our enrollments plummeted to a third of what we'd had before," says Keshavan. Today, the pendulum is swinging back.

Most conventional methods of sewage treatment involve high levels of energy, require a great deal of space, and create by-products that include odor-causing compounds. But a new technique, deep-shaft wet well oxidation, is self-sustaining and produces no air pollution. In the process, a foot-wide, mile-deep hole is lined with stainless steel. Liquid sludge is pushed through the tube, and the resulting pressure causes oxidation at the bottom.

got in touch with the Smithsonian," says Wagner. "They asked us to send the removed livers to determine if they were cancerous. So we sent sections of the worst ones down to Washington." The findings from the Smithsonian were, fortunately, less dire than expected: "None of the tumors were cancerous," says Wagner. "They were still caused by the heavy metals, but weren't cancerous."

Another recent project concerning fish also involved the Nashua River. A tributary of the Merrimack River, the Nashua not long ago was deemed too polluted to support Atlantic salmon. As a result, when federal game officials began restocking the Merrimack with salmon, they decided to avoid the Nashua altogether, a move which greatly frustrated NRWA members.

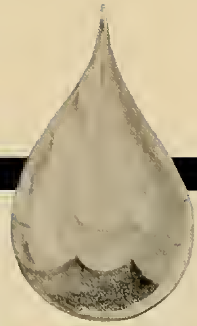
For help, they turned to Bob Wagner and WPI undergraduates David Kolstad and Gregory Tashjian. "First we went to most of the towns along the Nashua to gain evidence that in earlier years, Atlantic salmon ran the river," Wagner says. "But the latest reports dated back to the 1860s, before power dams stopped the salmon."

Armed with proof that the river had, at least 100 years ago, supported salmon, the students next began to research the federal government's decision not to restock the Nashua. "They had based their decision on a report that was more than ten years old," says Wagner. "But the Nashua had been cleaned up tremendously in that time. So we got the state to analyze the river, and it found that the water quality is now up to standards for stocking salmon."

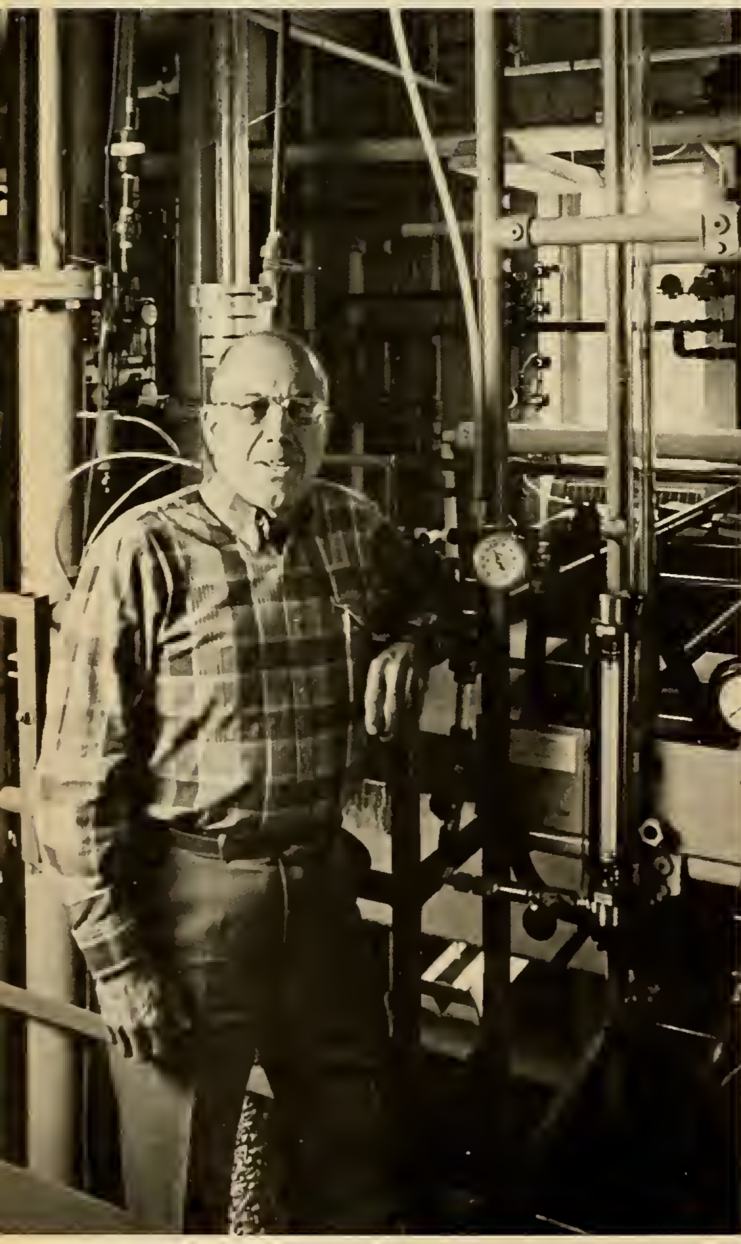
That project, one of Wagner's favorites, earned him and his students a letter of commendation from state officials. "It was a very interesting project," he recalls with a smile. "I feel we did some good there."

Another memorable project involved a very different and rather forbidding locale, the top of New England's highest mountain, 6,288-foot-high Mt. Washington. There, several

"IT'S SUPPOSED TO BE POLLUTED. IT'S NOT A STREAM — IT'S PURE INDUSTRIAL WASTE."



Dr. Robert E. Wagner, professor emeritus of chemical engineering, has worked with scores of students on environmental projects ranging from studying pollution in the Nashua River to building cloud collectors to test for acid rain.



years ago, Appalachian Mountain Club (AMC) research director Dr. Kenneth Kimball had been frustrated in his attempts to measure the acid content of clouds that envelop the summit most of the year.

The problem was significant because the cloud-water data was being used to test a pioneering hypothesis in acid rain research: the idea that fog particles contained in clouds are more acidic than rainwater. If true, the theory would help explain why red spruce atop New Hampshire's White Mountains were dying, while vegetation in the valleys below showed no signs of similar damage.

Working with Cornell University's Dr. Gene E. Likens and Dr. F. Herbert Bormann of Yale University, the AMC had placed cloud-water collectors at two White Mountains locations: Greenleaf Hut on Mt. Lafayette and Lake of the Clouds Hut in a col, or pass, between Mt. Washington and Mt. Monroe. But severe weather and high winds plagued the collectors from the start, rendering data unreliable.

Enter Wagner, himself a past AMC vice president, and four students: Andrew Cott '85, Bruce Daube '84, Reynold Dodson '85, and Peter Lamar '85. The students' mission, which included a seven-week term at Lake of the Clouds Hut, involved designing and testing a better cloud collector.

As things turned out, the students' design was so effective that Likens and Bormann offered two of the students, Daube and Lamar, a $10,000 grant to build 12 more collectors to be placed at sites from Alaska to Puerto Rico. The students' accomplishments still give Bob Wagner good reason to glow with pride when recounting their story.

"I've just had wonderful students," he says, summing up his years of advising. "They've produced fantastically."

Challenging projects such as these are certainly the stuff that can draw students into the field of environmental engineering. And, thinks Malcolm FitzPatrick, exposing students to the complexity of real world environmental problems is critical to developing their ability to devise realistic solutions that will do more good than harm.

"Flood control is not just a question of building a new dam," says FitzPatrick. "First you have to understand how the natural system works and the alternatives available for flood prevention. Then if you alter the system, you realize the constraints of that system and the potential impacts.

"Students can get discouraged taking environmental courses when they discover that many problems are so large that they cannot be handled individually. We've got to train engineers to work together to solve these problems, not just provide them technical solutions. They have to develop an ongoing understanding of the environmental system as a whole first."

Evelyn Herwitz, a freelance writer living in Worcester, is a frequent contributor to the Journal.

No big deal, nothing fancy—that's how Falls Machine founder Raymond Perreault '38 would have his life story read.

A Simple Story

By Michael Shanley

Photos by Robert S. Arnold

Ray Perreault doesn't really want to have a story written about him.

"There's no story here," the self-effacing 73-year-old tells me when I call to set up an interview. "I'm not an intellectual or an inventor or anything like that."

It's not false modesty that prompts this response, but rather a genuine concern that he not be portrayed as anyone other than who he really is.

When I arrive in Chicopee to visit Perreault at the Falls Machine Screw Company, the attitude hasn't changed.

"I'm nothing special," insists Perreault, founder and president of Falls Machine. "I can't imagine why anyone would want to read anything about me."

He's reluctant to talk about himself, but in the course of a tour through the Falls Machine plant, where he can discuss equipment, production, and precision, he warms to the subject. Slowly, a portrait emerges of a man who sees himself as the product of heredity, environment, and circumstance.

To Perreault, success is more a matter of determination and desire than brilliance and creativity. In that sense, he is something of an everyman among those who built businesses in the years following the Depression. Nothing flashy, you see, just a lot of hard work, a certain sense of intuition, and a couple of decent breaks.

If it's hard to get Ray Perreault to talk about himself, it's easy to get him to give others credit, and one of his favorite topics is WPI.

"That's the real story," he says from his simple office in the one-story structure that houses Falls Machine, "WPI and what it's done for people, the role it's played in people's lives. I honestly believe that. What you see here had its roots at WPI."

As if to underscore his words, the wall behind his desk holds several sketches of the college, as well as a WPI calendar. While most people have good feelings about their alma maters, it's unusual to encounter such genuine passion in an alumnus.

Part of the reason dates back to childhood, which is when Perreault's memories of WPI begin. He grew up in the Newton Square section of Worcester, just down the street from the college.

"It seems that Worcester Tech was always a part of my life," he recalls. "We'd go over there and swing golf clubs on the fields—if they didn't kick us off—and ski down the hills in the winter."

Perhaps a more telling memory involves the old Washburn Shops. "I used to sit on the window sill and watch them working," says Perreault, a trustee and scholarship fund sponsor at WPI. "And I remember that very clearly."

He paid tribute to the memory by funding a machining module in the new Washburn Shops when they were renovated several years ago.

For nearly 50 years, through good times and bad, Perreault has provided direction for Falls Machine.

Perreault also credits his family background and upbringing for setting him on a course that would ultimately involve manufacturing. His grandfather was a mechanic, and his father, Henry, was in the jewelry business in Worcester. So Ray and his four brothers grew up in an environment where things were designed, assembled, and repaired.

"When I was a kid living on Roxbury Street," Perreault muses, "I remember delivering papers on my route. I was about 12 years old. One day I stopped at a house, and there was a motor wheel on the back of a bike. It was covered with cobwebs. I asked the lady about it and she sold it to me for eight bucks. I took it home and pulled it apart, then put it back together. I put it on the back of my bicycle and we'd run it down the street at 35 miles an hour.

"After that, I bought a near-a-car, a little one-cylinder thing that looked like a bicycle. And I used to take it all apart. The next thing I knew, my brothers would come home with a 1930 Ford, a used one, a wreck they bought for 35 bucks, and we'd fix that up. So I got oriented toward that kind of thing early in life.

"My father was one of the first people in Worcester to have an automobile, and back in those days, you didn't drive anywhere without a mechanic. He always encouraged us when we were working on things, but he never told us what to do. He'd make us do it ourselves.

"So if you ask how I happened to get into the business I'm in, I say, 'Who knows?'" Perreault continues with a good-natured shrug. "Why does someone end up a writer, or anything else? There's something in our genes that leads us in a given direction. In a certain sense, it's just in the blood."

WPI also turned out to be in the blood, in a manner of speaking. Perreault's older brothers, George and Harvey, both graduated from the college (classes of '30 and '33, respectively). When the time came for Ray to decide what to do with his future after high school, he followed in their footsteps.

"I was actually more interested in the business end of things than the mechanical," he explains. "But I went to WPI because it was the Depression, and that was an easy way to get a good education and to learn discipline."

After graduation, Perreault took a job briefly with Matthews Manufacturing and then with Wright Machine Company, which, like Perreault's current firm, makes screw machine products. It was there that he met Raymond Chevalier, who would become his partner in founding Falls Machine.

"It was 1939 and everyone told us we would fall on our faces," says Perreault, who funded his share of the start-up costs with money borrowed from his parents. "And we damn near did just that. Just after we got through the normal start-up problems any new company encounters, the war started and restrictions were placed on civilian manufacturing. It was a struggle."

The young company, founded in Chicopee on Chevalier's suggestion, survived by making parts for firms that built such military products as guns, trucks, and walkie-talkies. "In those days," he says, "I'd put in 60- or 70-hour weeks—

scheduling work, designing tools, making layouts, pricing, talking with customers."

Originally, Falls Machine had 20 or so employees, although it would later expand to about 40, the level at which it stands today.

"We've had the normal ups and downs," Perreault says in looking back over the company's history. "We go with the economy. When times are good, we swing with it and take advantage of it. When times are bad, we survive by belt-tightening. You just do the best you can."

Perreault is quick to credit Chevalier, who served as both a teacher and a role model. He also notes that his brother Harvey, who was with the company for several years before retiring in 1981, provided a boost.

But Chevalier retired in 1959, and his brother was with him for less than a decade. So while Perreault downplays his own role, it's clear that in the overall scheme of things the company has been a reflection of one man. (One man, Perreault would add, who relied on the full support and patience of his wife, Ina.)

From the outset, Falls Machine has concentrated on high-quality precision work. It produces parts for all types of companies, from high-tech electronic firms to paper conversion companies to sporting gun and hardware manufacturers. By design, the company has not expanded to compete for huge, mass production orders.

"We're like a restaurant that has a regular clientele," he explains. "Our customers stay with us and we stay with them. They pretty much determine what we do."

Falls Machine specializes in product orders that often call for tiny bevels, flattened sides (centerless grinding), or precise roll threading—details that require a combination of automatic machining and hand work.

The machine screw industry itself represents a segment of manufacturing that hasn't changed dramatically, even during the last couple of decades with the advent of the computer revolution. As Perreault notes, the new machinery housed in the shop today is pretty much the same as the equipment he bought decades ago—just more expensive.

"The toughest times were the late 1940s, after World War II," Perreault says, charting the company's history since its founding, "and then again in the late '50s and early '60s."

The machine screw industry has seen little change in the past few decades. It still demands extreme precision and a combination of machine and hand work.

The nature of Perreault's business is such that production increases during wartime. So his reaction to the 1960s and the Vietnam War tells more about Ray Perreault the man than Ray Perreault the businessman:

"The personal tragedy was so severe," he says. "If you talk to the boys who went over, none of them wants to discuss it. It was a horrible experience to subject anyone to.

"It was tragic what that war did to us. And the inflation that resulted seriously damaged the economy."

Since the mid-1970s, Perreault says, Falls Machine's biggest challenge has been dealing with that inflation. In general, however, the last decade has seen fewer peaks and valleys and more stability.

The expansion of its grinding operation allowed the company to do more precise work in-house. It was during this period that the production facility was expanded and the work force doubled to its current mid-40s range.

"Movement to that plateau enabled us to be more flexible and do better quality work," he explains.

More importantly, it allowed Falls Machine to take on more difficult jobs during a period when demand for complex, high-precision parts was increasing. "There weren't that many other shops that could do those kinds of jobs, so expansion helped us through what otherwise would have been lean years."

It was a textbook case of adaptation to a changing marketplace, but Perreault refuses to take

Perreault confers with a technician at the Falls Machine factory in Chicopee, Mass.

much credit for the accomplishment.

"I think any business can stay afloat if it really wants to," he says. "It's a matter of sound judgment and determination."

While Perreault believes that a conservative business approach is vital, he's the first to point out that in his own case, he thinks he overdid it on more than one occasion.

"I could have been more courageous in some instances," he admits. "The conservative part of me was a result of the Depression.

"But I don't feel cheated at all. I feel very fortunate to have gotten into business doing something I like, and to have had the chance to make a contribution by producing good parts for people."

Perreault truly does enjoy the business, a business that might appear mundane to outsiders. After touring the production facilities, however, it's easier to understand the attraction. It has to do with a fundamental nature of the operation: Out of an environment that must by its character be noisy and oily and, for some workers at least, boringly repetitive, there is at heart a transformation of basic metal into wonderfully tooled, utilitarian parts. It's a variation of the spinning of straw into gold. And to see, at the end of the production line, a boxed set of paper-cutting parts, for example, in their gleaming fine detail, is to see a thing of beauty.

So the key, Perreault would say to an aspiring young engineer, has to do not with salaries and trends, but with joy and simple satisfaction.

"You try a job and if you're not content, you try to figure out why," he explains. "Then you give yourself a kick in the butt and move on as fast as you can. And you do that until you find something that you enjoy.

"So many people talk to me about retirement," he continues, "and I can't fathom why people would want to retire unless they're unhappy in what they're doing. Then I begin to feel sorry for them for spending 40 years of their life doing what they didn't want to be doing. What a waste."

Coming out of WPI, Perreault felt a complete distaste for the typical manufacturing environment of the day.

"So when I had my own business, I set out from the beginning to create an environment where there was adequate lighting, proper tools, clean rest rooms, a place to sit down and have a sandwich—the simple things."

Such an attitude has given Falls Machine a stable work force over the years, and a good reputation in the community.

Perreault's one concession to advancing years is a slightly reduced workload. "A good friend of mine called me a fool 15 years ago," he recalls. "And when I asked why, he said, 'Pardon me for saying so, but you're still at the center of things too much. You haven't learned how to delegate.' And he was right. So I've learned. Now, if I'm not here for the day, I know the business goes on."

As I am about to leave, Perreault makes a few things clear for the record.

"Keep it simple," he says of the story, "because it is simple. I've had fun. I haven't invented anything. I haven't designed or built anything that would mean anything to most people. It's been just a little bit every day."

Michael Shanley is a frequent contributor to this magazine.

Nine-to-five is no longer the routine for Americans trying to reconcile the demands of the marketplace with the needs of family and personal life.

Changing Work, Changing Times

By Julia Ridgely
Illustrations by Amy D. Wells

There are offices at which 5 p.m. passes with little recognition, where a thin stream of employees trickles out until 9 p.m. There are offices where lights burn on the weekends and staff members spend evenings at company dinners and Sunday afternoons with clients. And there are homes in which parents sit in front of the computer long after the children are in bed.

Working late is nothing new, but changes in the economy have made it more necessary, even as the demands of the two-career family have made it more difficult. The growth of the service sector, the rising cost of living, and the move toward non-salaried labor are transforming the economy. Along with a society dominated by industry, the 40-hour, five-day work week is vanishing, and in its place is rising a week without weekends and work days running into nights. People work at midnight, shop for clothes on Sunday, and pick up their laundry late Tuesday nights.

On a national scale, the changes are about productivity: To be competitive, companies need to get the greatest amount of work for the smallest investment. On a personal level, the changes center on time—time to secure a place in an increasingly unstable job market, and time at home to enjoy the lifestyle the job is supposed to support.

These two absolute needs are clearly in conflict, and the battleground for the two antagonists—work time and home time—has so far been the individual lives of American workers. As a partial solution, companies and unions have proposed alternative work schedules like flextime and the four-day week. But so far, few workers have benefited from these innovations; a May 1985 survey by the Bureau of Labor Statistics (BLS) showed that only one in eight full-time workers had a schedule that was at all flexible. Meanwhile, more Americans are working overtime, moonlighting, and taking work home. During the BLS's sample week, more than eight million workers did at least eight hours of work at home; most held full-time jobs. Some 5.4 percent of all workers held more than one job, the highest level in 20 years.

"There's a real conflict because companies want more from their employees, but young people in particular want more leisure hours," says Dan Rees, associate professor of sociology at Western Maryland College (WMC) and a consultant to small businesses. "People are basically working to enjoy life. When a job becomes life, and when life falls out of balance, it can lead to frustration." There are people who thrive no matter how much they work, he says, "but they're the exception."

The leaner, meaner service economy

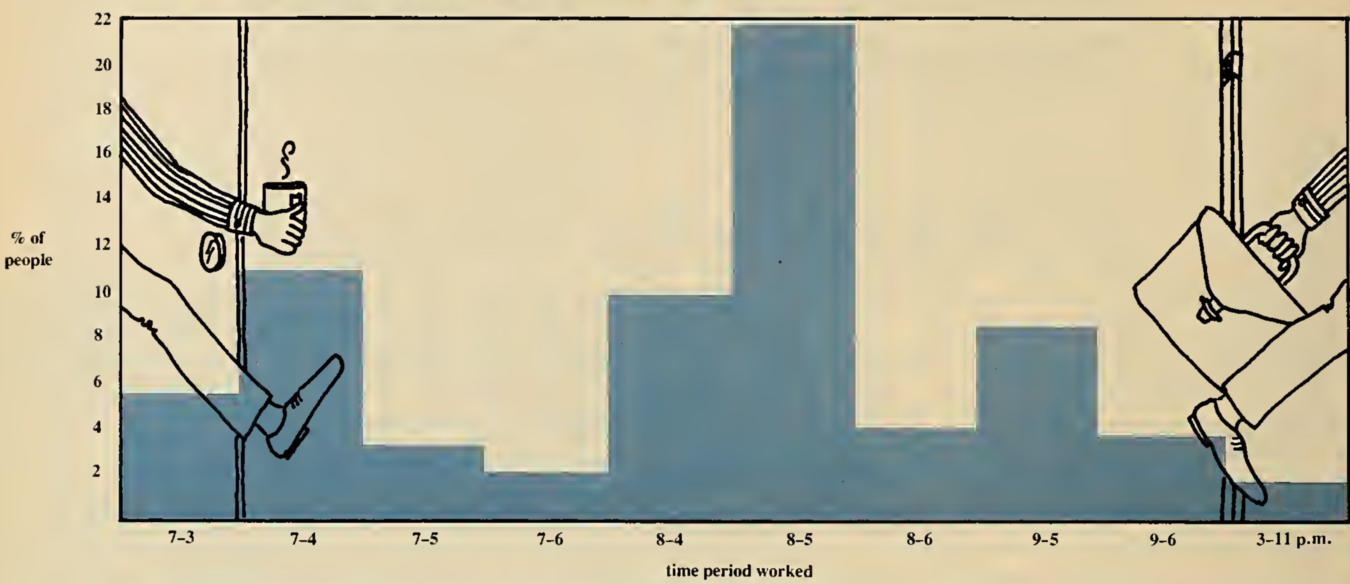
THE BOUNDARIES of work in a factory are clear: a certain number of hours and a certain rate of production equal so many items manufactured. Being at work means taking your position on the line; when the shift ends and the whistle blows, you may go home.

The majority of Americans, however, do not work in industry. While certain areas of manufacturing, like steel and autos, have been hit hard by foreign competition, the total number of jobs in industry has not decreased. But the proportion of people employed in industry has been declining steadily. The BLS reported last year that while 60 percent of employed people worked in the goods-producing sector in 1959, that figure had dropped to 28 percent by 1984. The BLS also predicted that nine out of 10 new jobs to be added by 1995 will be in the service sector; "miscellaneous" services (including business, personal, and medical) will account for one out of every four jobs in the United States by 1995.

"With the shift to the service sector, clients, not products, become the main form of how you cultivate business," says Ellen Auster, an associate professor in the management of organizations department at Columbia University. "It's not a question of what you make, but what service you sell."

Establishing a good relationship with clients can mean breaking down the barriers between work time and personal time, as well as between business and pleasure. "In the service industries, you end up going out to their houses, taking them out to dinner, playing golf, and so

The most common daily schedules of full-time workers



Times are rounded to nearest hour: 9 a.m. can be any time between 8:30 and 9:29. Wage and salary workers only.

on," says Robert Stokes, director of the Career Development Center at Villanova University and a business consultant. "The further you go up the ladder, the more you have those additional responsibilities."

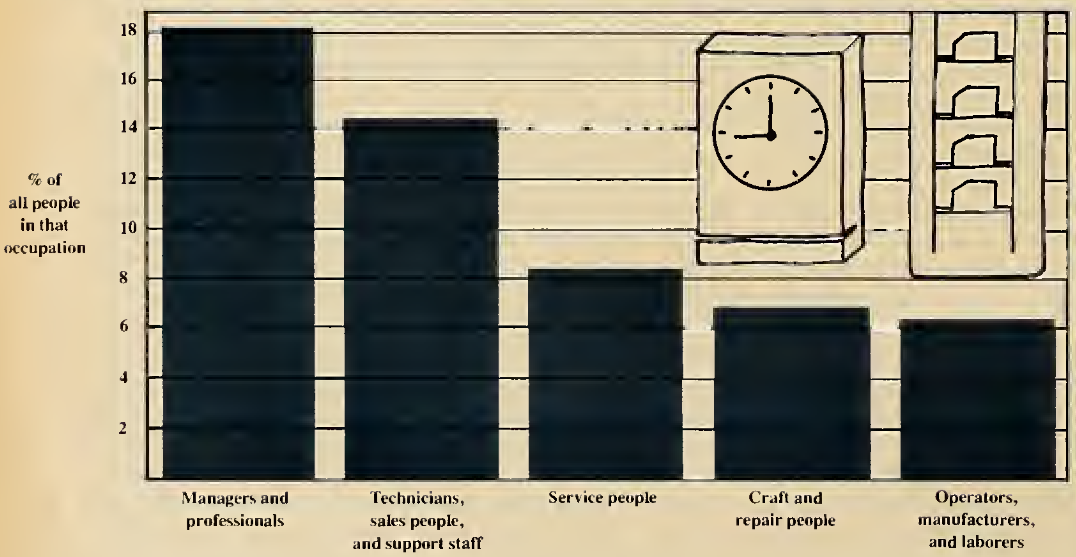
The service economy demands more from individual workers than a heavy load of business lunches. As part of the effort to make American business more competitive by cutting back on overhead costs, many companies are undergoing "restructuring." This umbrella term covers, among other things, combining jobs and departments with similar functions and wholesale cutbacks of full-time employees. Elimination of redundant managerial positions is one of the most feared side effects of mergers. The BLS reported that between 1981 and 1985, nearly 500,000 executive, administrative, and managerial employees lost jobs they had held for three years or more. Of those, 72 percent have found new jobs, but they have lost the fringe benefits that come with seniority.

Paring down management saves money; so does having a work force that can be hired or fired as the need arises. These ideas form the base for a "two-tiered" system for business, one in which a select few will hold full-time jobs with their attendant perks and benefits. This privileged inner circle will set policy and make decisions, while a transient force of part-time and "contract" employees will carry out day-to-day business. Since the early 1970s, Motorola, Inc., has divided its 90,000 employees into those with 10 years' seniority and total job security (30 percent), regular employees (40 percent), and a contingent force on six-month contracts that may be laid off on 24 hours' notice.

Rodney Austin, a WMC alumnus and trustee whose 34 years with R.J. Reynolds included 25 as senior vice president of human resources, sees restructuring as a herald of the last days of the golden age of American prosperity. While the economy was rock solid and jobs were plentiful, he says, workers reaped the benefits of salary, leisure, and security with little sense of how great a windfall they were receiving.

"I think we have had a tragic, sad period of generally lackadaisical attitudes among many in the work force," Austin says. "I don't want to imply that everybody's attitude is bad, but I do believe that it's the affluence of our

Who has flexible schedules?



Statistics excerpted from the U.S. Bureau of Labor Statistics' May 1985 supplement to the Current Population Survey.

times. Paraphrasing Mr. Churchill, never have so many had so much for which we did so little and have been so ungrateful. We've been here, by chance of birth, at a time of huge payoff coming for our work force."

Austin points out that the change is reflected in the most basic attitudes toward work. In previous decades, he says, young people entering business sought job security in the form of a long association with a powerful corporation. Security meant a good salary, a good lifestyle for the family, and plenty of vacation time. Now such a goal may be beyond the reach of all but the most driven.

"The bigger the corporation was, the better the security," he says. "As part of the restructuring not only of individual companies, but of world economies, that is no longer going to be the case. There will be a small, corporate structure of perhaps 30 to 50 key people, and you will contract out the rest. The parking lots will still be full, and people will be rushing in at 8 a.m. People will work on a skill basis and be competitive in that sense. The ultimate promotion would be to the 'politburo' of the corporation."

To move up in such a competitive environment requires dedication, and one of the most visible ways to prove dedication is working long hours. Like the "organization man" of the 1950s, ambitious workers of today try to send a message that nothing comes before their job.

"Face work"—using your physical presence as proof of dedication—"is still around, and, if anything, worse," says Ross Webber, professor of management at The Wharton School of the University of Pennsylvania. Webber believes that young professionals making high salaries are particularly prone: "To show that you're worthy of the money, you work these horrendously long hours without any overtime pay, or with the informal understanding that, although you're entitled to overtime, you're supposed to eat it."

Korn/Ferry International, an executive recruiting firm, surveyed 1,362 senior executives at top corporations in 1985. The average executive put in 56 hours a week, three hours more than in 1979. But working late to score points can be propagated all the way down the corporate ladder. Employees who see a supervisor staying past 5 p.m. take it as a hint that they should do the same. "That has an incredible effect on you," says Helen Vassallo, M.D., associate professor of management at Worcester Polytechnic Institute (WPI). "You're saying to yourself, 'If my boss stays late and takes short coffee breaks, of course he or she is using modeling to influence my behavior.' "

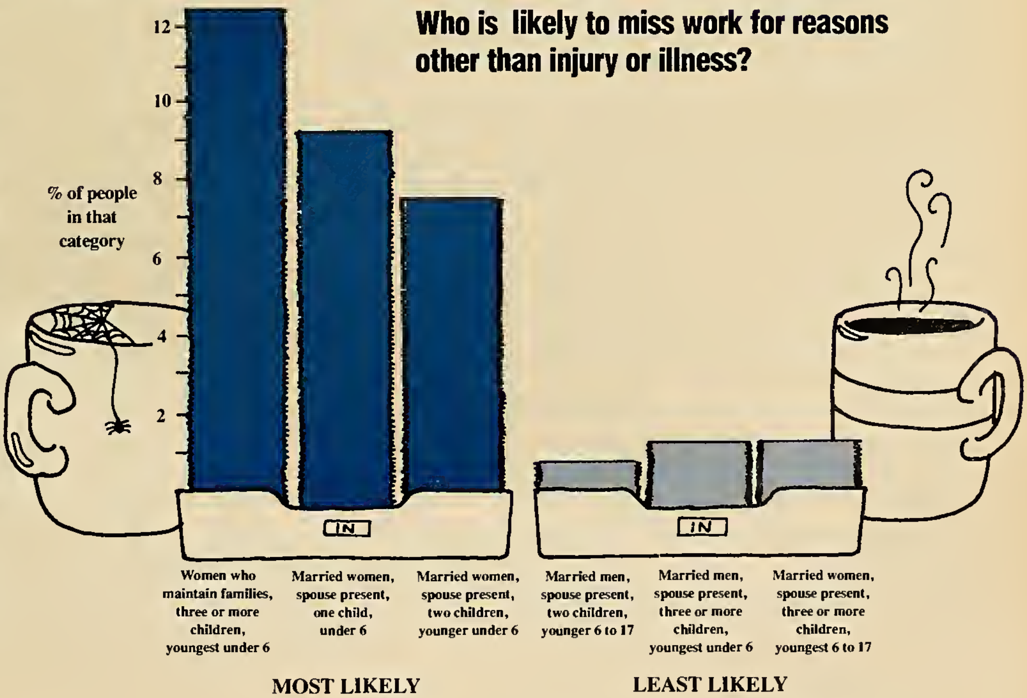
Extreme dedication, desire for promotion, studious efforts to please those in power—it all sounds like a return to the gray-suit-and-briefcase world of television programs like "Ozzie and Harriet." The difference, of course, is that sometime between then and now, Harriet went to work.

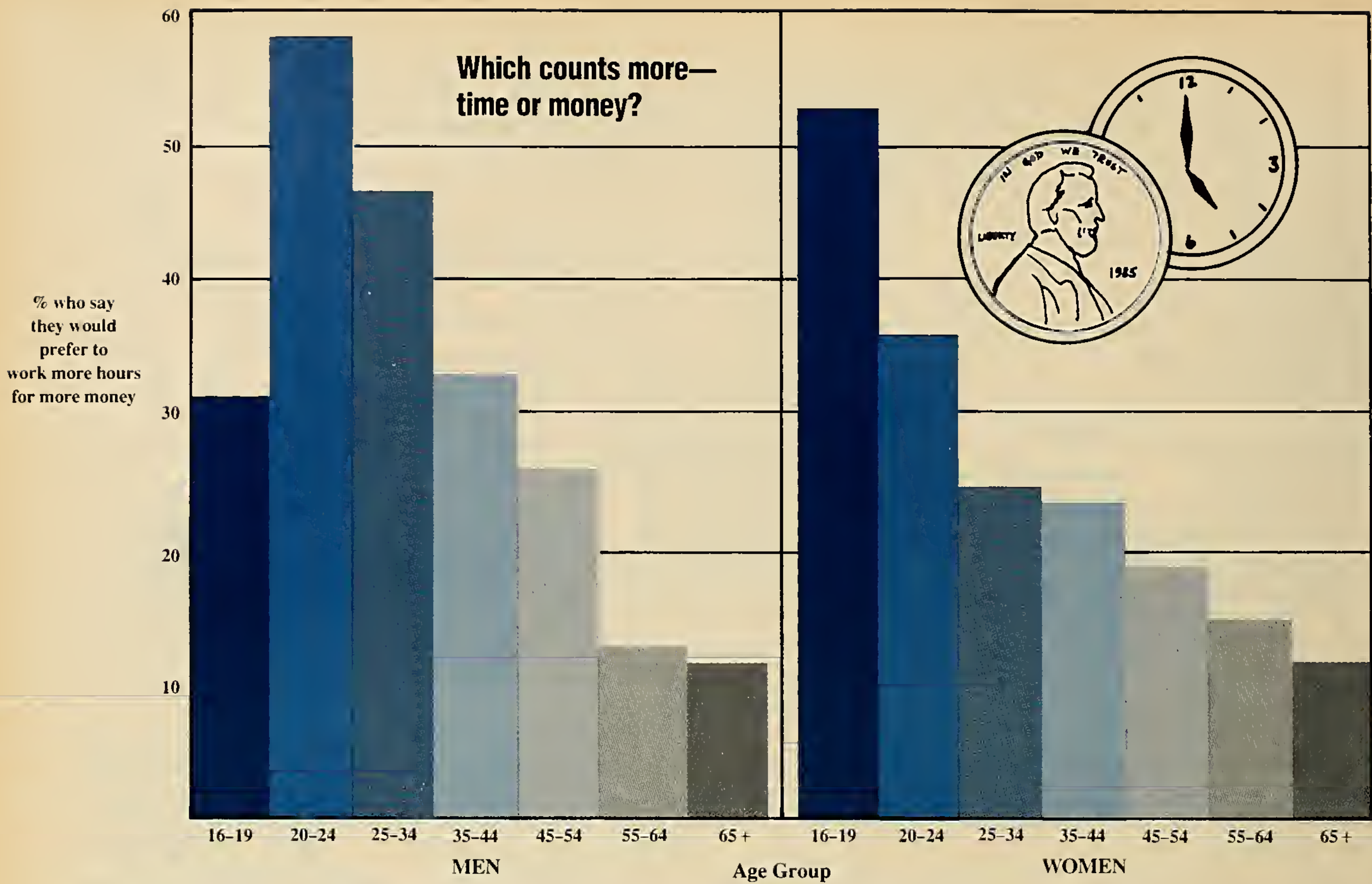
Women and flexible hours: a risky tradeoff

"ONE THING OUR SOCIETY has not dealt with very well is that we've not really addressed the issues of work and family coming together," says Carol Auster, assistant professor of sociology at Franklin and Marshall College (F&M). "We're still where we were 20 years ago, although there have been some improvements, like flextime and day care on site."

America has a long history of manipulating the female work force by using the competing demands of the economy and the home, Auster notes. During World War II, "the federal government was saying, 'Please come to work!' and making films on how to cook fast meals." When the men came home from the war and women were expected to leave the workforce, "they made films on how to make wonderful, five-hour meals. There were

Like the "organization man" of the 1950s, ambitious workers of today try to send a message that nothing comes before their job.





Helpful Hints for Working at Home When the House Talks Back

To set your own hours, to have no visible supervisor, to commute only a few steps to the office—to work at home and be paid for it—seems like the perfect compromise between job and family.

But it is the much-envied flexibility of home-based work that can create conflict and anxiety for those who do it. Kathleen Christiansen, director of the Project on Home-Based Work at City University of New York, says the biggest challenge such workers face is putting time and space between being at work and off work.

"When you shut the front door as you leave for work in the morning, you symbolically and literally put a boundary between self and personal life," Christiansen says. The office is a place designed for work; the home teems with distractions.

"Home has its own language, which seems to afflict more women than men. As one woman said to me, 'If you work in an office and you go to get a drink of water, the water cooler doesn't say, 'Defrost me.'"

Even more compelling than the pleas of appliances can be the demands of children, friends, or pets, especially since one of the main attractions of home work is the opportunity to take care of children or elderly relatives. People who would avoid taking personal calls at the office find it difficult to ignore a ringing doorbell or a four-year-old's pleas.

Christiansen says that home workers often devise going-to-work rituals to reinforce the difference between being on the job and in the home:

"People would walk out the front door, go around the block, and come home. Many would turn on the answering machine promptly at 5 p.m. and go out and walk the dog. A story I've heard from several sources is about a man who worked as a broker who had a tape recording of the market opening and closing."

Creating time limits can also help home workers avoid the feeling that whenever they're not attending to the family, they should be sitting in front of the typewriter. Christiansen reports a high rate of burnout, especially among people operating businesses out of the home. An office worker who wakes up at 3 a.m., inspired or driven to finish a job, can't hop out of bed and rush to the office. But the home-based worker can—and often does.

Setting aside a work-only space in the home is essential. The bedroom may be the most comfortable place to work at the computer, but the bookshelves, TV set, and unironed laundry can be distracting, while the computer can become a haunting, around-the-clock reminder of work—especially at bedtime. The ideal home work place has a separate entrance from the rest of the home and contains things that symbolize work: a file cabinet, a desk set, a desk calendar.

Christiansen explains that this separate entrance may be a necessary luxury:

"Particularly when you have a young child, the door to the office is not a sufficient boundary. The child doesn't understand that Mommy has to work now." She notes that men working at home traditionally have had wives to act as films showing how children were running around on the streets and getting into trouble because there was no one to watch them."

Women have always worked in the home, but their financial contribution in the 20th century began after the enactment of child labor laws. "In working class families, traditionally the father and the children worked," says Lois Scharf, adjunct associate professor of history at Case Western Reserve University (CWRU). "By the 1920s, there were signs of reduction in child labor and of wives entering the work force, in a sense replacing their children.

"In the '20s and '30s, with the increase of working wives, you began to get the sense that families wanted more money as the consumer society developed. In some ways, the two-income family today is really revolutionary, as much as anything is. Middle class families really can't attain their desired standard of living on one income."

The need to work and the shortage of day care have forced women in particular to find ingenious ways to make extra money and, when possible, decide when and where they will work. Moonlighting and multiple job-holding, for instance, are on the rise; the BLS reported that in 1985, 2.2 million women held more than one job, an increase of 40 percent since 1980. Kathleen Christiansen, professor of organizational behavior at City University of New York and director of its Project on Home-Based Work, surveyed 14,000 women through a national women's magazine, and interviewed many personally. Based on her research, she cites the need for women to hold more than one job.

"You've got to take a look at the median income," she says. "It's going to take a job and a half to earn what a man makes in one job. In most jobs, there are still rigid 8-to-5 or 9-to-5 schedules. A lot of the women I've interviewed take multiple jobs: one for benefits, another for money or creativity."

Another popular alternative is home-based work, which ranges in scope from a few hours of clerical work or telemarketing to full-scale businesses. Based on her study, Christiansen now concludes: "Home-based work may still be the best of not very good alternatives for providing for work and family." Companies out to recruit home workers often show women sitting at computers while their young children play contentedly—and silently—behind. In reality, of course, the children demand attention and the work gets put off until after bedtime or before breakfast, she notes. "To me," Christiansen says, "'flexibility' is a horrible euphemism for exhaustion."

As it happens, home-based and part-time jobs fit conveniently into the mold of corporate restructuring, but not necessarily to women's advantage. "There's a potentially dangerous intersection between the corporate need to downsize and the fact that women are increasingly looking for flexibility. To go out on their own offers them more in the short term. But I think as corporations are professionally restructuring, these jobs are being changed to part time," Christiansen explains.

So, she warns, women who choose non-salaried work, planning to re-enter the full-time force later, may find when they return that such jobs are no longer available. The positions will belong instead to the unencumbered few who Christiansen says, based on current seniority,

As corporations scale down, women now stopping out of full-time work may later have little choice but part-time jobs.

"gatekeepers," screening interruptions. As it is, one-third of the women in Christiansen's study used some form of child care even while working full time at home.

While home workers are spared the pressures of commuting or the rigid time constraints of the office, they often do feel lonely and isolated, with no co-workers to talk to or lunch with. Such feelings can put them in conflict with a partner who works outside the home.

"The problem is that they're on entirely different rhythms," Christiansen says. "The spouse who works outside wants to come home and collapse. The spouse that has been at home wants to get out. They've worked alone all day; they want to talk."

Finding a middle ground that satisfies both is a matter of bargaining. Constance Pilla Uliano, a Franklin and Marshall graduate who is a part-time teacher and free-lance editor, has an informal arrangement with her husband, who works long hours managing his own construction business. She does grocery shopping on week nights, leaving the care of the two small children to her husband once he is comfortably settled in front of the VCR. "It's true you have to negotiate," she says. "For instance, I'll say to him, 'I'm not cooking on Wednesday and Thursday nights because I have a long day at school.'"

Between balancing work and family and facing the condescension of those who don't believe their jobs are "real," it's no wonder that home workers often feel tired, stressed, and frustrated. But Christiansen admires them for their ability to turn a tangle of conflicting needs into a functional way of life: "I think the remarkable stories are about those who really do well."

"will be older, white, middle-class men." F&M's Carol Auster notes that the promotions-for-loyalty exchange still favors men because "organizations use male indicators for what they consider loyalty. They assume that there's someone at home taking care of things. Men are still less likely to say, 'I've got to stay home because I've got a sick kid.' "

Since circumstances favor men in management positions, women who have left the work force may have to settle for a part-time role. "The peripheral workers are going to be women, older workers, and teenagers," Christiansen says. "Older workers will be more in demand because of their experience."

For those left outside, work can still be profitable and satisfying, even more so than a salaried job, as in the case of small-business owners. But the potential exists to create an exploited class that works as hard, and in constraints as rigid, as salaried workers, but reaps few of the rewards. Companies often do not pay for benefits, vacations, or sick leave for part-time workers, but according to Christiansen, "They're likely to get at least three-quarters of a day's work out of each person sharing a job."

Contract workers, who make up the majority of home clerical workers, are particularly vulnerable to abuses of their time. In theory, a woman who does computer data entry for an insurance company may receive no company benefits and a flat rate for the number of forms she completes, but can set her own hours and "vacations." In practice, she may be subjected to a heavy work load and strict time limits, but may fear to complain because she needs the money.

The system reminds Lois Scharf of the "piece work" done by women at the beginning of the century: "The truth of the matter is, it has always been a terribly exploitative enterprise. This is the 1980 version of the 1910 immigrant family making artificial flowers or finishing up buttonholes in tenement apartments."

Regardless of its hazards, Christiansen sees non-salaried work as an overall plus for women: "I think companies are motivated by their own bottom-line interests. It just happens that the supply side is very willing to take part-time jobs. The most beneficial thing is that it exists as a choice."

The rise and fall of the 40-hour week

IN SPITE OF the leakage between work and home time—taking an hour off for a child's dentist appointment, finishing a report at the dining-room table—the five-day, 40-hour week rivals perhaps only the weather as a topic of universal interest. From Monday morning cartoons to Friday afternoon resort-bound traffic jams, city culture reflects a way of life that is only half a century old. In 1938, the Fair Labor Standards Act instituted a 40-hour week and set the minimum wage at 25 cents.

"My sense is that the five-day, 40-hour week is really a product of the Depression mentality and the need to spread the jobs around," CWRU's Lois Scharf says. But the drive for a shortened week dated almost to the beginning of the 19th-century industrial revolution and the extraordinary changes it brought about in attitudes toward work itself.

In agricultural society, Scharf says, "work was task-oriented. You did what you had to do as long as you had to; then, you could do nothing." Early industry followed the same cycle: "When the first New England mill girls went into factories, the work day and the work week were much like they had been traditionally. You worked from sunup to sundown, longer in the summer and shorter in the winter."

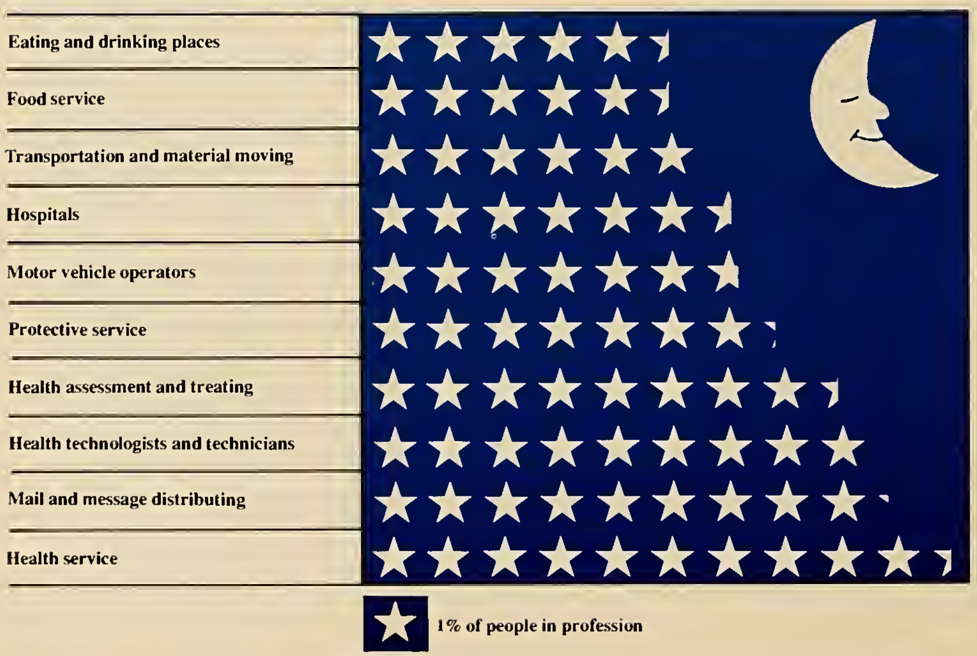
The advent of assembly-line machines with interrelated functions brought the need to work set hours at a steady pace. "A new sense of work discipline developed, and it became a discipline that was time-oriented," Scharf says.

The emphasis on time rather than on intensity of labor was reflected in what American workers wanted—and what unions tried to get for them. "Up until the 1950s, the U.S. had taken half of its increase in production in real income and half in the form of a reduced work week," says Wharton's Ross Webber. "For a while in the 1950s, unions still pushed for a reduction of the work week, and we certainly got solidification of the five-day work week. Since that time, the formal work week has stayed sort of stable, partially because the rate of increase of production has slowed down. But what was going on in reality was that the work week for managers and professional people started to increase through the '60s and '70s."

Webber points out that the increase in the amount of hours people spend on work conflicted with a new attitude about work's importance: "You had this phenomenon of recognition, a residue of '60s counterculture, which argued that life shouldn't be completely subservient to work."

Trying to accommodate the

Who is most likely to work the night shift?



Multiple jobholding is on the rise for women

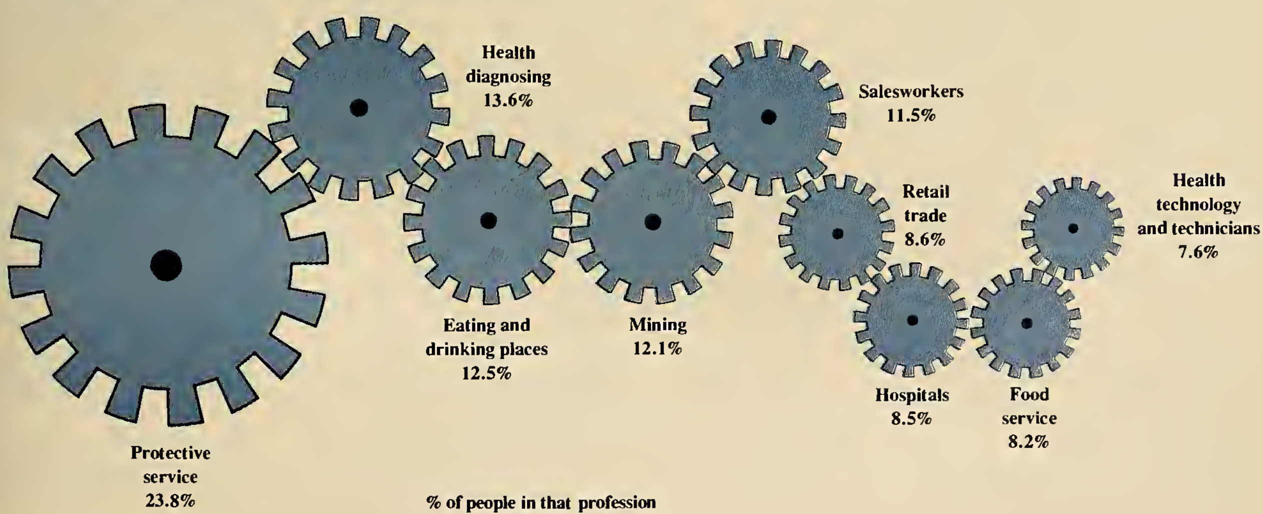
desire for a less regimented and demanding schedule, business introduced innovations like flextime (in which employees can choose from a range of starting and ending times); the four-day, 10-hour work week; and work "sabbaticals." These ventures were part of a general move to make the work place more relaxed and comfortable. A focus of this drive was the care and feeding of people whose responsibilities consisted of more thinking than doing. The almost legendary pampering of research and development whizzes in California's Silicon Valley stemmed from the realization that "creative work can't be turned on and off by the clock," Webber says. High-tech factories began to leave the doors unlocked so that people's offices would be available in the event of sudden inspiration.

The new machine age brought an attitude toward work reminiscent of the age before machines, when the work day conformed to the tasks that had to be done. But the idea of more flexibility also appealed strongly to a growing group in the labor force that was feeling the constraints of time. "Flextime is rooted in the idea of creativity of professional workers, but was also very hospitable to what the feminist movement was trying to achieve," says Webber.

The political drive to promote flextime has been most successful in government employment. In 1985, the Bureau of Labor Statistics found that 20 percent of federal employees now have the option of more flexible hours. Studies show no decrease in productivity, modest gains in work satisfaction, and fewer sick days taken. But despite the widespread attention to and strong appeal of flextime, the same study showed that only 12 percent of workers at large had flexible schedules

Since the advent of factories—and the time clock—employees have fought for a shorter week.

Who is most likely to work rotating shifts?



Is It Your Fault You Work Late?

Pressure to prove oneself to the company is responsible for a lot of late nights, but often employees must share the blame. Although books like *The One-Minute Manager* have drawn attention to personal time management, there are many otherwise successful people who can't set goals, limit interruptions, and arrange tasks efficiently. Though they feel overworked, their real problem may be that they are underorganized.

Dr. Helen Vassallo of Worcester Polytechnic Institute, who has led executive seminars on organizing time, believes that a "system" for management is less important than having a clear sense of what needs to be done, when, and how. "I think there's more return on time management by not only doing things right, but by doing the right thing," she says. "If you set your goals properly, you'll do a better job of time management." She compares setting short-term goals to scuba diving: "Every time you come up, you've got to take a sighting. It's important to constantly set goals in small enough pieces that you can accomplish them."

Dan Rees, professor of sociology at Western Maryland College and a consultant to small businesses, believes interruptions are the leading time-waster for managers, a sign they may not trust employees to handle a problem alone. "Managers don't confront employees to handle it themselves," he says. "They make people too dependent. I find with many that they say, 'I come in on weekends and stay after work so that I don't get interrupted.'"

Arranging tasks to fit the natural rhythm of the day can help people be more productive. "Time management is looking at what type of person you are," says Robert Stokes of Villanova University. "A lot of it depends on your peak hours." If you're at your most alert in the morning, "pick the activities that are mentally draining and do them early, then save the other activities for later. If you are a writer who also has to talk to clients, then maybe you should do the heavy-duty writing in the morning."

Making the most of work time is especially important since productivity begins to decline after a certain number of hours on the job. How long people can work before they start to feel the effects depends on the interest level of the job and how they respond to pressure.

"People can't work well after six hours," says Dan Rees. "After that, decision-makers as well as assembly-line workers fall off in productivity. A stimulating and exciting job allows them to work longer hours, but decision-making ability does fall off."

When people work long hours to the detriment of their health or productivity, companies must take action, Rees says, even if it means ordering the worker to stay away one Friday every month, or on weekends. "Believe it or not, they'll get upset, even if they're getting paid for that time," he says.

As long as companies are demanding more work, he feels, they should offer more than just the occasional workshop to help people control their time: "What I find is that the effort is too piecemeal. Really bright people go into management, but the demands are so great that they can't keep up. Companies should definitely get people to balance work and personal life."

available to them. One reason for the slow take-off may be that jobs themselves have become more demanding than ever before.

From daytime to work time to no time

BETWEEN THE AVAILABILITY of a part-time work force and the apparent readiness of full-timers to work as long and hard as necessary to advance, companies seem well equipped to deal with the transformation of the economy. Given this convenient situation, what motivation is there for companies to offer flextime or other alternative schedules?

The answer—fortunately for workers—is that the quality of work is as important as the quantity. The last decade has seen a gradual awakening to the idea that the identity of employees extends beyond work hours, and that for them to be content—and therefore productive—companies must pay attention to all aspects of their lives.

Some of the new perks—like providing free sandwiches so that lunch breaks won't stretch to an hour and a half—have obvious payoffs in time saved on the job. But others, like on-site health clubs, child care, and employee assistance programs, aim at easing the pressures of personal life. "I think employee counseling can really help," says Villanova's Robert Stokes. "Stress is really a matter of how we react to a particular situation."

Today, stress and time are practically synonymous. Together with longer work hours, the growth of international business and such innovations as electronic communications have eroded evenings and weekends.

Victims of the lengthening day include not only executives but the "blue collar" service workers—hair dressers, dry cleaners, supermarket clerks—whose hours have been extended to accommodate their clients. The row of local businesses that locks up promptly at 6 p.m. has been exchanged for the permanent day of the shopping mall. In large cities especially, concepts like "after work" and "Sunday afternoon" have little meaning.

"I'm struck, particularly in New York, by the fact that at certain times of night, even if it's very late, you can be in a restaurant and it's full of people," says Columbia's Ellen Auster. "If it weren't dark outside, you'd have no idea it wasn't noon. There's no official off time anymore. It's such a contrast to some other cultures. When I was in Italy, whole cities closed down from 1 to 3."

Perhaps nothing attests more strongly to the preciousness of free time than how much people will pay to get it. "One of the biggest rewards people give themselves now is time," says Stokes. "People buy time by getting a babysitter or someone to cut the grass."

No amount of money will buy the time most people—especially if they have children—now need. As companies adjust to the new constraints of the marketplace, individuals are finding it hard to accept that what they do to balance their lives is both heroic and insufficient.

"The big message," says Ellen Auster, "is that you can't have it all at the same time. Something gets hurt. Over a lifetime you may have it all, but at different stages, your marriage, your career, your children will suffer." For those who have yet to realize this, time is running out.

Julia Ridgely works an 8:30-to-5 schedule as assistant editor of the Alumni Magazine Consortium.

Painters prolong the life of Maryland's Chesapeake Bay Bridge. One span is closed until May for deck repairs.

Where the Rubber Meets the Road

Today's civil engineers follow in the tread of giants. But the path to progress has its share of accidents, detours, and crossroads.

By Donna Shoemaker

A Roman aqueduct or an Aztec temple, a Stonehenge or a Great Wall, an Egyptian pyramid or a Colossus of Rhodes: These are solid legacies of civilizations past. All were engineered even before the profession had a name, before the artistry had been fused with science.

Modern manifestations of civil engineering are the industrial counterparts of those earlier edifices, the colossal commonplaces of our age: skyscrapers and supertankers, airports and interstates. Most people notice the flashier aspects of engineering, like the restoration of the Statue of Liberty (which earned this year's highest award from the American Society of Civil Engineers).

But it is in the more mundane areas that engineering ingenuity may have raised its torch the highest by vastly improving the quality of daily life. Consider, for instance, facilities for generating electrical power, treating sewage, and purifying water. "The contributions of civil engineering to improving public health have probably exceeded those of medicine," says Fred Moses. There is no hint of hyperbole in the voice of the Case Western Reserve University (CWRU) professor of civil engineering. Engineers know that their projects will be used the day after they are finished, he adds.

In spite of such accomplishments, in a society already highly industrialized, civil engineers seem to have less status today than do their counterparts in the "hot" fields of electrical or computer engineering. They earn less money (although the salary gap is narrowing). They tend to get attention only when

AP/Wide World Photos (all)

What goes up has been known to come down. Structural trouble spots during the last decade included (left to right) the windows that fell out of Boston's John Hancock tower in 1985; the collapse this year of an unfinished high-rise apartment in Bridgeport, Conn.; the cave-in of the Rosemont Horizon Stadium roof in Illinois in 1979 (top right); and the fallen roof of the Washington Bible School under construction in 1978 in Prince George's County, Md.

their projects fail. And they are accused of upsetting the ecological balance. All of this has dimmed their light.

In the United States, "our infrastructure is in place, and we tend to take it for granted. Laymen get the impression that the breakthroughs aren't there. Only when it doesn't work do we notice and get annoyed. But that's misrepresenting it," states Ross B. Corotis, chair of The Johns Hopkins University civil engineering department.

The United States in the last 100 years or so experienced an engineering heyday. With the growth of cities and suburbs, buildings towered above ground and a technological maze of pipes, sewers, and subways spread out below it. Showstopping spans like the Brooklyn Bridge (1883), the Golden Gate Bridge (1937), and the Chesapeake Bay Bridge (1952) linked thriving areas with more isolated ones. "People sometimes make the argument that anything man builds diminishes the effect of a great landscape," says author David McCullough. "But I think at heart that is a dishonest argument." He believes a bridge like the Golden Gate "makes a magnificent place even greater," for it gives both scale and drama to the landscape.

The time between the Civil War and World War I was engineering's greatest epoch, says McCullough; he chronicled two of its milestones in *A Great Bridge* (the Brooklyn) and in *The Path Between the Seas* (the Panama Canal). In that era, "it was as if these engineers were taking part in one of the great crusades, and they knew it. The culture in which they lived believed in their work, and what they were doing was heroic," he says, his resonant voice reflecting the excitement of those days.

Engineering flourished as well in the next few decades. Such massive projects as the Tennessee Valley Authority, launched by Franklin D. Roosevelt in 1933, reshaped the region's landscape and economy by creating 16 new hydroelectric dams and modifying five more. The great era of public works before World War II produced the big projects—the Hoover dams—that "captured the

public's imagination," notes Richard H. Gallagher, a civil engineer and provost and vice president for academic affairs of Worcester Polytechnic Institute (WPI).

The late 1930s, some would say, were "a time of buying our way out of the Depression—of getting the farmer out of the mud and onto the highway network," notes Villanova graduate Stephen Lester, a district engineer for the most populous region of PennDOT (the Pennsylvania Department of Transportation).

During this bustling age, what virtually entered American folklore was the image of the engineer as the "lone surveyor in boots and mackinaw, the wizard inventor in his workshop, and the master of the industrial dynamo," as a National Research Council report put it in 1985.

That image still is a beacon in developing countries, where civil engineers are held in high respect. As agrarian societies undergo rapid modernization, these Third-World engineers find fertile frontiers. Some 200 cities worldwide now have populations exceeding one million, creating tremendous demands for sanitation facilities, roads, housing, buildings, mass transit, and power plants.

"The very brightest people from around the world want to be civil engineers, and they come to America because our training is premier," Corotis notes. Foreign nationals account for more than half of all engineering doctoral students in America.

Our nation's successors to the ancient world's builders and planners are seldom the heroes here anymore. Instead, people notice the highly public mistakes. Architects take the credit if a building is a success; civil engineers take the rap when one falls down. "When we fail, we do it in such a spectacular way," says Corotis, who heads the American Society of Civil Engineers' Committee on the Safety of Buildings. The collapse of the Kansas City Hyatt Regency walkway; of a Bridgeport, Conn., high-rise apartment building under construction; of an interstate bridge in Greenwich, Conn., are hard to keep under wraps.

On-site with Four in the Field

What has happened lately to the romance of the road, the rails, and the bridges? What's the terrain like for civil engineers today?

From the Philadelphia area, Stephen Lester oversees the design, maintenance, and construction program for 3,900 miles of highways with 2,900 bridges. His turf includes the recently refurbished Schuylkill Expressway (traveled by a half-million vehicles a day), and the last—and most controversial—sections of the mid-county expressway, inching its way through populous neighborhoods. Lester earned his bachelor's (1965) and master's (1969) in civil engineering at Villanova University, and since June has been the district engineer in charge of PennDOT's five-county Philadelphia area.

"The need for highways will be with us forever—it's not a fad field," he notes. He is quite conscious of how much thought goes into designing roadways, making them safer for drivers and for the crews repairing them. For example, transportation engineers seek ways to help drivers avoid the "dilemma zone" right before traffic lights: those critical few feet in which you have to decide whether to run the yellow or screech to a stop. (Sensors that can detect gaps in the lines of vehicles will improve sequencing of stoplights.) Lester is looking at alternatives to using salt on icy roads to avoid its corrosive effects. He is interested in improved skid-resistant coatings for bridges. He wants "to get new technology down to the municipalities."

Extending roads through neighborhoods requires care, says Lester.

Peter Howard

Pennsylvania in 1982 dedicated $1.4 billion to rebuilding its deteriorating bridges, and added to that $1.6 billion in 1986 (the state has some 23,500 bridges over 20 feet in length). The need is "absolutely essential," Lester believes. "We're routinely inspecting every one of our bridges. Because of the billion-dollar program, we're able to go ahead and get construction done ahead of schedule."

In upstate New York, Tony Leketa heads out every day in his four-wheel-drive vehicle to an 11-square-mile area of rolling farmland. There, 2,300 workers are building a new Army base. Three years ago, Fort Drum was only an idea, but one that swiftly got the Army's green light. Four years and some $1.3 billion from now, the base will be getting its finishing touches. "The speed with which this whole thing is happening is historic," explains Leketa.

Fort Drum will house 10,000 soldiers (6,000 of them move in this November). Thirty-five miles of new roads will lead them to all-new facilities: barracks, homes, schools, a day-care center, a fire station, a heating plant, equipment and supply shops, maintenance areas, a skills development center, athletic fields, a bowling alley, and, of course, a shopping mall. "A new shopping center in the metro Washington, D.C., area would be no big deal," says Leketa, "but there's nothing like that here." An area engineer with the Army Corps of Engineers, Leketa supervises a staff of 30. He earned his civil engineering degree from Worcester Polytechnic Institute in 1969.

The construction of Fort Drum includes the single largest Army Corps of Engineers contract awarded since World War II, and the Corps is the world's largest construction organization. The adjacent town of Watertown, which will see its population double as a result, "was a little reluctant to accept that it was going to be the new Fort Drum. We were cutting roads through and people still didn't believe it."

Often accused in the past of bulldozing environmental concerns, the Corps has had to pay strict attention to the fact that this project lies just 25 miles from Lake Ontario. "We were very concerned about sediment control and the environmental impact," says Leketa. Miles of scrub had to be disposed of through controlled burning. Dozens of abandoned farms on the site came under scrutiny from the Corps and from state preservationists.

Building Fort Drum brings into play many specialties in the civil-engineering catalog: soil and site analysis, wind engineering, structural reliability, hydraulics, fluid dynamics, urban planning, surveying, transportation, water resources, construction, pipelines, and mechanics.

For Leketa, gazing over the site, "there's a tremendous sense of accomplishment. There's not much opportunity to build something from scratch, right out of the ground. My idea of hell is sitting at a desk doing design calculations. If I couldn't get out in my four-wheel-drive vehicle and see what's out there, it would drive me crazy."

Based in Cleveland, Gregory P. Chacos is a detective called in to find out what went wrong and why, so that those at fault will know "whether to fight, run, or settle out of court." He eschews the more fashionable term of forensic engineer in favor of calling himself a structural consultant. After earning a bachelor's (1951) and master's (1958) in civil engineer-

Plan courtesy Army Corps of Engineers

Fort Drum's master plan shows the massive scope of the Army base rising from the farms of upstate New York.

ing from Case Institute of Technology (part of Case Western Reserve University), for 18 years Chacos headed his own engineering firm, providing design services to architects, contractors, and owners.

Chacos is all in favor of advanced technology and used computers in design 15 years ago. But, he says, "to be a bit flip, a lot of the increases in current technology end up giving me more work. I see difficulties in projects that take stuff right off the computer printout and put it into the building design—the more automated the design becomes, the more I see funny things happening. Projects get horrendously complicated, and needlessly so."

Consulting takes him to New Jersey, West Virginia, Oregon, Washington, D.C., and often into the courtroom to testify. He was called to Detroit to consult on repairing the new 2.9-mile "People Mover" elevated rail system, which suffered cracked guideway girders and overran its $137.5 million budget by more than $60 million. In Motown, a city more reluctant than most to give up its cars, the People Mover was dubbed "the rich people's roller coaster."

His style of consulting, says the affable engineer, is best done alone and onsite. "If I can't see it, smell it, and feel it, I can't get the proper approach to the problem."

Around Worcester, Mass., "the climate has been ripe for development, and it's come," says Carl Koontz. He monitors all building permits for the city's 50,000 structures. Like Chacos, he's wary of the revolution in computerized design, concerned that, to reduce costs, engineers are "designing tighter and tighter to meet acceptable factors of safety." He emphasizes that "building codes are specifically built on experience collected in the past. When people start extrapolating past that experience, when engineers try to creep up on that factor of safety, the lessons learned are costly." A professor emeritus of civil engineering who taught at Worcester Polytechnic Institute for 35 years, Koontz last year took up this second career as Worcester's commissioner of buildings and code inspections.

Quite typical of New England's older industrial areas, in this city of 175,000 people, through the years, the main water and sewer pipes have become clogged, covered with scale, and a breeding ground for bacteria. With any decayed system in need of replacement, "a whole host of problems develops. How they'll be conquered only time will tell." Boston—only 40 miles away—faces a $3 billion job of replacing its outdated sewers and cleaning up its harbor. Koontz sees these seemingly more ordinary problems—corrosion, wear and tear, repairing of hard-to-access structures, conserving energy vs. preventing indoor pollution—as being far more worthy of research than are some of the profession's enticing new options.

The public "hears about the monsters," John Loss points out. Through a databank called the Architecture and Engineering Performance Information Center (AEPIC) at the University of Maryland, the architecture professor keeps track of basic information on 58,000 buildings and public-works structures, some dating back to 19th-century railroad days and even earlier. Graduate students are coding far more detailed information on 5,000 cases from the past 20 to 30 years from state and federal appellate courts, forensic engineering files, and insurance claims. By the end of next year, AEPIC will have 10,000 detailed cases, and thus can give the industry (and the lawyers who use AEPIC heavily) "a pretty good idea of what's happening" in terms of deaths and injuries, cost overruns, delays, and structural failures.

Leafing through his printouts, Loss pulls out data on the new cases coded so far: "The percentage of problems is running highest for sewage treatment plants, highways, pipelines, and bridges." Metals become fatigued; cracks develop. When steel embedded in concrete corrodes, a bridge pile gives way. Highways built to bear truck loads of 20,000 lbs. show the strain of tractor-trailers weighing 90,000 lbs.

Loss's figures show that in sewage treatment plants, design errors account for 40 percent of all failures, with the major defects to be found in mechanical equipment. But it is not always easy to determine how such problems developed. Maintenance may have been faulty or a plant may have had soil stability problems. "Sewage treatment plants are going into the worst environment—one that no one else wants. They're much less predictable sites to be working on," Loss says.

Through AEPIC, he explains, "one of the things I'm attempting to do is to get a better handle on the problems. There's been a lot of misinformation in the past, and we haven't had much back-up data."

Not all failures are spectacular. Routine wear and tear takes an enormous toll. By the mid-1980s, civil engineering had come to be identified with propping up America's crumbling infrastructure—at a staggering projected cost of $1 trillion. Students then, who might have entered the specialty, instead detoured around a career they perceived to be drearily shackled to refilling the nation's potholes, replacing its rail tracks, and resurfacing its bridges, notes James O'Shaughnessy, head of civil engineering at WPI. But the students have been coming back—and the field has been attracting women as well. One-fifth of civil engineering undergraduates at Villanova and WPI are women, about the national average.

Fred Moses at CWRU points out, "At first glance, it appears less glamorous to be involved in maintaining existing systems, but in the long run, the jobs are there and it is socially useful." Dick Gallagher at WPI—whose daughter and four sons all became civil or materials-science engineers—sees students now choosing civil engineering because of the significant jobs created by repairing that infrastructure. Villanova's graduating civil engineers can select from four or five good offers, says Jim Schuster, a professor of civil engineering who has taught there for 28 years.

"Enlivened and enlightened teachers," adds David McCullough, can inspire in students a sense that this is a profession that "walks in the tread of giants." Good teachers can encourage future engineers to avoid what he calls the "tunnel vision" of narrow specializations with no humanistic, civilizing perspective. They can lead students to become the problem-solvers for the "very large, very important, very critical problems" that lie ahead. "There has never been a greater opportunity for talent," the author believes. "So much of what we built in the past has to be replaced and rethought."

Who would not want a bridge to be safe, or a highway kept in good shape? But in many areas of engineering, the solutions aren't so clear. Recently, the perception has been growing that the civil engineer is a "morally ambiguous actor in society," noted another 1985 National Research Council report. The professionals once admired for harnessing nature and its resources are now seen as contributing to an "insupportable insult to the environment."

"Our activities are much more under scrutiny today—nuclear power plants, off-shore oil platforms—these take layers of review to provide adequate protection against errors," explains Fred Moses at CWRU. Adds Stephen Lester at PennDOT, "We have to be very conscious of the environmental problems. You can't go in and build a highway from point A to point B. You have to take into account water quality, residential neighborhoods, safety factors, blending in improvements with existing contours, and keeping in mind the priorities people have."

Engineers tend to look at the use of land "in terms of time periods that are human and historic," states geomorphologist Dorothy Merritts, "but geologists look at it in terms of millions of years." Geologists are especially concerned about the dangers of overusing resources and underestimating the long-term effects of large-scale projects. If not sited properly, construction and development can lead to landslides, erosion, the lowering of groundwater levels, and subsidence. That confluence of human land use and natural forces has produced a caldron of controversy.

In a city like Los Angeles, "they've paved everything solid" and lined the river and stream beds in concrete, adds Merritts, a Franklin and Marshall College assistant professor of geology. After heavy rains, deep gullies form, streams overrun their banks, and flooding can be severe. Los Angeles draws its water from as far away (some 500 miles) as the

Civilizing a Nation in its Youth

For lack of a homegrown crop, America of the late 1700s imported civil engineers. To taper off that dependence on European expertise, Thomas Jefferson, in 1802, established West Point Academy, hoping it would develop an American corps of civil engineers, and it did.

It was an Englishman who had to show the Yankees how to build a turnpike when the first major one to be constructed in the United States (1792–94) washed out in the rain and sent horses stumbling. Pennsylvania's Lancaster Pike, a 66-foot-wide earth-and-pounded-stone road, joined its namesake (the largest inland city at that time) with the largest metropolis, the port of Philadelphia, 62 miles away.

By the mid-1800s, civil engineering had earned its spurs as a profession—the first engineering specialty to do so. The railroads had played a major part. In 1869 in Utah, the Golden Spike was pounded in to complete the first transcontinental railroad, thus linking the coasts and opening up the country as never before.

But even at the end of the 1800s, a city Philadelphia's size had no municipal waterworks, until the British-born Benjamin Henry Latrobe designed the first steam-powered water pumps. His project met with great skepticism, but he won over the doubtful when he and three friends opened the hydrants one night, fired up the wood-and-coal-fueled boiler, and showed how the Schuylkill River could be pumped to the people.

In early America, "a lot of barns sagged and buildings fell down, and gradually people adjusted and learned to build them better," Henry Muller explains. The former school principal, after retirement, turned his attention to his avocation, historic buildings. Muller supervises teams of masons, contractors, carpenters, historians, architects, and blacksmiths who are restoring private homes and churches in the central Maryland area.

When the roofs leak badly, the walls wobble, or the floors sink into the cellar, Muller calls in the civil engineers. In such cases, "we're afraid to do anything without someone who understands the forces involved," especially for structures built long before the days of stress-tested materials, notes the 1949 graduate of Western Maryland College.

Those buildings that stood the test of time did so because they were "basically overbuilt." Massive beams, thick masonry walls, and mortar lavishly applied held many a homestead together. Yet we may have lost some valuable construction techniques from the past, says Muller, among them mortise and pinion joints to fasten wood. "Those things have some usefulness—it's sad they're so labor intensive."

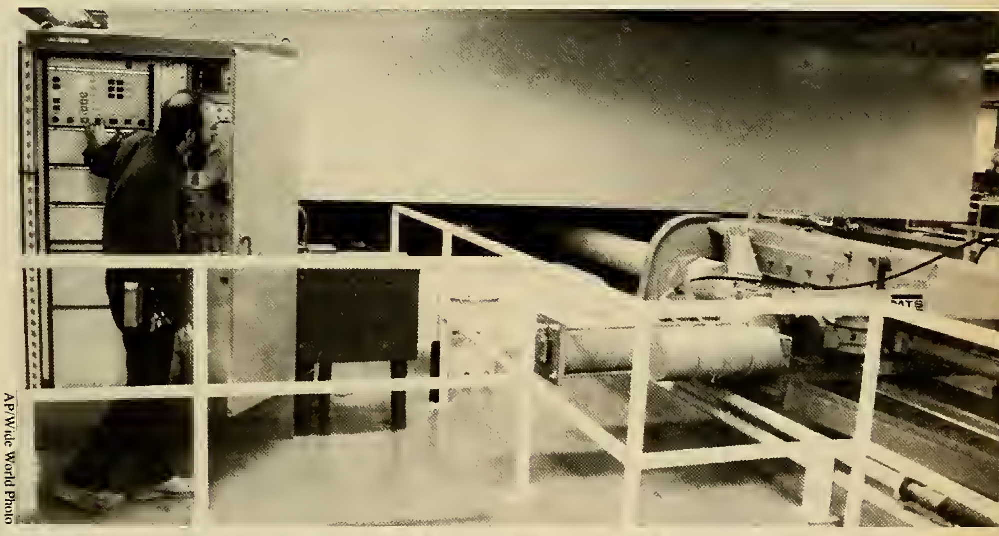
Colorado River, also heavily tapped by Southwestern cities. As a result, lakes once plied by steamboats now are dry or too saline to be of much use, animal life has been displaced, and the variety of plant life reduced.

The 1970s environmental movement brought far more rigid requirements for assessing the impact of construction on swamps, marshes, and wetlands; on the food chain; on endangered species; on the pollution of water, land, and air; and on historical and archaeological sites. In less developed countries, such environmental effects are cause for concern as well. That Third-World dam generating power for city dwellers deprives the surrounding farm land of its fertilizing floods and thus may ruin the rural economy. Add to those challenges such emerging problems as the disposal and transportation of hazardous wastes, and it appears that "we keep finding new problems faster than we can alleviate the old ones," notes O'Shaughnessy at WPI.

"Many engineers recognize that they create an impact on the environment and on residential areas, and they have to design to mitigate that impact," says Jim Schuster at Villanova, who designed the walls used to reduce traffic noise following the widening of the Pennsylvania Turnpike. He talks about how design now "is for people and the environment and not the vehicle in the roadway." Years ago, highway signs were encased in concrete; now "breakaway" design reduces injuries when a car hits one head-on. The industry calls it "forgiving" design.

There is a lot of talk—and action—in civil engineering about serving the public as well as a client. But the private sector is assuming a larger responsibility for what were once considered public works, for example, constructing a plant to transform trash into energy or connecting a freeway ramp directly to a shopping mall. IBM is picking up the multimillion-dollar tab for roads and a sewage treatment plant for its office in Southbury, Conn. Businesses know, says Villanova's Schuster, that with dampers on taxes and a drying up of federal funds, "they won't get it built in the near future unless *they* do it."

Building better, sturdier, safer, and more economically—amidst growing constraints—characterizes the challenge to civil engineering. Once built, facilities have to be maintained, says Schuster, so the design has to make it easy to get in there and paint, repair, or resurface. Some new materials have reduced the frequency of repairs: For instance, highway bridges constructed since the '60s use steel that resists atmospheric corrosion. As resources shrink, "we have to show how best to use them. You can't replace the nation's 250,000 bridges tomorrow. So what's the best strategy considering cost, safety, public liability? Often the repair requires much more planning, coordination, and thought than building the original structures," notes CWRU's Fred Moses, with whom Ohio officials consult frequently to evaluate the safety of the state's bridges.


AP/Wide World Photo

In high winds, a 400-ton concrete block running up the middle of the Citicorp Center in New York can be moved to control the superskyscraper's sway.

To search for cracks, leaks, and flaws, engineers are employing nondestructive evaluation techniques, among them electromagnetic radiation and stress waves as well as ultrasonics, radar, infrared thermography, and other methods. "Civil engineering sounds very rudimentary because we use natural materials, steel, and concrete," explains Ross Corotis at Hopkins. But it's not. Composite materials behave in complicated ways, and the waves used in the tests may not always pinpoint the problem, he adds. But progress is being made. Researchers at Hopkins, for example, have been able to induce a magnetic field to find rust spots (called holidays) as small as a dime when the plastic coating on gas pipelines deteriorates and exposes the steel to oxygen.

Such technologies and methods—more so than the materials—are where the most promising recent developments have come from. Civil engineers have found numerous significant uses for computers, Corotis points out. Engineers can reduce corrosion by using a direct electrical current on steel anchor cables on bridges. They can deploy sophisticated remote sensing—which grew from the 19th-century French military's use of hot-air balloons for aerial photography—for mapping routes, conducting feasibility studies, and gathering data on terrains. A computational method WPI's Dick Gallagher pioneered in the 1950s at Bell Aircraft, called the finite element method, enables engineers to understand and design such complicated systems as Lunar Excursion Modules, computer components, and superskyscrapers by studying their smaller, discrete parts, then linking them back together to analyze the whole.

Civil engineers will continue to set their sights on such societal needs as constructing correctional facilities, improving overcrowded airports, and providing innovative ways to build under water. They are designing megastructures in which 10 to 20 stories function as a single structural unit, they are stretching suspension spans across several miles, and they are contributing to building ships and to the exploration of space. For professionals so closely tied to the earth's surface, civil engineers—far from feeling earthbound—see their future projects digging deeper, stretching wider, and soaring higher than ever before.

Donna Shoemaker is editor of the Alumni Magazine Consortium.

FRESHMAN DISORIENTATION

...a short-lived rite of fall

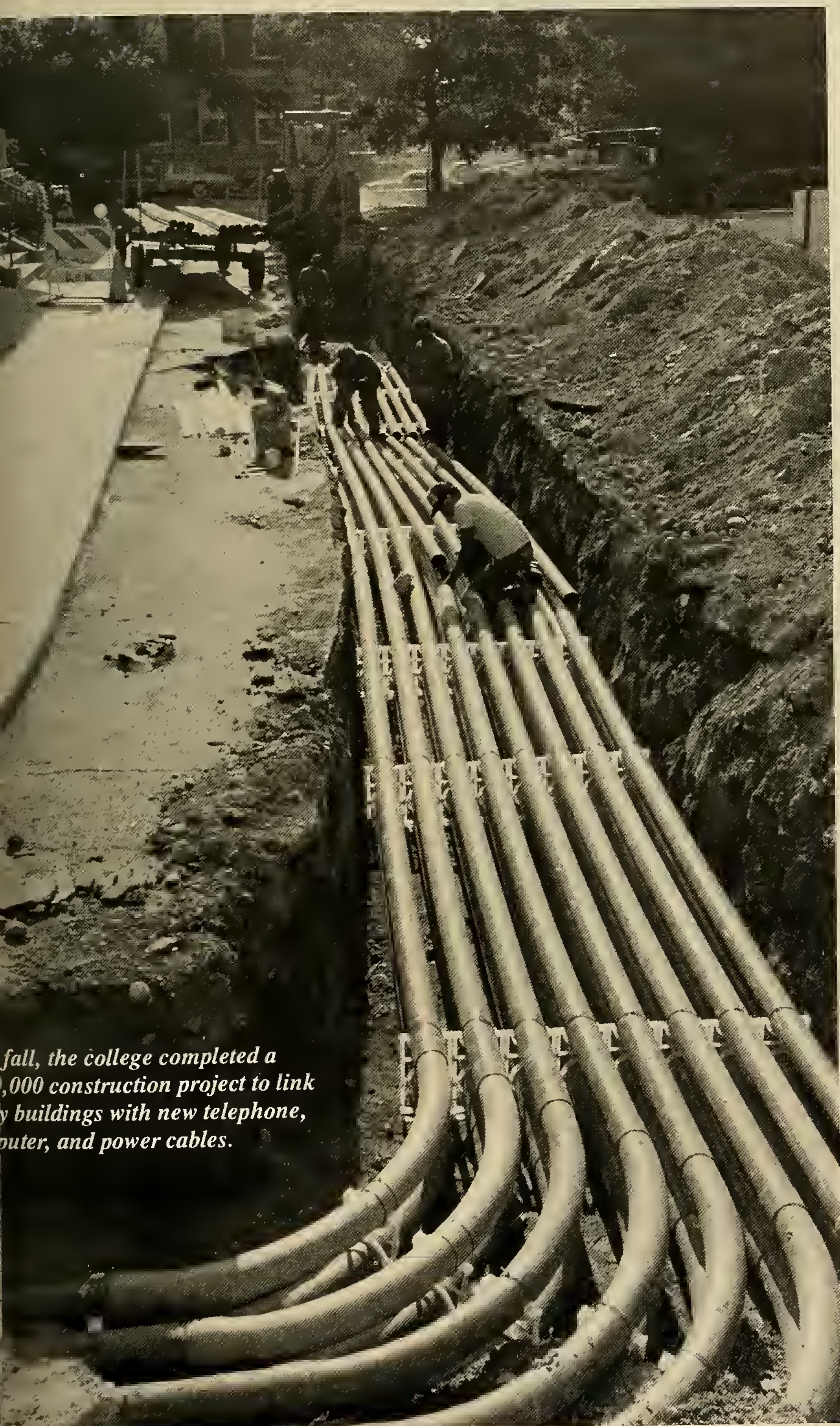
Sid Harris takes a fresh look at the first semester. The cartoonist's collected works include *Chicken Soup and Other Medical Matters*, *What's So Funny About Computers?*, and *Science Goes to the Dogs*.

"I don't think Wally is going to last here. He found orientation week too difficult."

Type A Freshman: Changed courses four times, took a job, organized a protest, quit the job, plans to take second semester abroad.

"You find out about starting salaries when you *finish* college—not when you *start* it."

Here, as at other universities, those who build and maintain physical resources have a unique perspective on the campus.



fall, the college completed a
,000 construction project to link
y buildings with new telephone,
puter, and power cables.

Kenneth McDonnell

Always Growing, Forever Changing

By Bonnie Gelbwasser

Take a walk through the campus and it won't be long before you encounter someone from the Department of Plant Services painting the trim in a hallway, reseeding a grassy area, tending to custodial chores, or restaining the intricately carved arches of Alden Memorial.

John E. Miller, vice president for physical plant, explains that the department's mission is to "maintain and operate facilities, plan for their major upkeep and repair, and work with architects and engineers to develop designs and construct new facilities. Former College Engineer Anthony Ruksnaitis '53 puts it another way: "The department is there for the safety, comfort, and convenience of the students, faculty, and staff."

The objectives of the $52.5-million *Campaign for Excellence* reflect the

To remain the pleasant place it is, the campus requires year-round maintenance and attention to detail.

Institute's commitment to the upkeep of the campus as a vital component of a WPI education. In addition to seeking funds for enhancing the undergraduate academic program and adding faculty and new programs, a goal of $19.6 million has been set for physical plant development.

The money, Miller explains, will be used for projects like the construction of Fuller Laboratories, which will house WPI's information sciences, the Computing Services Department, and a 400-seat lecture hall; completion of renovations to Salisbury Laboratories for programs in biomedical engineering, biology, and biotechnology; construction of an addition to Goddard Hall for the Chemical Engineering Department; renovation of the outdoor athletic facilities (completed in 1986); property acquisition to meet future needs for student residences and offices for support functions; and a continuation of the campus beautification program.

Once assigned to a few faculty members, operation and upkeep of the campus now rests in the hands of the 80-member Plant Services Department.

An additional $5 million in unrestricted funds is being raised to enable the college to take advantage of unforeseen opportunities and to limit the need for deferred maintenance (like long-term wear and tear on buildings, roof replacements, and masonry repairs).

Donald F. Berth '57, vice president for university relations and executive officer of the *Campaign*, admits that generating contributions for Plant Services can be difficult. "Tuition represents only 45 to 48 percent of the actual operating cost of the institution, which includes such items as heat, plumbing, and grass for the baseball diamond," he says. "It's tough to raise money to replace rusted nails in slate roofs, to take out bricks that have cracked because of water penetration, to replace dead trees on the campus, to repair parking lots, pull the weeds, and paint the residence halls."

Ruksnaitis, who retired earlier this year, established the plant services department in 1956, when an active building and renovation program was under way. In the mid- to late 1950s, Morgan and Olin Halls were completed, along with an addition to Alumni Gymnasium; Boynton Hall, Washburn Shops North Wing, and Atwater Kent were renovated.

Before that, Ruksnaitis says, faculty members were assigned particular maintenance tasks. He recalls, for example, that A.J. Knight, professor of engineering, was charged with the upkeep of the buildings and grounds. William Locke of electrical engineering supervised electrical maintenance and distribution, and the power plant was under the direction of Prof. Robert Kolb of the mechanical engineering department.

These days, Miller says, his department maintains 1.1 million square feet of buildings, from academic and administration buildings to two gymnasiums and 62 acres of landscaped grounds, parking lots, and access ways. Miller, who has a bachelor's degree in mechanical engineering and a master's degree in management from Clarkson University in Potsdam, N.Y., came to WPI in 1982 from American Optical Co. in Southbridge, Mass. He says the work of Plant Services is divided into three categories: engineering, administration, and operations.

Engineering, he says, involves participation in the design and construction of new buildings. "There has been about $13 million in capital construction here at WPI in this five-year period," he says, "and we work annually on about 60 to 80 other projects in a wide range that includes deferred maintenance, smaller renovations, and the construction of new labs and reallocation of space."

WPI Locksmith Frank Mancini

Michael Carroll

Frank Mancini is a modern-day keeper of the keys. For the past dozen years, this quiet, dignified man has been responsible for keeping track of every key on campus—no small task, considering that there are locks on approximately 3,000 classrooms, laboratories, mechanical rooms (like elevator control and electrical rooms), offices, bathrooms, and dormitories.

A member of the Department of Plant Services, Mancini works closely with campus police and tradespeople to provide access and security for students and staff members. "My job is the most demanding classification on campus. Security here is *very* big," he says.

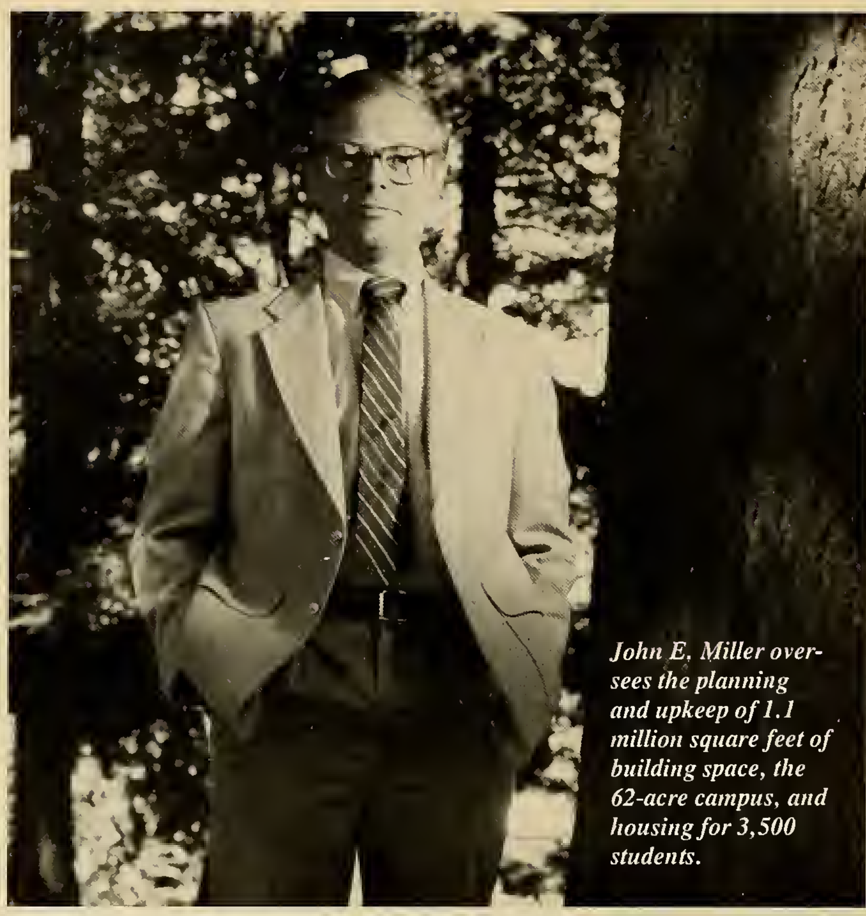
In his crisply pressed khaki uniform and visored cap, calmly fielding calls that come in one after another on his mobile telephone, Mancini explains that his job includes "repairing and replacing broken locks, resetting locks, and re-keying buildings or doors if keys are lost. Every school key is made right in my shop using special blanks provided by just two key manufacturers."

He adds that whenever a building is constructed or renovated new locks are installed and keys made. Most of the time, "the factory and I coordinate the job together. They make the locks and install the hardware; I install the permanent lock and maintain the system." A soon-to-be-computerized file of 7,000 key codes ("the cut of the key") enables him to create new keys, duplicate keys, and set up locks as needs arise.

Mancini was a construction worker and union carpenter before he joined the WPI staff. Day to day, he says, "you learn by trial and error." He notes that the trade has been changing as the industry expands to include computerized locks, electronic locks, and alarm locks.

Although students sometimes test his skills and patience—"They kick off the door knobs or put shaving cream and glue into the locks"—Mancini remains philosophical. "I expect that here, because the kids come here to study and also to have a little fun. It's par for working at a school where kids will be kids."

Despite the frustrations, and his view that the shop "needs more than two hands to operate," Mancini says he loves his work: "The people are nice, and management is great—very knowledgeable and conscientious."



John E. Miller oversees the planning and upkeep of 1.1 million square feet of building space, the 62-acre campus, and housing for 3,500 students.

Administratively, the department oversees the operation of the 800-line telephone system; internal material acquisitions; purchase order preparation for goods, services, and contracts; and approximately 3,000 work orders a year. In addition, he says, "We lead the safety efforts on the campus." Miller is chairman of the Campus Safety Committee, which is "concerned with fire safety, the right-to-know law, hazardous waste disposal, and machine shop and general safety."

A total of 60 employees staff the operational division of Plant Services, which includes the power house—"We have three boilers and use more than a half-million gallons of heating oil each year"—the buildings department, which handles custodial duties; the grounds

John M. Cuth '72 ME:
Snow and Sports in Marquette, Michigan

As manager of trades and utilities at Northern Michigan University, John M. Cuth is responsible for an annual budget of $1.4 million, 67 buildings encompassing six million square feet—including all building systems, heating, ventilation, cooling, and operation—and maintenance of the central heating plant. But because of the university's location, Cuth deals routinely with problems most college plant administrators never face.

The 300-acre main campus (an additional 175 acres is used for summer research camps) is located on the shores of Lake Superior in the city of Marquette, which Cuth describes as "the fourth coldest place in the lower 48 states," with 250 to 300 inches of snow each year. Although his department is not charged with snow removal, he says that "the challenges include the heating load and the added sense of urgency if things aren't working when it's minus 35 and the winds are blowing."

In addition, Cuth says he has to contend with "a very, very short construction season," which has an impact on the timing of such projects as repairs and outdoor painting. "There's snow on the ground as late as the last week in May and generally by the first of October," he adds. "We're in a rural area, 175 miles north of Green Bay, Wis., and 80 to 90 miles from the nearest interstate highway. We have a lot of trouble getting all kinds of supplies and materials, which has an impact on scheduling and planning."

In February 1985, the university was one of only three to be designated a training center by the United States Olympic Committee. Ground breaking for a new sports complex with an enclosed dome—the largest clear span wood structure in North America—took place this fall.

The Michigan State Track and Field Games were held on the campus in August. More than 4,000 athletes were on campus for three days of competition. Cuth's department responsibilities included providing shuttle buses, 600-amp service, scaffolds, and staging. "It was a tremendous organizational experience," he says.

Cuth says that because physical plant is second only to personnel in cost for an organization, good management and maintenance "can be translated into large dollar savings.

"We as engineers have to sell our programs and show the cost advantages of a first-rate maintenance organization, particularly with regard to problems like shrinking enrollment and cutbacks in funding." Of engineering as a whole he says, "It's an interesting profession. People never call you and say, 'Thanks a lot, my roof isn't leaking.' People call when they have problems."

department; and the trades group, a manager and 12 employees responsible for technical maintenance like carpentry, plumbing, electrical work, heating, painting, and lock and door repair.

Miller's annual budget, he says, is about $3.9 million, which represents 10 percent of the college's budget. Deferred maintenance is one of the major challenges in keeping the plant up to date. The buildings are of different types, uses, and construction. They were built over a number of years—the oldest is nearly 125, the newest just two years old. All are unique, and they wear out. Every organization that has a physical plant must recognize that buildings are constantly, perhaps imperceptibly, deteriorating. If there are no funds for upkeep, owners can accrue a "debt" to their buildings that will be expensive to pay off.

> "If classrooms weren't open in the morning or the dormitory showers ran cold, the campus would be a very different place."

"In general, that has not been the case at WPI over the years," says Miller. "We want to keep it that way by aggressively budgeting and planning over a special time cycle the maintenance and replacement of major building components." Based on the types of buildings, he adds, an organization can be expected to spend 1 to 2 percent of the replacement value of the buildings in annual maintenance. If the buildings average over $100 per square foot in value, $1 to $2 million could be the cost of day-to-day and long-term maintenance.

William R. Grogan '46, dean of undergraduate studies, underscores the importance of Miller's goals to the entire

Frank Kuszpa '68: Growing with the University of Hartford

"The challenge for administrators is achieving a balance between the academic and operational needs of colleges and universities," says Frank Kuszpa, assistant vice president for operations at the University of Hartford in West Hartford, Ct. "There will never be enough money to run the campus as we'd like to. The issues are balancing the budget and providing education at a college without sacrificing the facilities."

Kuszpa was director of physical plant at the university before assuming his current post in 1986. He is responsible for a 175-member staff and supervises all physical plant operations for the 8,000-student liberal arts college.

He also serves as president of the Southern New England Association of Physical Plant Managers and is secretary of the national organization. After graduating from WPI in mechanical engineering, he went on to earn a master's in mechanical engineering from Rensselaer Polytechnic Institute, and is completing an executive M.B.A. at the University of Hartford.

"Engineering gave me a great background and taught me logical thought processes," he says. "But being successful in my work means going out and talking with people. I don't like sitting in an office and shuffling papers. I visit students, faculty members, and deans to discuss their concerns and problems." Kuszpa agrees with Malcolm Forbes, who said that his most important resources were the people who reported to him. "I am very much that way. I see myself as mentor to my staff."

The University of Hartford was founded almost 30 years ago. "As you reach 30," says Kuszpa, "maintenance starts piling up." He recently formulated a capital spending plan that has placed all university projects in one computer data base: "This way, when the time does come to make a decision between academic programs and other needs, you can make an educated choice."

The university is growing, with several projects on the books or under way: an 850-bed dormitory, a new physical education center, and a $21-million university center, expect to be completed in September 1988.

"We're toward the end of a $30-million capital campaign, and generating funds for plant maintenance has been one of our major challenges," he says. "You could construct all these buildings and you approach a company and say, 'Wouldn't you like to give a million dollars toward the maintenance?' They want to see their money in concrete or their names on the building. Donors generally aren't interested in saying, 'I'm helping to keep the place clean.'"

David R. Collette '67: Serving Mount Holyoke

Asked to describe his job, David R. Collette '67, Mount Holyoke College's director of physical facilities, says laughingly, "I'm responsible for everything that's broken." He then explains, "I have about 200 people working for me: custodians, housekeepers, craftsmen (plumbers, painters, steamfitters, carpenters, electricians), office staff, storekeepers, general laborers, and groundskeepers."

Mount Holyoke, founded in 1837, is the country's oldest institution offering higher education to women. The 800-acre campus, located 12 miles north of Springfield, Mass., has 100 buildings with 2 million gross square feet. Approximately 1,950 female students are enrolled in undergraduate and a limited number of graduate programs.

Collette says that as a women's school, "the challenges are different—security problems are higher, damage problems are lower," but adds that Mount Holyoke, like other private institutions, share needs to hold the line on spending in spite of a growing facility.

Mount Holyoke is celebrating its 150th birthday this year, and members of Collette's staff are responsible for maintaining everything from the earliest structures—"Some of my housing units were built before 1800"—to the new, 65-stall equestrian center, which is part of the physical education facilities. A new campus center, expansion of the library, and the construction of an academic building for the language department are planned for the future.

Collette says of his work, "It's a service position, so you get the joy of meeting the needs of an academic community. Personally, I like working with people directly, seeing them grow, making them better managers and better workers, putting fun in the workplace." Any maintenance position has an image problem, he claims. "Maintenance people feel insecure more than they should. My own personal feeling is that the relationship between maintenance people and faculty at Mount Holyoke is excellent."

Collette, who has a master's degree in business from American International College and has held his current post for two years, says that in order to succeed at the job, "You have to be a good manager and a good engineer."

"In large part, prospective students measure colleges in terms of what they can touch and see."

educational program. "If the classroom buildings aren't open in the morning," he says, "or the showers in the residence halls don't have hot water, the campus would be a very different place to live in and to operate." To a certain extent, he notes, Plant Services provides all those things we take for granted—"And they do it day after day. People only think of them when something goes awry."

Plant Services also plays a less obvious role, he adds. In a college with 2,600 undergraduates, it's vital that the ambience of the campus and buildings be maintained: "There really are only two states for a college campus," Grogan claims: "very well maintained, where the staff respects and continues that high quality of maintenance; and one that when things start to slip, they very quickly go all the way with graffiti, holes in the walls, junk on the lawn, and broken windows. It takes considerable energy on the part of Plant Services to maintain the top state. We feel we have a very attractive campus here. It has a big effect on admissions." Especially at the price of a WPI education, he says, *Completed in 1985, the 225-bed Founders Hall was the largest construction project undertaken by WPI. Now on the drawing board is Fuller Laboratories, a $6 million information sciences center (inset).*

"Nobody wants to live in a dump!"

Robert G. Voss, executive director of admissions and financial aid, says that a survey of undergraduates admitted for 1986 revealed that 92 percent of the respondents said that campus appearance was an important factor in their selection of the college. Other items included project activities, which rated first at 95 percent, and quality of labs and student activities, rated at 93 and 91 percent, respectively.

Voss says that a positive campus image is an important marketing strategy: "If people perceive our campus to be pleasing, and it's important to them, then we want to promote that fact. It's awfully difficult to measure the quality of academic programs. Students have a heck of a time figuring that out, so they often measure colleges in terms of what they can touch and see."

"The physical plant is incredibly important to the functioning of the college," Miller claims. "It provides the roof; it provides the services. The plant people do their jobs and more. We're responsible for so many of these little things for so many people. We're the service sector."

The department's toughest job, he says, is realizing its importance and the importance of the services its people provide. "It's sometimes difficult to find our role in such a sophisticated environment," Miller says. "The service we provide at this college is essential to its operation. These needs exist, and they have to be addressed."

Bonnie Gelbwasser is a freelance writer living in Rutland, Mass.

Winthrop M. Wassenar '59, '60 MCE:
Williams College Director Finds His Job Interesting and Frustrating

Winthrop M. Wassenar '59, of Williams College in Williamstown, Mass., says, "The job at different schools varies. At the larger ones, planning and plant are separate; at Williams, what I do is serve as director of facilities and planning.

"The job has two parts: the day-to-day maintenance and operation of the campus from the custodial to the grounds crew with responsibility for all the trades necessary to keep a large plant going, and planning, accomplished with a full-time staff, including a registered architect, a registered mechanical engineer, and a registered civil engineer." Wassenar himself is a registered civil engineer and a member of APPA, the Association of Physical Plant Administrators.

Wiliams College, founded in 1793, is an undergraduate college (there are also two master's programs) with an enrollment of about 2,000 men and women. The central campus encompasses 450 acres with 98 buildings totaling approximately 1.8 million square feet. The college owns an additional 2,500 acres including the 2,000-acre Hopkins Memorial Forest.

Wassenar administers an annual operating budget of approximately $8 million and says, "For the last two years, the total value of construction projects in progress has been averaging about $20 million. In the last 20 years, we've built a new science center, dormitories, track, football and baseball fields, a new infirmary, two additions to the Williams College Museum of Art, and a new library and field house."

His office is involved from the initial conception of a project. Once that decision is made, he notes, he gets involved with the interview and selection of the architect and then shepherds the whole design process through the various stages to the point of going out to bid. "We supervise the construction of the project to occupancy, and then we maintain and operate it forever more. It's a total facilities aspect, from inception to design to construction, occupancy, and day-to-day operation.

"I personally get more pleasure out of the planning and creative aspects of the job," he says. "The other aspect I think is really rewarding is dealing with the students, who can be both interesting and frustrating, the faculty, the administration and, in a small town like this, the community. The frustrations are like those in any job—like when the power goes out in the middle of the day and the computer shuts down . . . It adds to the excitement."

By Paul Susca

In Praise of What Persists

If engineering students can graduate without tackling science and mathematics courses, those subjects can't be too important to the field. Not so, say top educators.

Michael Carroll

Physics Professor Robert Long says that the department recommends courses in modern physics to few students because "they aren't going to get much out of that that's applicable to what they're doing in later life." Classical physics is still the mainstay of physics education for undergraduates.

Engineering does not stand on its own; it stands on the shoulders of science. That point is often taken for granted, but every once in a while someone suggests that engineers don't use much science, and that therefore engineering students only need to be exposed to just enough science and mathematics to get by in their engineering courses.

WPI's experience with the evolution of the Plan (*WPI Journal*, August 1986) has revealed the idea that science might be superfluous for the engineering student. In fact, William Grogan '46, dean of undergraduate studies and one of the chief architects of the Plan, recalls that when science requirements were removed in the Plan's early years, students stopped taking those courses.

"Word got around," Grogan says today, "that they could pass their engineering courses and their Competency Examinations without having taken the traditional math and science courses." That was true, he adds, "because the engineering courses tend to be stand-alone events; whatever science is needed is presented in the course."

The science and math requirements were reinstituted in 1986 at the insistence of the Accreditation Board for Engineering and Technology (ABET). But if WPI students managed to graduate and to function in their engineering careers without math and science courses, are they really needed?

Grogan poses a different question: What's important, he says, is not whether every engineer *needs* science to function, but whether science *should* be in the background of an engineer? "I would say very definitely yes, absolutely," he answers. The same holds true for humanities: "It's just plain good education. An educated person, whether an engineer or a liberal arts graduate, should understand the nature of the universe in which he or she lives, as explained by scientific principles."

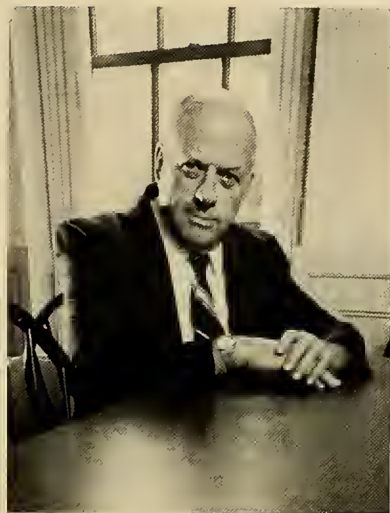
A command of scientific principles offers more than an understanding of the world in which we live; some argue that an education that focuses on technology without relying heavily on the scientific basis of technology does not prepare students to be engineers at all, but to be technologists. But while the prevalence and variety of technology in modern society has created a niche for innovation for the new class of technologists, the practice of engineering has come to rely even more heavily on basic science.

In the field of mechanical engineering, for example, advances in physics and mathematics have led to the relatively recent development of nondestructive measurement techniques. One of those techniques, laser Doppler anemometry (LDA), which is used almost daily in Mechanical Engineering Professor William Durgin's fluid mechanics laboratory, is based on laser techniques developed by physicists. LDA makes possible the measurement of air velocities anywhere in a wind tunnel without putting an instrument inside the tunnel. The technique was first developed around 1970, Durgin says, and is now used routinely around the country.

A look at the science curriculum shows how close the relationship is between cutting edge science and new technology—so close that the line between science and technology becomes blurred. The physics department, for example, offers courses in multilayered semiconducting heterostructures and optoelectronics, two areas that are revolutionizing electronics. And just across the street, biology and biotechnology has courses in fermentation and downstream processing, relying on biology to expand the horizons of process engineering.

The increasing interactions between fields, especially the life sciences and various engineering fields, make an even stronger case for a solid grounding in science, says Robert H. Goff '52, associate dean of engineering at the University of Rhode Island. Goff cites the importance of biology to environmental problems faced by civil engineers, physiology applied to robotics, and, of course, biotechnology. "I think we want more creativity out of our engineers—less being the technician," says Goff. "And I think you're more apt to function in a creative fashion if you have a broader basic science background."

But short of increasing the number of years required to earn a bachelor's degree in engineering, boosting the basic science content of engineering programs would involve some trade-off of engineering design skills. In a conflict between the science basics and engineering practice, some criterion must be found that can be relied upon to measure the long-term value of the two competing aspects of engineering education. The test that educators often apply in this comparison is the question, What aspect of education endures longest?


Michael Carroll

"Science *should* be part of every engineer's background. It's just plain good education," says William R. Grogan '46, dean of undergraduate studies.

"The important thing," says Goff, "is that the graduates realize that there is a lot they never learned in school, some of it because it was unknown at the time. Therefore, if they're going to stay on the cutting edge of what's happening, they've got to be learners for the rest of their professional careers."

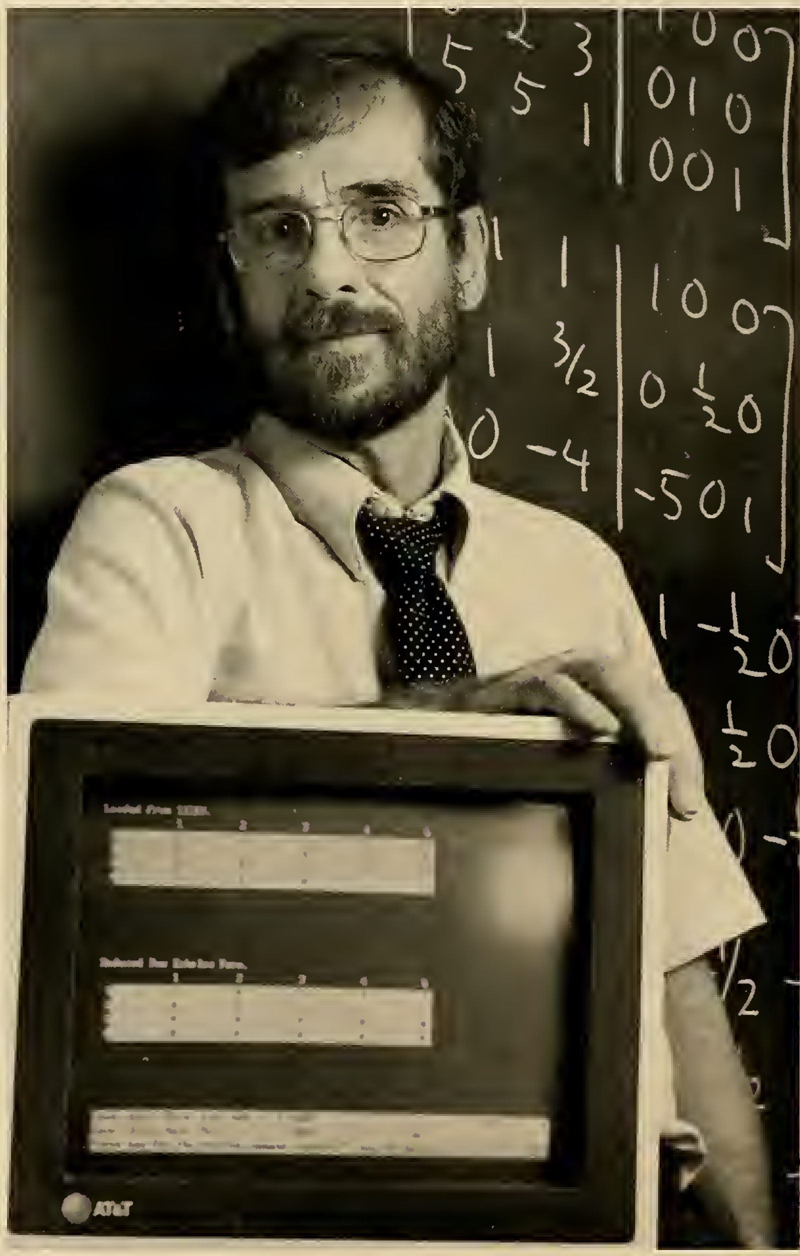
Surveying the continually shifting landscape of high technology—microelectronics, optoelectronics, computers, and the entire field of biotechnology—Donald E. Sands '51 also sees an increasingly strong case for science. Sands, academic vice chancellor at the University of Kentucky in Lexington, says, "If there's one lesson in all of this, it's that we can't predict what the future will hold, and our students do need to be prepared to continue their learning. Whatever they learn now is going to be obsolete in a few years."

Bill Durgin echoes the idea of the durability of a solid background in science. "I was educated under the philosophy that if one understands the basics well—and by the basics I mean the math and science underlying our field of engineering—then one can address any new fields that come along or any new applications that come along," he says. "And I've always found that to be true in my experience."

There is a large school of educators who favor bolstering the science content of engineering education for that very reason, says David T. Hayhurst '72, chairman of the chemical engineering department at Cleveland State University. He cites separation processes as an example. Distillation has long been taught as a separation process, but industry is moving increasingly into other separation methods such as adsorption. "Some people feel we should be giving students a fundamental understanding of the basic mass transfer concepts, says Hayhurst. "Let industry, they would say, bring students up to speed with the state of the art."

If the role of advanced techniques in engineering practice yields ground to an increased emphasis on underlying scientific concepts, then industry has to take up the slack. But according to Professor of Electrical Engineering James Demetry '58, that has long been the case. "Companies take in young, bright people with four years of engineering school, and they teach them what they have to know to be productive and creative people inside the company. I don't think they

Professor of Mathematics J.J. Malone says that because students don't think in terms of long-range goals, "they often look upon the math and science as a necessary evil."



Michael Carroll

expect them to be productive from day one."

Grogan also champions science and mathematics for the durability and flexibility they provide to graduates. "We tend to be very application-oriented," Grogan says, "sometimes at the expense of understanding. I think the price we pay for that is ultimately a lack of flexibility on the part of students. Once the technique they learned is superseded by a newer technique, too often students do not have a depth of understanding of the scientific principles that enable them to adapt to a new situation."

That aspect of the relationship between science and engineering is nothing new, the former electrical engineering professor points out. "The historical evolution of engineering is from science. So in a highly changing technology, a deeper understanding of science would seem to be a more durable element in education than the more volatile state-of-the-art technique."

The durability of science is borne out by how little freshman science courses have changed over the years. True, says Robert Long, professor of physics, the advances that have taken place in physics in the last 50 years have led to previously unimagined developments in nuclear and electronic technology and sophisticated instrumental methods used in chemical analysis. Still, he says, the department recommends its course in modern physics to few engineering students. "They probably won't get much out of the course that will be directly applicable to their future careers," Long says. Because of its lasting relevance, classical physics is still the mainstay of the physics background for undergraduate engineers. The same is true of mathematics, chemistry, and biology: Material that is presented to students in the first few courses has not changed radically over the years, except when it has been updated to reflect new knowledge.

There is, however, a movement afoot nationwide in the mathematics community to investigate to what extent courses in discrete math should be introduced into the first-year curriculum for scientists, engineers, and mathematicians. This, says J. Richard Lundgren '64, chairman of the mathematics department at the University of Colorado at Denver, is because of the ubiquity of computers and the need for computer users to exploit the machines' use of finite math, as opposed to the traditional calculus that every technically inclined freshman learns.

A computer is a finite machine, Lundgren explains, meaning that much of what it does can be shown on a graph with discrete points rather than the smooth lines characteristic of calculus. So computers handle information in a very different way than it is often described in calculus. Finite math is also useful in choosing how to structure data in a computer program, Lundgren says. And the importance of finite math to engineers will continue to grow, he adds. "This field of mathematics is absolutely essential to building models and solving problems using supercomputers and parallel computers, which engineers will find themselves using more and more."

"Finite math is absolutely essential to solving problems using supercomputers," says Colorado's J. Richard Lundgren '64.

In upper-level courses, Lundgren notes, a significant advance is the increased activity in computational math—the development of numerical methods and algorithms for use in solving physical problems on the new generation of supercomputers.

This already accounts for a major part of Lundgren's department at Colorado. And he is already seeing many undergraduate engineering students taking as electivcs, in addition to the required math (the calculus sequence, differential equations, and linear algebra), such courses as discrete (finite) math, mathematical modeling, and numerical analysis—all prompted by the needs of technical computing. "In 10 years," he claims, "you'll see a revolution in the teaching of mathematics."

University of Rhode Island Dean Robert H. Goff '52: "We want more creativity from our engineers—less being the technician."

As the importance of various types of mathematics shifts, what does that portend for the courses recommended for engineers? Professor of Mathematics Gordon Branche says the growing importance of numerical data analysis necessitates an understanding of its mathematical underpinnings. But he notes that the question of how to make room for the new material is a delicate issue. Eventually, he says, some kind of accommodation will have to be made between adding more material or courses and shifting the emphasis of the courses that are currently required. But the process of assimilating discrete math into engineers' preparation is a slow one, Branche says, because it is not exactly clear how the math is going to be used.

To make matters worse, students already in the dark about the applications of the math they are learning can often look forward to at least two more years of study without using it. Branche says that sophomore and junior engineering courses sometimes fail to reinforce freshman calculus, so by the time senior year rolls around students have lost whatever calculus they once knew. "One of the things I would like to see as we incorporate discrete math is that we somehow have to reinforce calculus concepts," Branche says, "because calculus is cumulative."

Although science courses have remained relatively stable over the years, the relationship between science and engineering, particularly the role of science in engineering education, has changed. Since its emergence as a discipline during the Industrial Revolution, engineering was taught essentially as a set of skills. William Grogan characterizes the state of engineering before World War II as "rather stodgy, very pragmatic." But the military importance of radar and electronics in general, Grogan says, "kicked up the scientific component of engineering significantly. Then it plateaued and Sputnik kicked it up again."

Mason H. Somerville '64, dean of the College of Engineering at Texas Tech University, sees Sputnik as the catalyst that precipitated a major shift away from the "technology-based curriculum" he graduated under, comprising design courses, hands-on lab courses, drafting, machine shop, and foundry in addition to theory courses. As the U.S. space program was stepped up, he believes, it became much easier to get funding related to the space race, and the emphasis of engineering research and teaching shifted toward high technology—meaning engineering science—which in turn required engineers to have more math and science background. As a result, Somerville says, students became much more proficient at math, science, and engineering science at the expense of the traditional engineering skills.

As the practice of engineering has become more scientific, engineering departments, in response to the accrediting boards, have prescribed more math and science to prepare their graduates for the demands of their careers. But students don't always swallow their teachers' prescriptions without question. According to Professor of Mathematics J.J. Malone, chief architect and teacher of linear algebra courses at WPI, "Students have fairly immediate goals. Sometimes it's hard for them to be tolerant of the goals that fit into the long-range goals. So they often look upon the math and science as a necessary evil, and they even question the 'necessary' part of that."

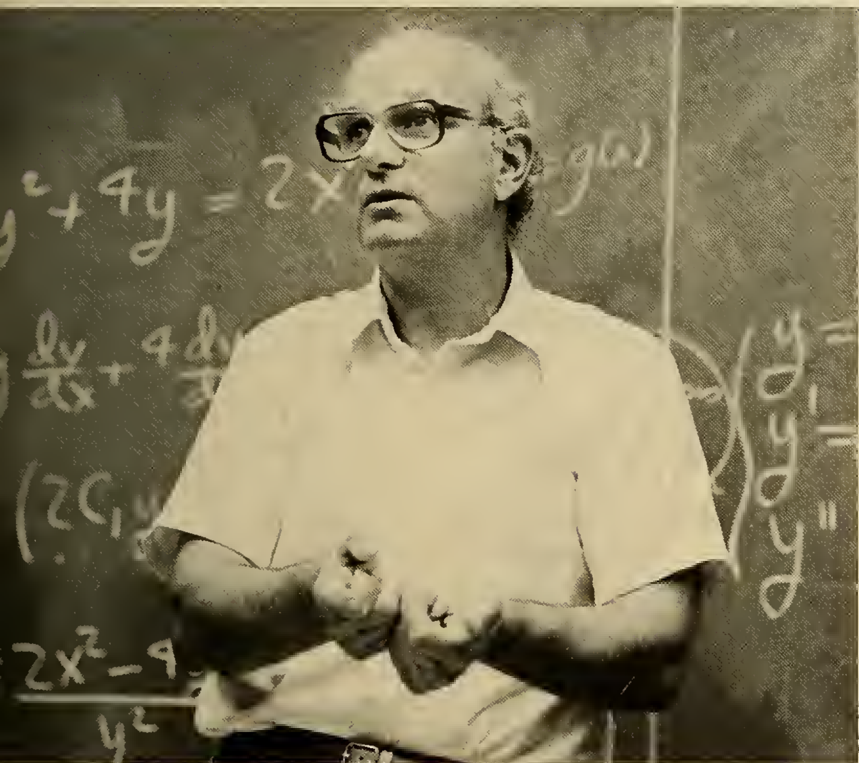
At Cleveland State, David T. Hayhurst '72 has brought in engineers with industrial experience to teach math to chemical engineering students.

Malone has seen the annual enrollment in linear algebra courses, which typically come after calculus and differential equations—usually some time in the sophomore year—grow from less than 80 to over 400 in his time at WPI. "That's not because students have the foresight to anticipate the need for linear algebra," he claims, but because many of the engineering departments, particularly electrical engineering, specifically recommend the courses." But because students sometimes question the need for more math, Malone feels it is the joint responsibility of the mathematics and engineering departments to show students that it is indeed necessary.

In 1984 Malone advised a student doing an Interactive Qualifying Project (IQP) that successfully sought to identify applications of linear algebra in undergraduate engineering courses at WPI. Now, Malone says, "You can say to students, 'In your first chemical engineering course, here is how you used linear algebra. And in your early electrical engineering you used systems of equations to figure out circuits. And in civil engineering you're using eigenvalues to study questions of structural stability.'"

David Hayhurst says his department has found a different way to address the question of the relevance of mathematics material to engineering students. At Cleveland State, engineers with industry experience are brought in to teach math—in particular numerical methods using computers—as part of the core curriculum in engineering sciences. That's after students have already taken the usual courses in calculus, linear algebra, and differential equations.

A mathematics professor, Hayhurst says, does not have the experience to teach the numerical methods course at the same level that a seasoned engineer can. At a large university, this approach to teaching numerical methods, which concentrates on subjects rather than departments, can result in some turf battles. Hayhurst says that "Every time the mathematics department asks us what we're teaching, we tell them it's engineering, but the engineers swear it's mathematics. Most likely, this is a phenomenon that is not unique to Cleveland State, but is shared by many institutions."



Michael Carroll

As new directions in math emerge, says Dr. Gordon C. Branche, associate professor of mathematics, "we'll have to decide how best to make room for the new material in an already crowded curriculum."

What will be the next episode in the saga of engineering and science is anybody's guess. But some educators are willing to do some crystal ball gazing. Citing the eroded competitive position of the United States in manufacturing and the Soviets' leading position in space with an almost continually manned space station in orbit for several years, Bill Durgin thinks the time may be ripe for another upheaval like the one that followed Sputnik.

Mason Somerville says Star Wars may turn out to be the next landmark event, although it is hard to say what its impact will be. In any case, Somerville sees a division of labor between engineers and technologists. Because major advances in technology depend on exploiting basic phenomena—molecular and even subatomic—engineers with substantial math and science backgrounds will work on the cutting edge.

Technologists, those with associate degrees in engineering or B.S. degrees in technology, will become the stewards of existing technology, operating and maintaining the economic and industrial infrastructure and implementing its slow evolution. Somerville also suggests that the rise of educational programs for technologists was sparked by Sputnik in the first place.

As far as the next chapter of engineering education is concerned, Donald Sands hopes to see it borrow a page from science, tempering engineers' tendency toward certitude with shades of gray. One of the things that science teaches, Sands says, is a sense of its own limitations. Sometimes this readiness to admit what isn't known even shows up as basic principles of science, such as the Heisenberg Uncertainty Principle, the second law of thermodynamics, and Goedel's Proof in mathematics.

"I'd like to see engineers impressed more with shades of gray," he says. "Engineering tends to be deterministic: If you connect this to this, the current will run from here to there and there's no doubt about it. Well, the real world is made up of lots of shades of gray."

THE PRESIDENT'S MESSAGE

WPI, Inc.

By Dr. Jon C. Strauss

Industrial involvement is both one of the oldest and one of the newest emphases for WPI. It is the oldest in the sense that it was the *raison d'être* for the industrial and community support that brought WPI into being as the Worcester County Free Institute of Industrial Science in 1865. And today, the rebirth of interest in industrial manufacturing is the key to the nation's international competitive strength. Cooperative ventures uniting universities and businesses are expanding nationwide in such high technology areas as aerospace, artificial intelligence, biomedicine and biotechnology, materials, microelectronics, nondestructive testing, and superconductivity.

Ichabod Washburn, one of the founders of WPI, built the Washburn Shops to house a for-profit manufacturing business in which WPI students could apprentice to learn firsthand the manufacturing skills and techniques of the day. In the 1890s, the increasing profitability (and competition) of the Shops had become such a *cause célèbre* with local industry and tax officials that the trustees of the college voted to de-emphasize for-profit manufacturing. As a result, Milton P. Higgins, the first superintendent of the Shops, resigned, along with his friend Prof. George Alden. The two went on to build Norton Company, which they had founded, into an international force in industrial abrasives manufacturing.

At that same time, Milton Higgins bought the rights to the hydraulic elevator that he had invented and manufactured in the Washburn Shops. Subsequently, he sold the rights to Otis Elevator, setting the stage for the company's rise to prominence. Higgins also founded the Worcester Pressed Steel Company, and a son-in-law, R. Sanford Riley, founded Riley Stoker Company. At about that time, H. Winfield Wyman '82 and Lyman F. Gordon '81 co-founded Wyman and Gordon Drop Forge Company; Charles Morgan, a founding trustee, established Morgan Construction Company; and alumnus James N. Heald founded Heald Machine Company. Obviously, WPI had enormous influence on the growth of Worcester as an industrial power in the late 1800s and early 1900s.

At WPI, this involvement with the real work of the world continues today. Its scope now extends considerably beyond the borders of Worcester County, and it manifests itself in many ways:

- Our trustees constitute a virtual *Who's Who* of American business and industry. They range from Fortune 500 presidents, such as Robert C. Stempel '55 (General Motors Corp.) and Paul A. Allaire '60 (Xerox Corp.), through investors and entrepreneurs, such as Howard G. Freeman '40 (Jamesbury Corp.) and S. Merrill Skeist '40 (Spellman High Voltage Electronics Corp.); to entrepreneurial leaders of small businesses, such as Raymond J. Perreault '38 (Falls Machine Screw Company), Robert H. Beckett '57 (Robec Distributors), and Irving James Donahue, Jr., '44 (Donahue Industries). In other dimensions, we find a financial leader in F. William Marshall, Jr., president and CEO of Shawmut Worcester County Bank; a utility executive in Samuel Huntington, president and CEO of New England Electric System; an attorney in C. Marshall Dann '35, former U.S. Commissioner of Patents and Trademarks; and educators, such as Prof. John J. Gabarro '61, of Harvard University Graduate School of Business; and Prof. Carol L. Reinisch, of Tufts University School of Veterinary Medicine. These and other board members are positioned well to help attain for WPI the recognition it deserves now and will continue to earn in the future.

- Our alumni, too, are well represented at all levels in the world of business and industry. In addition to those listed as trustees, several worthy of special mention for what they bring to WPI include Paul W. Bayliss '60, vice president for market planning and management of AT&T's Network Systems, and past president of the Alumni Association; Richard J. Kennedy '65, vice president of the Abrasives Marketing Group at Norton Company and president of the Alumni Association; George T. Abdow '53, founder and president of Abdow's Big Boy Family Restaurants; Michael A. DiPierro '68, president of Polyform Corporation; and Gordon H. Sigman, Jr., '59, vice president of strategic defense programs for United Technologies Corp. These and other alumni bring enormous talent to the service of WPI through the Alumni Association, departmental advising committees, and outreach activities of all kinds.

- It is among our faculty, however, that we see the real involvement in the development and application of new technology for the benefit of American industry. It takes many forms:

  - Prof. Ronald R. Biederman of Mechanical Engineering has for many years led an interdisciplinary program in materials science, working directly with companies like Wyman Gordon, Morgan Construction, Norton Company, C. R. Bard, General Dynamics Electric Boat, and AMP on applications ranging from ceramics to forging, powder metallurgy, and steel rolling, as well as biomaterials for artificial joints and angioplasty. Working closely with Dr. Biederman are Profs. Sara A. Dillich, Gary L. Leatherman, Ryszard Pryputniewicz, Richard D. Sisson, Jr., and Floyd R. Tuler.

  - Profs. Alex E. Emanuel, Dave Cyganski '75, and John A. Orr of Electrical Engineering are doing exciting work under the sponsorship of the Electric Power Research Institute, investigating the effects of harmonics produced by photovoltaic generation. In addition, Drs. Cyganski and Orr are also supported by Teledyne Corp. for work in vision systems for integrated circuit manufacturing.

• The Manufacturing Engineering Applications Center (MEAC), directed by Prof. Donald N. Zwiep, head of Mechanical Engineering, is both a laboratory for developing automated manufacturing processes and a program where industrial sponsors support generic research and proprietary projects for their own manufacturing processes. Digital Equipment Corp. (DEC), Emhart Corp., General Electric (GE), and Norton Co. have received significant benefits from their annual sponsorship of MEAC.

• The Management of Advanced Automation Technology (MAAT) program, directed by management Prof. Arthur Gerstenfeld, also works closely with industrial sponsors, including Barry Wright Corp., Combustion Engineering Corp., DEC, GTE, GE, Lockheed Corp., Polaroid Corp., and Wyman Gordon.

• Prof. Yi Hua Ma of Chemical Engineering has just organized a new center in inorganic membrane technology with support from Alcoa Co. He is joined in this effort by Profs. William M. Clark, Anthony Dixon, and William R. Moser, as well as Profs. Biederman and Sisson.

• One of our newest industrial joint ventures is the Center for Computer-Aided Engineering (CAE) for Manufacturing. This center derives from Provost Richard H. Gallagher's interest and expertise in computational

The work of Dr. Ronald R. Biederman represents WPI's historic alliance with industry.

mechanics in combination with a number of faculty members, including Profs. George Y. Jumper, Jr., James Kane, and Sunil Saigal from Mechanical Engineering; Paul W. Davis and Janos Turi from Mathematical Sciences; and Thomas A. Shannon from Humanities.

This summer, the center submitted a proposal to NSF for $12 million in support. Industrial sponsors include Avco Lycoming Corp; General Dynamics; Hewlett-Packard Co; Hibbitt Corp; Karlsson and Sorenson, Inc.; Micro Control Systems, Inc.; Norton Co.; Raytheon; United Technologies; and Wyman Gordon.

Of the $3.5 million in sponsored research performed by the faculty in 1986–87, more than 50 percent came from industrial sponsors.

• The Institute has several other forms of industrial support:

• WPI has an active Cooperative Education Program, which places more than 15 percent of our juniors and seniors in industrial assignments with companies such as DEC, IBM, Raytheon, and United Technologies. Under the leadership of its new director, Carolyn Tidwell, we anticipate that this program will grow significantly in both the number and the quality of assignments.

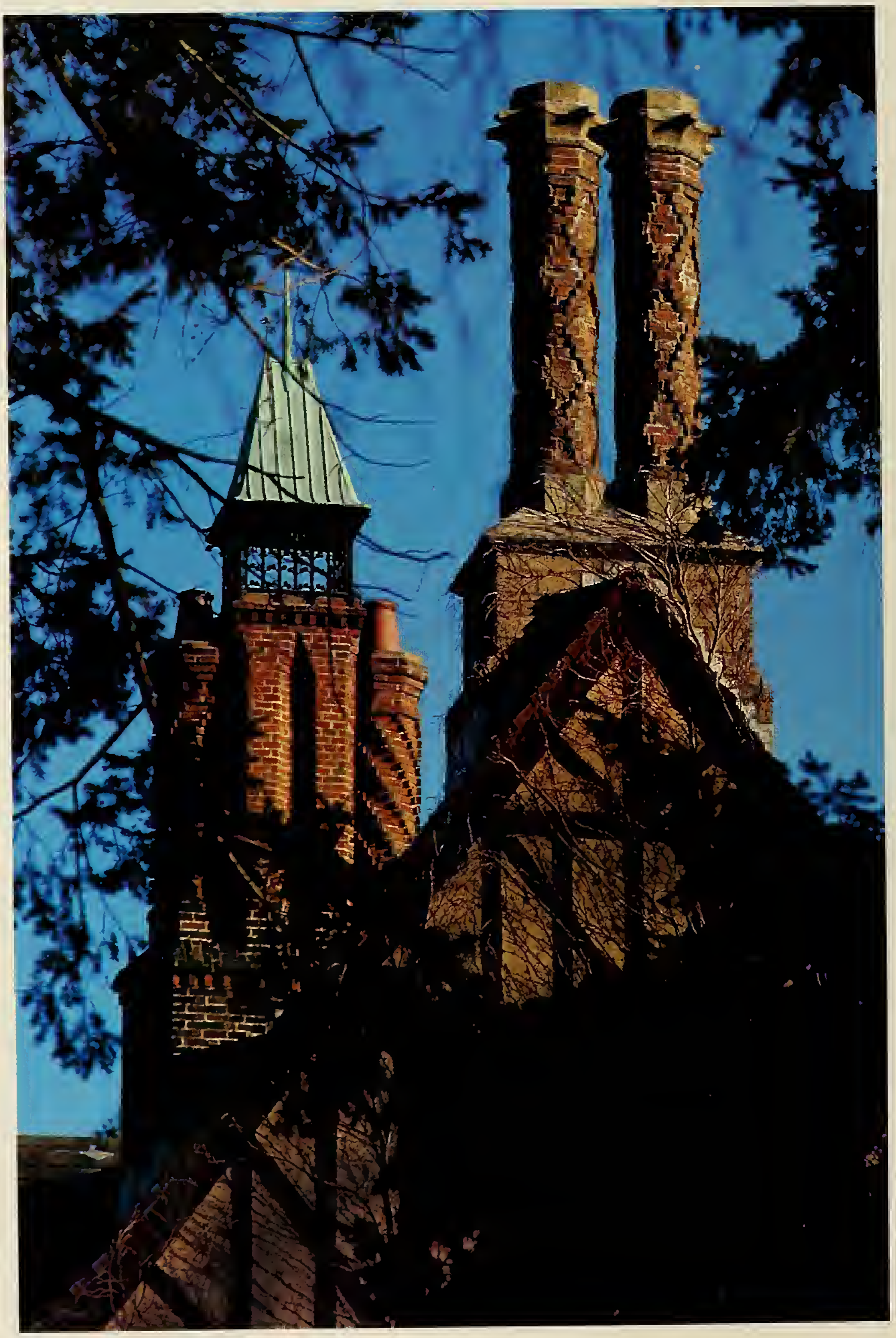
• Organizations such as ADI, DEC, Raytheon, and Wyman Gordon have found the support of fellowships at WPI to be a good investment.

• In recent years, AT&T, Convergent Technology, Inc., Datability Corp., DEC, Hewlett-Packard, IBM, Raytheon, Wright Line, Inc., and others have made generous gifts of equipment.

• Most New England firms have contributed generously to the recent renovations of Atwater Kent and the Washburn Shops and will be given the opportunity to invest further in WPI's continued new building and renovation program as part of the *Campaign for Excellence.*

We are not, however, seeking outright philanthropy in our industrial relationships. Rather, Dr. Ron Baird, director of corporate relations, is trying to establish sustained joint ventures in which the research interests of faculty members align with, and hopefully are sponsored by, industrial partners. We have had significant success with this approach over the first 122 years of WPI's existence, and we are looking to achieve even greater success in the future.

By now, you may well be aware of WPI's *Campaign for Excellence*, a five-year drive to raise $52.5 million to bring new levels of excellence to WPI. While industrial support of faculty research will not be counted in that total, the continuing direct involvement with business and industry that has been so much a hallmark of WPI remains a high priority for the future.



The chimneys of Higgins House in November.