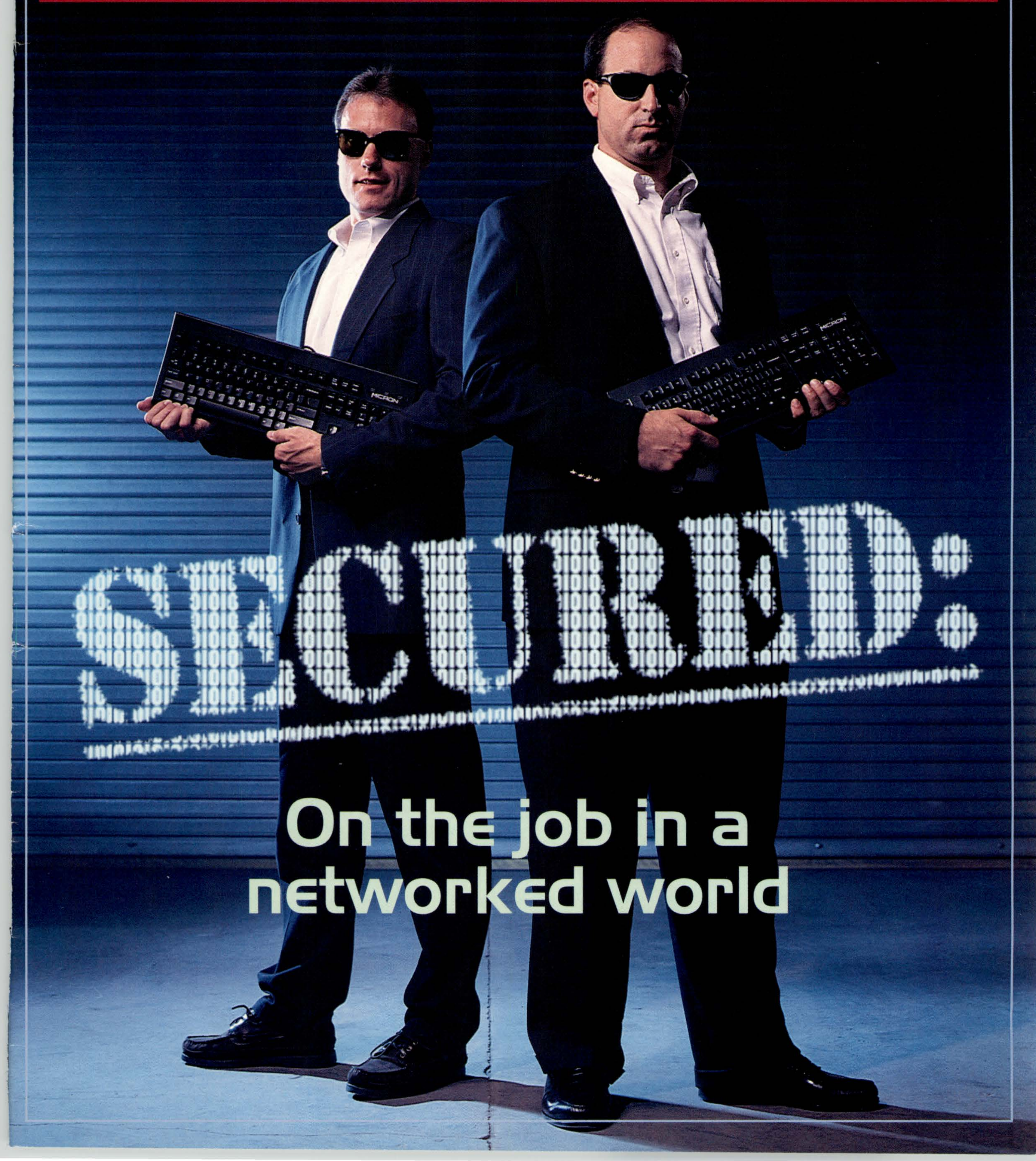
◆ A Vision of NASA's Future ◆ The State of the University ◆ Four Highwaymen

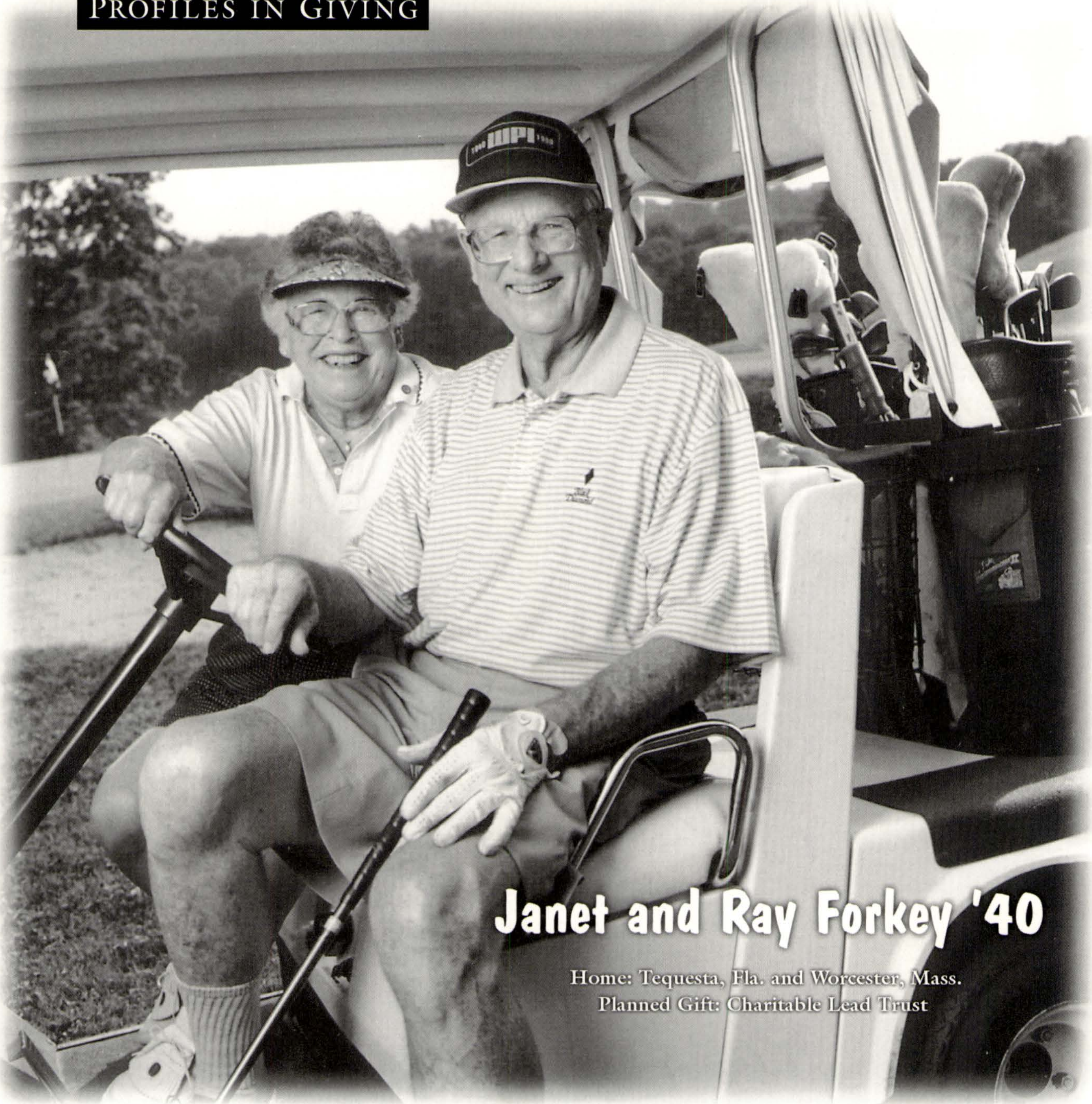
WPI Journal

SUMMER 1998



SECURED:

On the job in a networked world



— On the Game of Golf —

"People from all over the world share a connection in loving this game," says Ray. "Sure, it's competitive—that's a good part of the fun—but I also enjoy the camaraderie that makes playing the game a wonderful experience wherever we go." His love of golf has led Ray to serve on the boards of several senior golf organizations; he's been president of two. "These experiences have allowed me to give something back to the sport that's given me so much." Through his volunteer work, Ray and Janet have played more than 100 national and international courses, and Ray has been champion of four clubs, winning 11 titles at the Worcester Country Club. "I've shot my age well over 150 times since turning 72," Ray says, "and I hope to keep on swinging."

— On Planned Giving at WPI —

"Janet and I wanted to make a significant contribution to reflect our gratitude for my WPI experiences. I've always thought giving appreciated stock is an ideal way to contribute, but we also needed to find a way to reduce the taxable portion of our estate without detrimentally affecting our heirs. The Charitable Lead Trust was a good solution. It will generate gifts of stock directly to WPI for the next 10 years, then whatever is left in the trust will go to our family at a time when they can use it. We receive a significant estate tax deduction and WPI gets a gift it can use right away. That adds up to a 'hole-in-one' for the Forkey family and for WPI."

The current economic climate may be especially favorable for establishing lead trusts. To learn more about this or other planned giving opportunities at WPI, please contact Liz Siladi, Director of Planned Giving, at 1-888-WPI-GIFT.

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WPI JOURNAL

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DEPARTMENTS

Front Cover: Go ahead, make their day! Would-be data thieves and on-line impostors are being stopped in their tracks by software and hardware emerging from the minds of cryptographers and engineers like Jeff Breed '85 and Joe Vignaly '82 of GTE CyberTrust Solutions. Story on page 4. Photo by Jonathan Kannair. Back Cover: In the next 25 years, astronauts may depart from the International Space Station for Mars, near-Earth asteroids and other celestial destinations, says NASA Administrator Dan Goldin. Story on page 16. Photo courtesy NASA.

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Celebrating Five Years of Projects in Costa Rica

WPI made its first forays into global technological education more than 25 years ago with university exchange programs in London and Zurich. Its first overseas center for student project work opened 11 years ago in London. Since then, programs have been established in cities around the globe. The list of WPI's global project sites will expand over the next 18 months with the addition of Boston, Copenhagen, Melbourne, and Kariba, Zimbabwe.

From left, Malinda Danforth, Jocelyn Songer and Park Hays completed their project in Spanish.

As the University's Global Perspective Program matures, some project sites are reaching significant anniversaries. Last year, the London Project Center celebrated its first 10 years. A gala event is being organized for the summer of 1999 to note the 10th anniversary of the Venice Project Center. In July, WPI observed five years of project work in Costa Rica with a party in San Jose. Guests included students completing projects in Costa Rica, alumni, representatives of sponsoring corporations, museums and agencies, and prospective WPI students and their parents. Provost John F. Carney III gave the welcome address. Susan Vernon-Gerstenfeld, who directs the Costa Rica, Puerto Rico and Washington, D.C., project centers, discussed the history of the center and the range and focus of student projects there.

Since the center was established in 1993, 69 undergraduates have completed 24 Interactive Qualifying Projects there. Topics include reforestation, energy and water conservation, computerization, and tourism. "WPI students are doing valuable work within the cultural context of the country," says Vernon-Gerstenfeld. "Many of the students who complete IQPs in Costa Rica have completed their Humanities Sufficiencies in Spanish and write and present their work in that language. It's the perfect marriage of these two degree requirements."

The following projects were completed in Costa Rica this summer:

Market Analysis for a Museum

The National Museum of Costa Rico is planning to move its offices to a new building to provide space for a new café, new exhibits and additional services. Eric Detmer, Jaime Gibson, Jennifer Marinello and Michael Zocchi looked at how the museum might make the most of that space and surveyed visitors to determine the demographic mix and the types of administrators needed to implement changes.

A Warehousing Analysis

Atlas Industrial S.A. manufactures and distributes appliances throughout Costa Rica. After Electrolux purchased 20 percent of the company's stock, product volume increased and markets expanded, resulting in an overcrowded finished-product warehouse. Kate Burgess, Julie Kernis and Anthony Roccisano helped Atlas conduct a cost analysis that showed that expanding the current facility would be more effective than renting new space.

Reinventing the Garden

Lesley Chamberlain, Eric Las, Tim Miranda and Chris Tullman worked with the Lankester Botanical Gardens in San Jose. They analyzed and recommended software to track botanical information and create a map for the garden; developed a fund-raising program; redesigned the garden's Web page; restructured the inventory control process; and developed detailed greenhouse maps.

Environmental Marketing

Matthew Cole, Rodolfo King and Vrinda Nargund constructed a Web site for scientists interested in using the extensive rain forest system as a laboratory. Their mission was to advertise the Central Volcanic Cordillera Conservation Area (ACCVC) as a location for scientific studies. The students' plan included entrance brochures, signs, training programs for tour guides, and recommendations for foods to be sold at the site.

Telecommunications Analysis

ICETEL, the telecommunications division of the Costa Rican Institute of Electricity, is an autonomous government agency that holds a monopoly in the nation's electricity and telecommunications industries. To help it assess consumer needs, Malinda Danforth, Park Hays and Jocelyn Songer created a three-part system dynamics model to predict demand in Guanacaste and developed a detailed methodology ICE could use to expand the model to other regions. The entire assessment was done in Spanish.

A Focus on Waste Management

In return for some concessions, Baxter I.V. Systems Corp. donates its reusable and recyclable waste materials to the local municipality of Cartago. The company wanted to track its waste and reduce volume by 5 percent by the end of this year. Dina Carreiro, Michael Lavoie and Victoria Regan developed a database for Baxter to track and better manage cardboard and plastic packing waste.

Vernon-Gerstenfeld and her husband, WPI management Professor Arthur Gerstenfeld, served as project advisors. "Costa Rica, a thriving, modern industrialized nation, offers opportunities for WPI students to become immersed in a Central American culture where democracy, economic development and concern for the environment are a permanent part of the landscape," she says.

—Bonnie Gelbwasser

A High-Stakes Game of Cat and Mouse

Every day, millions of Americans tap into a sprawling global communications network, sending and receiving untold quantities of information through a largely insecure tapestry of copper wire and fiber-optic cable. As they transmit their orders and credit card numbers to online stores, dispatch confidential e-mail messages to friends or make long-distance calls with prepaid calling cards, they leave footprints —traces of themselves and their private lives— behind on the digital landscape.

The endless flow of information through the world's computer and telecommunications networks has become the subject of intense interest for researchers, businesses and entrepreneurs.

As you will see in the three stories that begin on page 4, the endless flow of information through the world's computer and telecommunications networks has become the subject of intense interest for researchers, businesses and entrepreneurs. Some of that interest revolves around the challenge of keeping track of those billions of bits and bytes. For Jay Gainsboro '75, that gargantuan task became the foundation of a successful business, one that catapulted him briefly into the national media spotlight.

Many others, including WPI professor Christof Paar and the alumni at GTE CyberTrust Solutions, are driven by a different challenge—finding ways to erase those virtual footprints, or at least hide them from information spies and thieves. The desire to keep information out of the hands of those who might illicitly profit from it has preoccupied governments, armies and businesses for centuries. In fact, historians of cryptography—the art and science of data scrambling—date the use of encryption back at least as far as 1900 BC.

With the rise of the Internet, the World Wide Web and the exploding domain of online commerce, the field of information security has taken on a new sense of urgency. The quest for newer, faster and more effective methods of encrypting information, and the equally compelling drive to break them, has become a high-stakes game of cat and mouse. It is a contest that marries the ancient mathematics of number theory with the latest high-tech tools of electrical and computer engineering.

While modern digital computers and global computer networks have opened up a new world of applications for cryptography, many of the challenges today's data scramblers face and many of the tools they use first made their appearance many years ago. In fact, the era of modern cryptography dawned 90 years ago with the brainstorm of Gilbert S. Vernam, a WPI graduate.

Vernam received his bachelor's degree in electrical engineering in 1914 and went to work for AT&T in New York. He joined a group of engineers who found themselves face to face with a conundrum that would sound quite familiar to cryptographers today: how to guarantee the security of private messages transmitted over a public communications network whose very design made it easy to intercept information. The network was not the Internet, of course, but the spider's web of telegraph wires that crisscrossed the nation.

The engineering group had been asked to study the security of the printing telegraph. They quickly discovered that even when multiple messages were speeding through a telegraph wire in both directions, a savvy hacker with an oscilloscope could monitor the frequency changes and transcribe the messages. After mulling the problem over, Vernam found an ingenious solution.

Printing telegraph machines typically used paper tapes for translating messages into electrical pulses and turning those pulses back into text. Vernam suggested using a second tape with a set of random pulses—a private key, in cryptographic terms—that would be added to the pulses of the text to create an encrypted message. An identical tape at the other end would enable the added pulses to be subtracted to reveal the message. Anyone intercepting the message would see only a meaningless jumble of pulses.

The idea of encrypting messages was nothing new. What Vernam accomplished was a method of coding and decoding messages automatically, in real time, which made cryptography, once a labor-intensive process that had to be done off-line, something that could be easily added to any communications system, from telephone calls, to radio transmissions, to e-mail messages flashed over the Internet.

Vernam's invention made him one of the "household names" of cryptography, and his accomplishments are included in many books on the field, including David Kahn's 1996 book *The Codebreakers.* Another seminal achievement in cryptography, the only unbreakable cryptosystem, called the one-time pad, is also often attributed to Vernam, because it arose from his invention of the encrypting telegraph machine.

Not long after he learned of Vernam's discovery, Major Joseph Mauborgne, head of the U.S. Army Signal Corps, discovered that if one employed a unique random key of the type developed by Vernam for each message and used each key only once, the result would be a system that even the most sophisticated code cracker could never break. Though impractical and rarely used (at least in commercial cryptography), such one-time systems are widely known in the field. (Interestingly, at press time, a firm known as Ultimate Privacy announced that it would market a cryptographic program for corporate networks that employs a one-time pad system.)

Vernam, who died in 1960, was president of the Wireless Association and a member of Tau Beta Pi, the engineering honor society, while at WPI. He spent 46 years in the communications field, earning 60 patents covering his work on cryptography, TWX systems, relay systems and switching centers. Nearly 40 years after his death, his work lives on in laboratories at WPI and around the world, where engineers, computer scientists and mathematicians continue the search for security that he began.

—MICHAEL DORSEY

SECURED:

"Who goes there?"

One of the thorniest problems facing Internet commerce is how to know who's really on the other end of the line. A group of alumni at GTE CyberTrust Solutions is solving the Net's identity problem with electronic passports.

BY ELIZABETH WALKER

Tom Cruise could have been stopped. As agent Ethan Hunt in the film *Mission Impossible*, Cruise trips up retinal scan, fingerprint and voiceprint security systems and ferrets out identification codes to gain entry to the CIA's "secure room" and download the agency's most sensitive data. But agent Hunt would have hit a virtual brick wall had he been trying to break in via the Internet and faced the data security and electronic identification systems designed, marketed and managed by Joseph Vignaly '82, Jeffrey Breed '85, Jeanne Gorman '87 and others of GTE CyberTrust Solutions.

In the real world of high-tech online data security, "you can't do a 'Tom Cruise,'" says Vignaly, director of marketing and business development for CyberTrust. "The security breaches through which Cruise and his coterie easily assumed and discarded identities in cyberspace could not have happened if our company's certification authority system had been in place."

One of Vignaly's favorite *New Yorker* cartoons illustrates pointedly the pitfalls of doing business over the Net, where people and businesses are known only through the electronic facades they present to other users. The cartoon shows a dog sitting at a computer. The caption reads, "No one knows you're a dog on the Internet." CyberTrust helps customers and vendors unveil the Net's "dogs" by providing a reliable means to verify the identity of another user.

This is more than a matter of satisfying one's curiosity. Being able to certify the identity of an individual, a business or a Web site is critical to the secure conduct of communication and commerce over networks. Banks want to know that users making withdrawals are entitled to the money. Retailers want to know that a customer is authorized to make purchases with the credit card number he's presenting. Stock brokers want to feel confident they know who they are trading with. And consumers want to know that the Web businesses they patronize are legitimate.

Vignaly says that it is also important to everyone doing business over the Net that their transactions have not been tampered with while in transit. "If someone issues a stock trade online, asking a broker to sell 100 shares, he wants to be assured that the broker gets the message he sent, and not one that's been changed to say, 'Sell 1,000 shares of stock.'"

To establish electronic identities, CyberTrust uses digital certificates that verify that all parties involved in a transaction are who they say they are. "Digital certificates are basically a means to securely identify yourself over the Internet. They are like a passport or a driver's license," Vignaly explains.

The certificates, which use the Secure Electronic Transaction (SET) protocol, can also be used to control access to data and Web sites, to ensure privacy for Internet transactions, to assure the secure transmission and integrity of sensitive information, like credit card numbers, and to provide proof that an electronic transaction has taken place. The key to the integrity of the certificates is that they

JONATHAN KANNAIR

Like high-tech security guards, the digital certificates developed by, from left, Joe Vignaly, Jeanne Gorman and Jorge Guajardo verify the identity of travelers on the information highway to make on-line transactions safer and more secure.

are "signed" by a trusted third party, a certification authority like CyberTrust, which binds its own digital identity to the certificate's public and private keys (for more on public-key cryptography, see "How Private? How Safe?," page 8).

Vignaly says digital certificates are safer and more reliable than traditional means of verifying the identity of computer users, including passwords and PIN numbers. "There's no way you can use PINs or passwords over and over again and keep them secure," he says. "Usually, the more PINs and passwords people have to remember, the easier they make them, increasing the risk of misuse and theft. With digital certificates, there's nothing to remember."

Vignaly cites the *Wall Street Journal's* on-line subscriber service as an ideal candidate for digital certificates. Currently, each subscriber gets a password to access the *Journal's* Web site. But when a password is given to somebody who has not paid to use the service, the newspaper loses revenue. "Digital certificates enable companies to limit use of their services and products to an individual rather than to a password," he says.

CyberTrust Solutions is a three-year-old commercial initiative for GTE, a telecommunications company known worldwide for developing government and defense communications systems and equipment. Its customers include the National Security Agency. CyberTrust evolved from work that GTE Government Systems was doing in high-security cryptography—specifically, developing key management systems for governments. The parent company quickly recognized that its electronic security products had wide-ranging commercial applications that could be tailored to business customers' specific security needs.

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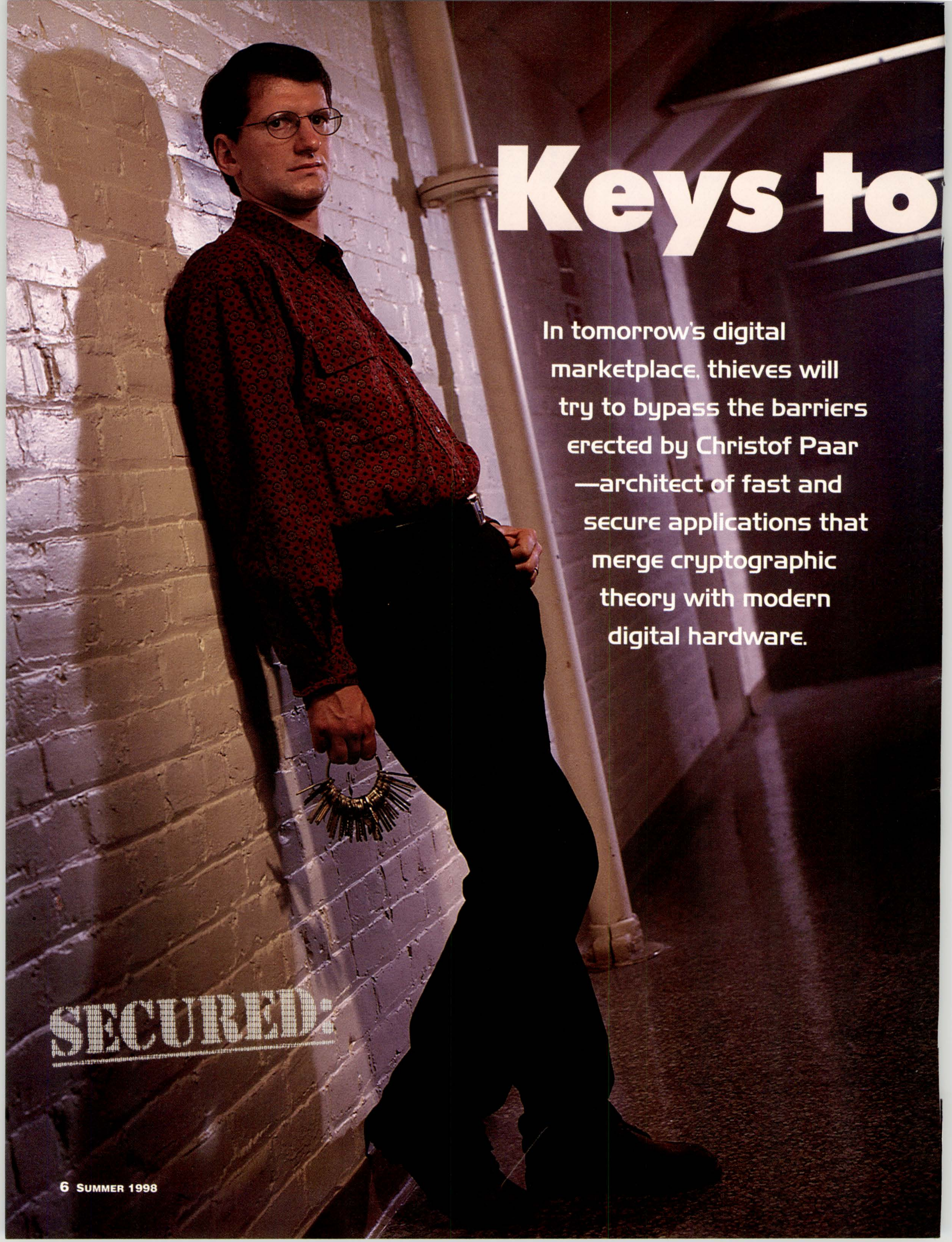


SECURED: Keys to

In tomorrow's digital marketplace, thieves will try to bypass the barriers erected by Christof Paar—architect of fast and secure applications that merge cryptographic theory with modern digital hardware.

the Future

BY MICHAEL W. DORSEY

The age of on-line commerce has arrived. Already, consumers can turn on their computers and buy everything from books to groceries to stocks to cars without leaving their homes or offices. All it takes is a modem, a Web browser and a credit card. But that's just the beginning, say technology forecasters, who predict that within the next five years anywhere from $300 billion to $1 trillion worth of business will be transacted over the Internet each year.

Perhaps the most remarkable fact about the explosion of Web-based business during just the past half decade is that the flow of orders and cash is taking place over an insecure conduit, one whose open structure—designed by academics for the free exchange of ideas and data—makes intercepting and altering sensitive information child's play. As more computer users tap into the Internet with wireless connections in the years ahead, snatching data may become even easier.

What has made possible the early success of Internet business—and what will prove absolutely vital to its future expansion—is a relatively new discipline that marries esoteric mathematics with computer science and electrical engineering. Called modern cryptography, the field is a digital descendent of cryptology, the centuries old practice of scrambling messages to keep state secrets and military communications from falling into the wrong hands. Once, cryptography was practiced almost exclusively by governments. But as businesses and researchers seek more effective and more efficient methods for encrypting information, data scrambling is becoming more and more the province of industry and academia.

"There is a gold rush for applications in cryptography today," says Christof Paar, assistant professor of electrical and computer engineering and founder of WPI's Cryptography and Information Security Research Laboratory (CRIS). "The Internet is taking off, with everyone thinking they can make some money in the on-line world. Financial transactions require security, so this growing desire to profit from the Net is the driving force behind an explosion of new security applications, including digital certificates, smart cards and digital cash."

Paar is one of the rising stars in this brave new crypto-world. He came to WPI three years ago after earning his bachelor's, master's and doctoral degrees in Germany, the last at the Institute for Experimental Mathematics at the University of Essen. His early research, conducted in Germany, as an exchange student at the Michigan Technological University, and as a visiting researcher at the University of Massachusetts, Amherst, focused on error codes, mathematical functions that enable audio and video CDs to continue playing even after they've been scratched.

"Error codes were already fairly well-established, so I came to WPI looking for a newer, hotter area of applications," he says. "Since the early 1990s, cryptography has been a fast growing field, and it happens to rely on the same mathematical principles as error codes."

Those principles belong to a field known as number theory, one of the oldest areas of mathematics. With its roots extending back to the writings of Pythagorus, number theory deals with the properties of integers and their relationship to one another. Until recently, it was thought to have no real-world applications. Number theory entered the limelight in 1976 with the publication of a seminal paper by Whitfield Diffie and Martin Hellmann. Diffie and Hellman invented public-key encryption, which solved a central problem in cryptography that had threatened to limit its utility in the blossoming on-line world (see "How Private? How Safe?,"page 8).

The development of public-key cryptography coincided with the rise of electronic commerce, wireless networks and high-quality multimedia services. What ties these emerging technologies together is the need to be able to send and receive large volumes of data across insecure networks in a safe manner. To meet this demand, a host of cryptographic software applications, with names like RSA, PGP (Pretty Good Privacy) and SSL (Secure Sockets Layer), have found their way into popular Web browsers and onto widely used commercial Internet sites.

For the most part, Paar says, the development of network security technology has been the exclusive province of computer scientists and mathematicians. In fact, Paar is one of relatively few researchers in the nation approaching cryptography from the perspective of an engineer. "One important aspect of modern cryptography," he says, "is implementing security protocols in hardware—chips, circuit boards, special-purpose

JONATHAN KANNAIR

computers, and so on—which is what electrical and computer engineers do. Few other research groups have the interest—or the capability—to pursue cryptographic hardware in such a systematic manner."

In CRIS, several graduate students and a number of teams of undergraduates completing their Major Qualifying Projects are focusing their efforts on two broad areas: the development of hardware architectures for modern cryptographic schemes and research in the area of fast software algorithms. Paar's research on both fronts has won him more than a half million dollars in grants and contracts from such companies as GTE Government Systems, Lockheed Martin, Texas Instruments, Technical Communications Corporation, and Bosch, a German company. Much of the current work in CRIS revolves around making cryptographic systems faster and more efficient. In part, that means developing speedier algorithms.

"RSA is the industry leader in public-key cryptography, accounting for the majority of commercial applications, including the security feature in the popular Netscape browser," Paar says. "But because the keys used in RSA applications are so large, and require so much arithmetic to process, security systems are becoming relatively slow. So people have started to look at alternatives."

One popular alternative that is rapidly gaining in acceptance employs a set of one-way mathematical functions known as elliptic curves. The advantage of elliptic curves is that they appear to provide as much security as RSA and similar public-key algorithms, but with much smaller keys (150 to 250 bits for elliptic curves, vs. 1,024 to 2,048 bits for RSA). "Elliptic curves execute much faster than RSA, but the big question is whether they really are as secure." (See "How Private? How Safe?," this page.)

Paar's research group has been looking, not at the security of elliptic curves, but at how to make them execute as fast as possible. The team has derived a new algorithm related to elliptic curves and has earned a patent for one particular fast implementation method.

This summer, Paar and Daniel V. Bailey '98, a computer science graduate who is working toward a master's degree in Paar's lab, presented a paper at Crypto '98, the nation's largest and most competitive conference on cryptography. The paper was based on Bailey's Major Qualifying Project, co-advised by Paar and Stanley Selkow, professor of computer science, which won the Provost's MQP Award in computer science in April. [Another MQP advised by Paar won the Provost's Award in Electrical and Computer Engineering in 1996.] The paper by Bailey and Paar details a method for speeding up elliptic curve cryptosystems using a mathematical approach Paar and Bailey call Optimal Extension Fields.

One of the most effective ways to speed up cryptographic algorithms is to implement them

(Continued on page 10)

How

Over the centuries, cryptographers have devised many ways to encode messages to make them unreadable to all but their intended recipients. They range from simple substitution, where each letter of the alphabet is replaced by another letter or a combination of letters, to ciphers, mathematical treatments that transform and jumble the letters in a message in complex ways. But no matter what methods are used, all cryptography systems make use of keys that enable recipients to unlock and read encrypted text.

Traditionally, the only way to assure that encrypted messages remained secure was to keep the keys secret, which usually meant hand-delivering them to the intended recipients. For small organizations like banks with just a few branches, or for organizations with established methods of transporting sensitive information, such as the military or the diplomatic corps, that was not a problem. But when the senders and receivers of encrypted messages became millions of computer users all over the globe, keeping keys a secret became a seemingly impossible feat.

In 1976, Whitfield Diffie, a professor at Stanford University, and Martin Hellman, a graduate student, proposed a solution to this thorny problem. In a paper titled "New Directions in Cryptography" published in *IEEE Transactions on Information Theory*, they introduced the idea of public-key encryption, which uses two keys: a private key that only the user knows, and a public key that is distributed freely. To send a secure message to another user, one encrypts it using the recipient's public key. The message can then only be decrypted by the recipient using his private key. An additional advantage of public-key encryption is that it can be used to create unforgeable digital signatures. A user creates a digital signature using her private key; it can only be unlocked with her public key. Since only someone who knows the private key could have created the signature, it verifies the sender's identity.

The first popular application of public-key cryptography was a product called RSA (named for the first letters of the last names of its inventors, MIT mathematicians Ron

Private? How Safe?

Rivest, Adi Shamir and Leonard Adleman). RSA, developed in 1977, makes use of trap-door, one-way mathematical functions.

A one-way function is a mathematical operation that can be performed easily in one direction, but is virtually impossible to do in the opposite direction. For example, two very large prime numbers can be easily multiplied; however, if one knows only the product, working backward to determine the original primes is virtually impossible if the number is large enough. A trap-door is another number or function that, if known, turns a one-way mathematical function into a two-way function—one that can be completed easily in both directions. In simple terms, the public key in RSA is related to the product of two prime numbers, while the private key is related to the prime numbers themselves and the trapdoor function.

For the nascent on-line business community, the availability of public-key cryptography was a Godsend. It helped overcome one of the greatest fears of potential consumers by making it possible for the first time to send e-mail, credit card numbers and personal information securely over the world's most insecure network, the Internet. But, notes Christof Paar, assistant professor of electrical and computer engineering, it can sometimes be a bit difficult to say just what "secure" means when it comes to encryption.

"Cryptography is a weird field," he explains. "In practice, you can never really prove that an algorithm is secure. You publish it and you hope a lot of people try to break it—and don't succeed. The recent history of modern cryptography is rich in examples of promising algorithms that were quickly broken."

The future of on-line commerce depends, in no small measure, on whether enough potential customers feel confident enough in the unbreakability of modern cryptographic algorithms to entrust their credit card numbers and personal information to the unprotected by-ways of the Internet. But as Paar notes, using any cryptographic algorithm is an act of faith.

The Clinton Administration would like to require that all strong encryption schemes have a sort of back door that would let the government unscramble messages or that users place their private keys in an escrow account with a third party.

Recent developments in the on-line world have demonstrated that even tried and true encryption systems can be vulnerable to attacks by a persistent hacker or by a researcher with the right resources and enough time. In June, a scientist at Bell Laboratories discovered a hole in a system used widely on the World Wide Web to encrypt passwords, credit card numbers and other sensitive information. Called the Secure Sockets Layer or SSL, it's the software that locks the little padlock in Netscape and Internet Explorer, telling users their communications are secure.

The flaw might have enabled a hacker to determine how to unscramble secret information by analyzing the patterns in error messages returned after failed attempts to read encrypted data. The researcher found that he could unlock the code after anywhere from one million and four million unsuccessful tries. Although it's unlikely that anyone has been unable to take advantage of the bug, a group of major software companies quickly developed a fix that plugged the hole.

Less than a month later, a group of cryptographers found a way to crack the Data Encryption Standard (DES), perhaps the most widely used data scrambling algorithm in the world. Using brute computing strength in the form of a custom-built, $250,000 cracking computer, they worked through 90 billion possible keys every second for 56 hours straight until they found one that worked. In all, they tried about a quarter of all possible keys.

The widely publicized feat heated up the debate over the U.S. government's policy on the export of encryption systems. Currently, the federal government, considering cryptography a military technology, restricts the export of encryption systems to foreign governments and companies. Although the rules are complicated, in general exported software is limited to 40-bit encryption (vs. the 56-bit to 128-bit systems commonly used in the United States), unless the systems give the government access to the keys needed to decipher messages. The relative ease with which a 56-bit DES key could be deciphered has made many observers ask whether the government is justified in relegating foreign computer users to much weaker 40-bit algorithms.

The encryption debate is not limited to software exports. The government, particularly the FBI, has always been wary of making it too easy for criminals to scramble their secret communications with unbreakable ciphers. Accordingly, the Clinton Administration would like to require that all strong encryption schemes have a sort of back door that would let the government unscramble messages or that users place their private keys in an escrow account with a third party, where the government could get them as part of a criminal investigation. The software industry and organizations like the Electronic Freedom Foundation believe that the government has no business being able to snoop on private citizens and that solutions like key escrow could prove highly expensive for the government and the private sector.

As Net commerce continues to grow, and as the value of the goods and services bought and sold over the global information network skyrockets, the demand for stronger and more confidence-inducing cryptography will likely rise in step, as will efforts to thwart it and control it.

—MWD

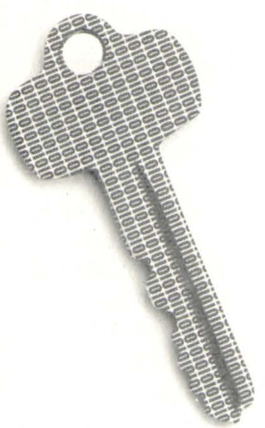
KEYS TO THE FUTURE

(Continued from page 8)

with dedicated hardware. Building a system into a computer chip or plug-in board not only makes it run faster, but makes it more secure, Paar says. "If your crypto system is running as software on your PC, there's a potential weakness because an attacker could get access to the algorithms or your keys. If everything is running in a chip, the physical access to that information is greatly restricted. The National Security Administration has known this for a long time, and now the commercial sector is slowly realizing that to get the greatest security, you need to start out with hardware."

One innovative approach to developing hardware for cryptography recently won Paar a prestigious faculty career development grant, called a CAREER Award, from the National Science Foundation. The four-year, $210,000 award will support the development of cryptographic systems using reconfigurable hardware. "This is the first NSF grant for crypto-hardware," Paar says.

"My proposal to the NSF combined two of the hottest areas in electrical engineering, cryptography and reconfigurable hardware. Usually, the disadvantage of implementing algorithms in hardware is that you give up the low development costs and flexibility of software. Once hardware is built you're stuck with it, but reconfigurable hardware is reprogrammable, so it combines the flexibility of software with the security of dedicated hardware. It represents a real paradigm shift in digital engineering."



Paar will be using a type of reconfigurable hardware known as field programmable gate arrays (FPGAs), logic chips that can be reprogrammed on the fly. "One of the new trends in cryptography is building systems that are algorithm independent," Paar says. "That means that the user and the server negotiate about which algorithm will be used in a particular transaction. Achieving this flexibility with software is not too difficult, but how can you do that with hardware? We are probably the first research group to think about doing this systematically with FPGAs."

Building hardware that can reconfigure itself within microseconds to run vastly different algorithms that employ keys of widely varying lengths will be no easy task, Paar says. Just designing a plug-in PC board that can handle the complicated arithmetic involved in processing a single cryptographic algorithm will be a challenge. "Your PC is designed to do math with 32-bit numbers," he says. "With RSA, you must perform computations with numbers that are 30 to 40 times that length. We have to look carefully at the kinds of gate structures that will allow that kind of arithmetic."

While the development of algorithm-independent FPGAs is just beginning, Paar and his students have already used the devices to speed up the implementation of the most widely used private-key algorithm, the Data Encryption Standard or DES. Developed by the federal government in the 1970s to be the standard for strong encryption, DES is used in applications where keys can be exchanged securely and is also the backbone of some public-key applications.

"Using FPGAs, we did an incredibly fast implementation of DES," Paar says. "In software, you are limited to data throughput speeds of about 10 megabits per second. With dedicated hardware, you can achieve speeds of up to 1,600 megabits. Our implementation was clocked at 400 megabits per second."

Because of the importance of information security to the future of on-line commerce, Paar's cryptography group at WPI has been in demand not just as researchers, but as educators. Paar teaches two graduate courses on cryptography and data security that have been offered on campus and, for three years running, on-site at GTE Corporation in Waltham, Mass. "Just a few years ago, when we first offered the initial course, we were one of the pioneers," he says. "Now, a number of universities offer one course, but only a few offer a follow-up course, as we do."

Paar also teaches a short course on applied cryptography and data security through WPI's Office of Continuing Education. It has proved a popular offering at WPI's Waltham Campus and has also been delivered at the NASA Lewis Research Center in Cleveland, Ohio, and at Philips Research Laboratories in Briarcliff Manor, N.Y. For the past two years, CRIS has offered the WPI Cryptography and Data Security Seminar Series. This year's series included speakers from WPI, the University of Massachusetts, MIT, GTE CyberTrust and RSA Labs.

Like Paar's courses and seminars, his students are in great demand. "Job opportunities in this field are completely crazy," he says. "There are many companies that are in or are just getting into Internet businesses, and they are desperately looking for people who are fluent in cryptography. There are very few schools that are offering this program, and even fewer schools doing it from an engineering perspective."

The German high-technology firm Secunet, a new subsidiary of one of the country's oldest technical holding companies, was so keen on hiring a student trained in Paar's lab that it held a contest, with the first prize being a one-year graduate fellowship in WPI's Electrical and Computer Engineering Department. The first recipient is Harald Weidner, a Ph.D. candidate at the University of Zurich.

"Our approach to cryptography is clearly what companies are looking for," Paar says. "But it is also, in a real sense, in tune with what WPI is all about. The University's philosophy is about combining theory and practice. That's what we do here. We take the theory of a highly arcane mathematical field, and implement it in a practical, usable manner. It's an approach that has proved highly successful for us, and for our students." ■

WHO GOES THERE?

(Continued from page 5)

"Bankers, retailers, credit card companies and other business clients seek the confidence, protection and privacy of traditional, face-to-face transactions as they conduct business by highly impersonal electronic means," Vignaly says.

"Our philosophy is that while the technology is new, the relationships between vendor and client have remained the same. What you need to know is that the people you're talking to are who you think they are. The traditional standards of trust that begin with eye contact and a handshake are not possible when you move business and legal transactions onto the Internet."

Not long after Vignaly went to work for GTE he moved from doing project-focused engineering to managing programs, then on to product management in what he calls a step-by-step migration. Along the way, he earned an M.B.A. at Babson College. Today he is fully immersed in the product side of the business, but finds that his solid understanding of the technology behind each project serves him well. At times, it causes his nontechnical colleagues to confer upon him a little mystique he believes is unwarranted.

"I do absolutely nothing related to my degree in mechanical engineering now," he says. "The advantage I have is that WPI taught me to break down a problem, analyze it, solve it, get it running and move on to the next project. While others might throw up their hands and say, 'It's math; I can't do it,' my technical background enables me to answer the broad questions and give potential customers an explanation of what's going on with the products we promote."

Jeff Breed's career has also evolved considerably since he joined GTE in 1985. Back then, the products he works with today—in fact, the whole electronic security industry itself—did not exist. He started out doing hardware design and eventually moved into customer support. In his current post as program manager, he oversees the development of complicated software solutions to electronic security problems that customers bring to CyberTrust. "We define the appropriate platform on which to run the certification authority software package we offer," he says. "Then we help integrate the customer's existing technology with the new platform, build the business around it, and train the customer to use it."

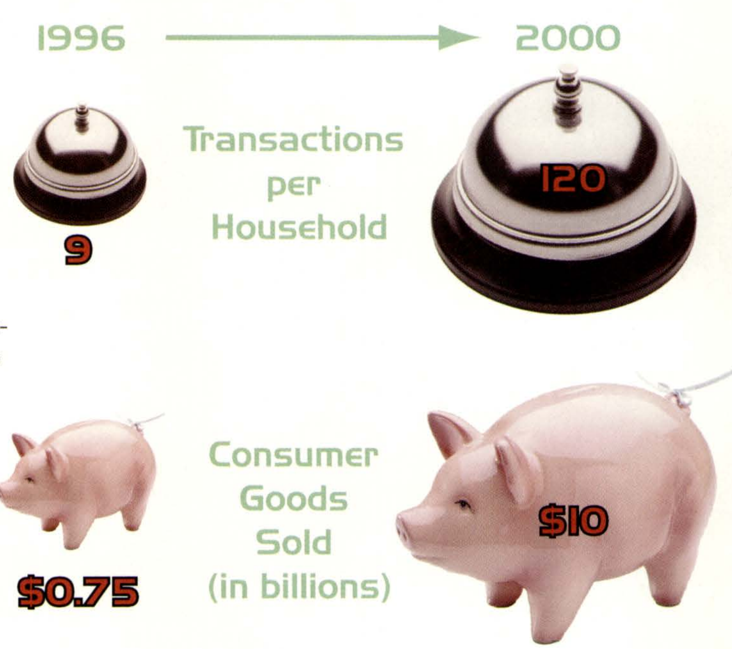
Breed says it is no surprise that GTE likes to hire WPI graduates. In addition to the obvious geographic considerations, Breed says WPI alumni are a natural fit at CyberTrust because of the strong technical and project-oriented education they bring to the company. "The focus on project work at WPI is important because that's the way industry works," he says. "The technical projects I worked on at WPI helped me think in broader terms and recognize how my work affects the work of others. I also think WPI attracts well-rounded people who have a broad array of interests and good communications skills."

GTE's CyberTrust division also employs David J. Altieri '76, Timothy J. Dray '85, Mohamed Dembele '95, Jorge Guajardo '95, Anu Karna '98, Richard L. Laferriere '89, Sergey Perepelitsa '96 M.S., Eugene R. Valois '89 and Benjamin Wu '94 M.S., and has been adding one or two new WPI grads a year. GTE and CyberTrust also work on other projects with WPI faculty and graduate students, including electrical and computer engineering professor Cristof Paar (see page 6).

Like Vignaly and Breed, Jeanne Gorman is working in an area she didn't foresee when she joined the company. "I went right to GTE after graduation thinking I would design hardware," says the electrical engineering major, who now works on access-control products. "I've had five different jobs at GTE as the communications projects I worked on slowly evolved into more security-related projects. I work on anything 'desktop': Web-servers, Internet and extranet (a subset of Internet) applications, business to business transactions—mostly with banking and telecommunications customers who are looking for technical solutions."

All three graduates see the financial and telecommunications industries as the most interesting and forward-thinking global markets when it comes to electronic security. "American Express and MasterCard are our cornerstone customers," says Vignaly. "We provide certification authority services to them from our Needham facility. We also have a number of international telecommunications customers, including Deutsche Telecom, Telecom Italia, and SwissCom, and a joint venture underway with Japan's NTT and the Nomura Research Institute."

Looking ahead, Vignaly sees the technology evolving and expanding as the company works to outpace high customer demand worldwide with solutions that provide even greater levels of security and reliability. ■



Source: eStats and Jupiter Communications

SECURED: His

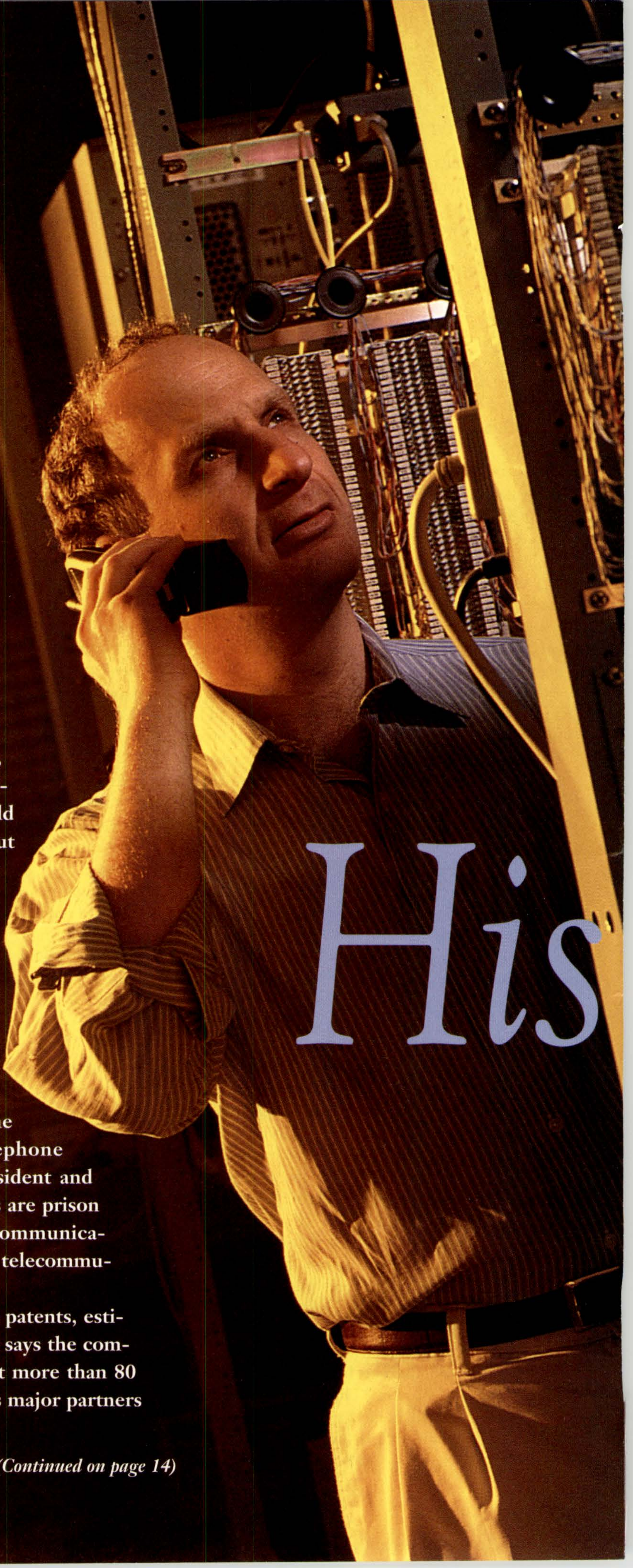
BY ELIZABETH WALKER

Name a person, place and thing that link deposed hotel queen Leona Helmsley, drug-dealing despot Manuel Noriega and convicted killer James Earl Ray. Try Jay Gainsboro '75, prison and the telephone.

When Helmsley, Noriega and Ray phoned home—or anywhere else—during their incarcerations, they shared a vital connection to this entrepreneurial WPI alum and they all paid for it—prepaid in fact. This infamous trio, whose collective rap sheet includes tax evasion, drug dealing and murder, has been counted among the "captive" client base of prisoners worldwide who use The Enforcer, an inmate telephone control and billing system developed by Opus Telecom Inc., Gainsboro's privately held company. Not long ago, Framingham-based Opus put its technology and Gainsboro's nerves to the test by focusing all its energy on a new customer. It was that attention to detail for which the company is widely known that helped convict Oklahoma City bomber Timothy McVeigh.

Opus Telecom, founded in 1979, specializes in applications of what is known as computer telephony integration or CTI. Opus makes CTI products primarily for two markets: prepaid telecommunications systems (such as prepaid phone cards) for the "teledebit" market and inmate telephone systems for the corrections market. Gainsboro, president and sole owner, says the company's two current strengths are prison calling and control systems and prepaid wireless communications, though it also has the burgeoning international telecommunications market in its scope.

Gainsboro, who holds several telecommunications patents, estimates Opus' combined sales at about $30 million. He says the company's 50 employees process 30 million calls a year at more than 80 sites in the United States and Europe. The company's major partners include AT&T, MCI, British Telecom and Lucent.



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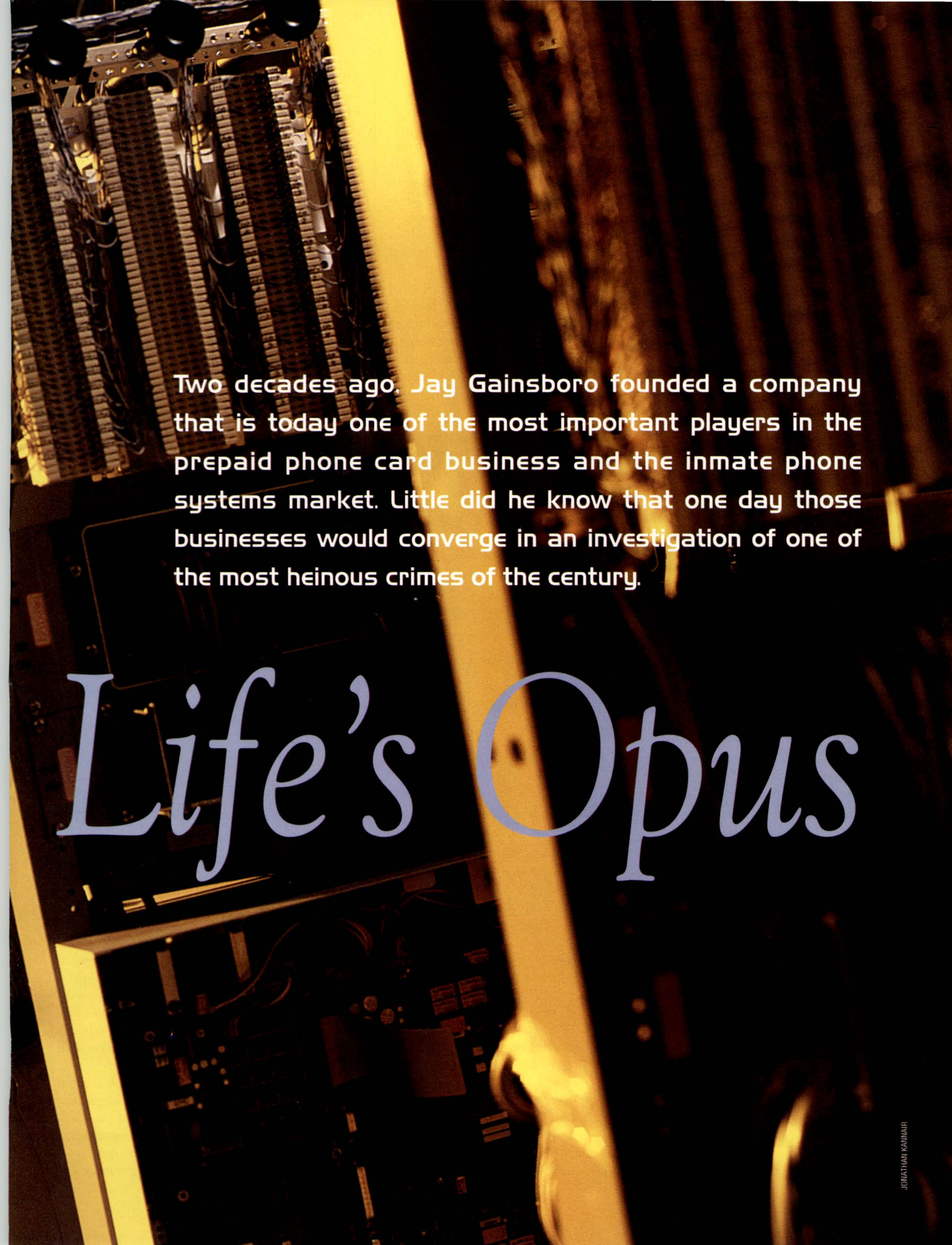


Two decades ago, Jay Gainsboro founded a company that is today one of the most important players in the prepaid phone card business and the inmate phone systems market. Little did he know that one day those businesses would converge in an investigation of one of the most heinous crimes of the century.

Life's Opus

JONATHAN KANNAIR

HIS LIFE'S OPUS

(Continued from page 12)

Among the many other functions they perform, Opus' busy computers track and store information on prepaid phone card use nationwide. It was a 17-month trail back in 1995 of a system to store debit card calls that helped convict Timothy McVeigh, whose bomb killed 168 people—including many children—and injured 500 others as it destroyed the Alfred P. Murrah Federal Building on April 19, 1995.

Using and recharging a phone debit card issued in the name of Darryl Bridges, McVeigh made nearly 700 calls, including some to former Army buddy Terry Nichols, to military surplus stores, to munitions and chemical companies, and to a Ryder truck rental outlet. Gainsboro and his team used their system to sift through eight billion bytes of stored data to identify the origin and destination of each call. The hundreds of non-reimbursed hours they invested helped federal prosecutors prove that "Darryl Bridges" was really Timothy McVeigh. "What I learned from this experience," says Gainsboro, "is that the government will find you if they put the resources in place to do it."

Opus' involvement in the McVeigh case began two days after the bombing, when Gainsboro got a call from an Opus client, West Coast Telecom (WCT). The caller, John Kane, was working with the FBI and the Secret Service to retrieve phone records concerning a suspect. Gainsboro and his team were asked to determine who made a 57-second call from the Dreamland Motel in Junction City, Kan., between 9 a.m. and 11 a.m. on April 17, 1995. The call, to an 800 number, went into WCT's switch, then into Opus' calling card platform. It was one call among 7.8 million calls tracked by Opus nationwide during that two-hour period. After identifying the call, the Opus system determined that the PIN and account number were for a phone card purchased from *Spotlight*, a magazine published by the Liberty Lobby in Washington, D.C. The Liberty Lobby provided the cardholder's name—Darryl Bridges. The FBI found a phone card in that name in the home of Terry Nichols and obtained other evidence linking the alias to McVeigh and Nichols.

The information was what federal prosecutors needed to start building their cases against the two suspects. After pinpointing that call, Opus was able to trace hundreds of other calls made with the card to people and businesses that figured in the preparations for the bombing. Gainsboro was slated to testify at McVeigh's trial in Denver, but was given an 11th-hour reprieve by a change in witnesses. "I was in the 'on-deck' room and was anxious," Gainsboro says. "I knew that the defense would try to undermine my credibility. I felt a tremendous responsibility to do a good job. I had met the families of the people who died. I got very close to the horrendous loss of life."

AP WIDE WORLD PHOTOS

Data recorded by Opus Telecom enabled federal investigators to link calls made with a prepaid phone card purchased in the name of Darryl Bridges to Timothy McVeigh. The evidence played a key role in McVeigh's conviction in the Oklahoma City bombing. Today, Opus tracks every call McVeigh makes from federal prison.

Supporting the government's efforts to convict McVeigh cost Opus about $100,000, but Gainsboro does not regret the time and resources he and his team invested. He cites those who claim that the phone records constituted 80 percent of the case against McVeigh. The records provided a kind of timeline—one that allowed the prosecutors and jury to watch, in retrospect, McVeigh's movements in the months, days and minutes leading up to the bombing.

Involvement in the high-profile Oklahoma City bombing was a sharp detour for Gainsboro, who never sought the limelight, just success. Growing up, he was surrounded by entrepreneurs. His father and uncles all owned their own businesses. After deciding at 14 that someday he would start a high-tech company, Gainsboro turned to a successful family friend for guidance. The friend's formula included a degree from a good technological university. That advice brought Gainsboro to WPI.

"My education at WPI was excellent," he says. "I majored in management and took some basic engineering courses. When I look back at the value of my years at WPI, I think of one professor in particular, Joe Mancuso. He was quite entrepreneurial and took me under his wing. He had a strong influence on helping me understand business issues. It was at WPI that I met my future business partners, Russ Vickery, Jeff Birkner and Dave Erickson. They helped me get started."

Prior to founding Opus in 1979, Gainsboro helped his father start a new consumer products business in Chicago. While there, he became aware of new long-distance carriers, such as MCI and Sprint, that billed themselves as alternatives to AT&T. He estimated that using Sprint could save his father's new company 30 percent on long distance charges. Though touch-tone service was not available through the local phone company's outdated central office, he still managed to save $1.50 on his first call. Using a screw-in keypad that attached to his rotary-dial telephone, he was able to punch in the 23-digit access code Sprint and MCI users had to enter before dialing every number. Gainsboro immediately saw a tremendous money-saving opportunity for millions of businesses; his father saw an inconvenience.

"My father wouldn't use the keypad," Gainsboro says. "He had no patience with the 23-digit access code. His refusal was the impetus that drove me to find a solution to the problem. I went out and bought an auto-dialer, so all he had to do was dial five digits plus an authorization code, but my dad was still frustrated by all the numbers and wouldn't use it."

His father's second refusal spurred Gainsboro to turn to Vickery, Birkner and Erickson, who designed and developed a "store and forward" dialer. The new dialer made gaining access to alternative long-distance carriers virtually transparent to the caller. The business user would dial calls in the usual fashion, and the unit would analyze the digits, check the telephone network, and forward the calls to the appropriate carrier. That was the birth of Opus Telecom. Not surprisingly, Sprint was excited about the dialers, the first of which were sold to hotels and motels.

Sales of the new dialers reached $3 million by 1983, the year AT&T settled its antitrust case and U.S. District Court Judge Harold Greene decreed that consumers should have equal access to all long-distance carriers. The ruling marked the end of the dialer business. But Gainsboro, fascinated since childhood with the possibilities and potential of the telephone, went on to invent several other telecommunications products.

"We got into the real-time rating of phone calls, building call accounting systems that rated and tracked calls," Gainsboro says. "We started selling these to law firms, country clubs and the like. Until 1987 all the features we offered were contained in a small box. The Army forced us out of our box."

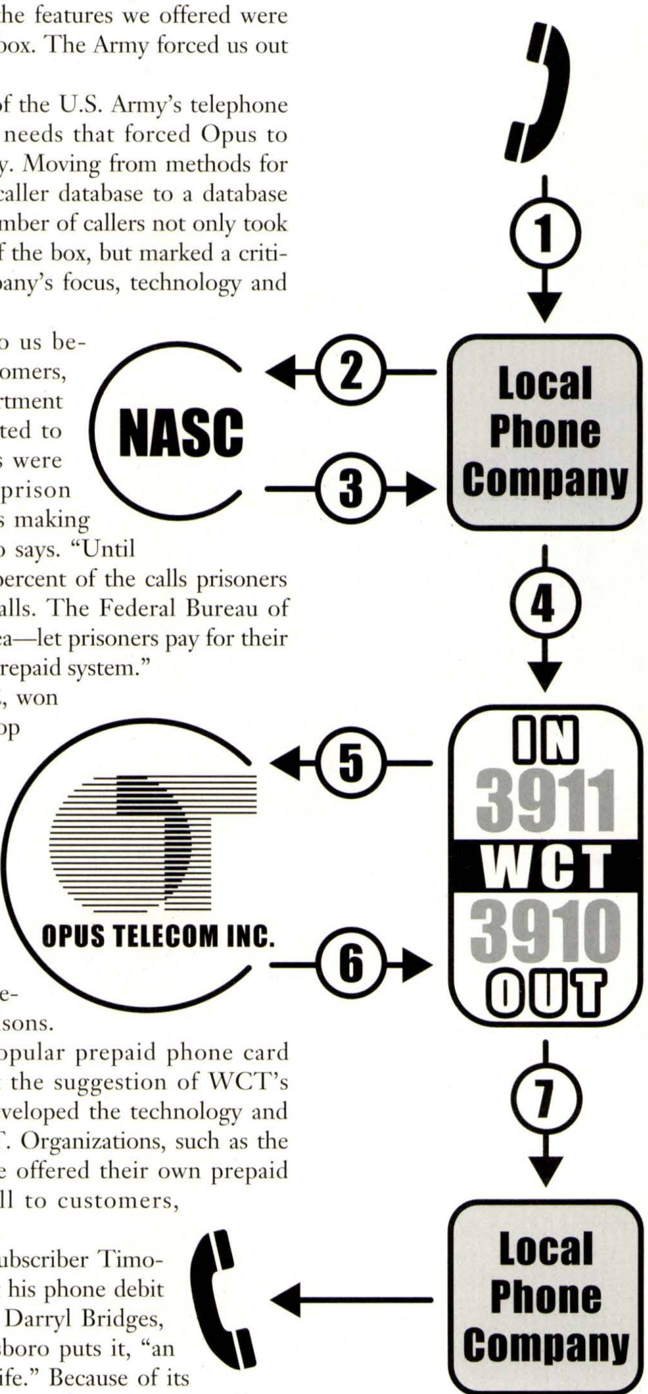
It was the scale of the U.S. Army's telephone tracking and rating needs that forced Opus to rethink its technology. Moving from methods for controlling a 3,000-caller database to a database with an unlimited number of callers not only took the technology out of the box, but marked a critical shift in the company's focus, technology and market.

"AT&T came to us because one of its customers, the New York Department of Corrections, wanted to know what numbers were being called from prison phones and who was making the calls," Gainsboro says. "Until that time, 80 to 90 percent of the calls prisoners made were collect calls. The Federal Bureau of Prisons had a new idea—let prisoners pay for their own calls through a prepaid system."

Opus, with GTE, won the contract to develop the new prepaid calling system, which quickly accounted for 80 percent of the market for prepaid and collect calling systems. In fact, prepaid calling technology was developed first for prisons. The idea for the popular prepaid phone card emerged in 1992 at the suggestion of WCT's John Kane. Opus developed the technology and sold it back to WCT. Organizations, such as the Liberty Lobby, were offered their own prepaid calling cards to sell to customers, clients or subscribers.

After *Spotlight* subscriber Timothy McVeigh bought his phone debit card under the alias Darryl Bridges, he became, as Gainsboro puts it, "an Opus customer for life." Because of its experience with prison phone systems, Opus maintains detailed records on all calls made with the cards it tracks. Had McVeigh bought his card in a retail store, it would have been more difficult to identify the card's owner, Gainsboro says. With McVeigh now behind bars, Gainsboro says he can expect the same high standard in customer service and attention to detail that helped land him there. Today, any calls McVeigh makes are tracked and stored in the Opus network database.

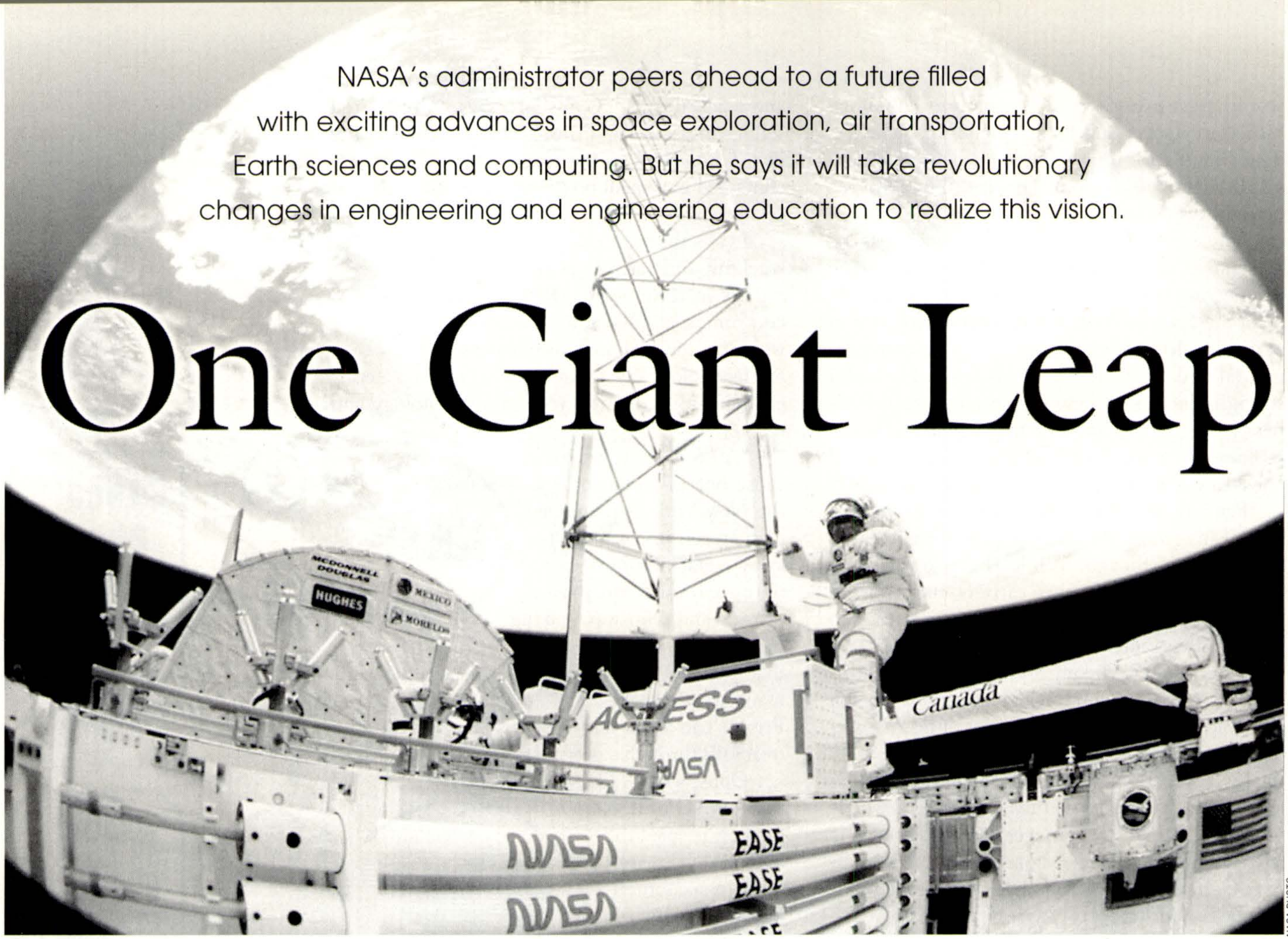
—Walker is a freelance writer whose last article for the Journal *was a profile of the late David Todd in the Spring 1998 issue.*



This flow chart shows the path taken by a 57-second call made by Timothy McVeigh with his prepaid phone card on April 17, 1995. After being routed through the 800 Number Administration and Service Center (NASC) and West Coast Telecom (WCT), the call passed through the computers at Opus Telecom, where detailed information about it was recorded.

NASA's administrator peers ahead to a future filled with exciting advances in space exploration, air transportation, Earth sciences and computing. But he says it will take revolutionary changes in engineering and engineering education to realize this vision.

One Giant Leap



NASA PHOTO

BY DANIEL GOLDIN

NASA is not just about opening air and space frontiers; we're also about building the tools we need to open those frontiers. While we've had some great successes, there's much more to do. We want to cut our system costs by about an order of magnitude. We want to cut our cycle time of development by a factor of 3 to 5, so we can build and launch a spacecraft within a year to a year and a half. We want to improve reliability by up to a factor of 10,000. To achieve these goals, we need bold, revolutionary leaps—not just at NASA, but in engineering and engineering education.

NASA has a bold strategic vision for the next 25 years. We want to develop technologies that cut travel time across the Pacific in half and cut costs and improve safety so space travel is not limited to our astronauts. We want to be able to make annual to multi-decade predictions of climate, environment and resource management to promote sustainable development on this planet. Within 10 to 15 years, we want to be able to detect Earth-sized planets around stars up to 100 light years away and see if those planets support life. Within 25 years, we want to be able to see geological and biological processes on those distant bodies. And we want to use the International Space Station as a platform so an astronaut can leave Earth orbit and maybe one day visit Mars or work on a research station on a near-Earth asteroid.

To make our vision a reality, we will need more intelligent systems, more flexible modular vehicles, breakthroughs in miniaturization, better, lighter materials, and advanced operating capability. For example, to send a probe to a distant star, where it will be too far away to receive operational commands from mission control, we'll need a spacecraft that can think for itself and learn and adapt as it goes. It will have to be self-diagnostic and self-repairing; in many ways, it will have to be like the human body. It will have sensors and actuators, it will react to stimuli, and it will adjust to changing environments.

Traditional numerical approaches will not work in such a spacecraft. Instead, we'll need soft computing that more closely resembles human intelligence—we need a vehicle IQ. We will develop modules from the chip level through the system level. With a modular design, we can assemble similar modules into different spacecraft to achieve different missions. This building block approach will also find its way into vehicles operating closer to Earth. For example, modular design will enable us to modify wing configuration to change the role of an aircraft.

To go beyond the solar system, we'll also need smaller and cheaper spacecraft. We've already made significant strides in that area. Viking, which landed on Mars in 1976, cost over $3 billion (in today's dollars), was about the size of a small car, and took about a decade to develop. By contrast, Mars Pathfinder cost less than $300 million, was much smaller and took less than three years to develop.

In the future, the costs and the sizes of spacecraft systems will continue to shrink as their capabilities grow. In the near term, we plan to build spacecraft about the size of a television set. Ultimately, we'll develop nanospacecraft that will weigh less than a kilogram, fit in the palm of your hand and have their entire avionics on a single chip. These spacecraft, which will operate in some of the harshest environments known, will also benefit from advances in materials and design tools.

It's not just the spacecraft that must get smarter and smaller. We must also develop intelligent, streamlined control systems and continue to reduce the work force needed for space missions. For every person you see in the space shuttle mission control, there are many others behind the scenes. Launching the shuttle takes thousands of people and a few hundreds of millions of dollars. NASA's new X-33 experimental vehicle, which will fly next summer, will require no more than 50 people for operations. The Viking program required about 1,000 people in mission control; Pathfinder took about 50. Future missions will require 12 or fewer.


NASA PHOTO


DENNIS VANDAL

NASA's Dan Goldin was the featured speaker when the Industry/University/Government Roundtable on Enhancing Engineering Education (IUGREEE) held a major meeting on the WPI campus in May. It was the first time that the organization, whose membership includes WPI President Edward Parrish, had met on a university campus.

"Because of current shortcomings, we commit about 90 percent of the cost of a new product when we only have about 10 percent of the knowledge about it."

How do we get from here to there? How do we take the engineering design culture from where it is today to where it must be for the missions of tomorrow? For a long time, engineering was a pencil-to-paper culture. In the 1960s, we moved from slide rules to electronic drafting boards and wireframe computer modeling. By the mid-1970s, we were using solid models to represent geometry and three-dimensional surface contours. Despite these advances, too much time was still wasted by the incompatibility of the analytical models used in such disciplines as aerodynamics, thermodynamics, structures and controls. The design process was sequential, with separate discipline groups. System design was optimized at the discipline level, not the system level. Data and design information had to be moved from one group to another—a task accomplished by people carrying large piles of paper.

About 20 years ago, we merged design with manufacturing. CAD/CAM, which significantly reduced design cycle, process time and engineering change orders, led to concurrent engineering—linking diverse disciplines through the use of digital data sets. The best example of concurrent engineering is the development of the Boeing 777. At the peak of design work, 238 design teams comprising 6,000 engineers, using data from 4,000 worldwide computer terminals, manipulated three trillion bytes of information representing 20,000 design releases.

But we still have a disconnect from discipline to discipline. We still have many distributed, unconnected databases across engineering fields and manufacturing. And because we don't have the capacity for real-time simulation, we can't get a real-time visualization and integration of all these tools. NASA is working to break this logjam. In our Product Design Center at the Jet Propulsion Laboratory, we are bringing disciplines together, which has enabled us to reduce analysis of preliminary mission design concepts from half a year to two weeks.

Because of the sequential nature and limitations of our tools, there is still far too much uncertainty throughout the life cycle of a product, there are too many people involved, and we have just begun to address the geographically distributed nature of what we do. We need to capture design knowledge earlier in the design process and learn to deal with the unprecedented quantity of data that confronts us and convert it into usable knowledge.

Because of current shortcomings, we commit about 90 percent of the cost of a new product when we only have about 10 percent of the knowledge about it. And the more we incur costs in any design process, the more our flexibility to make changes, without the risk of cost and schedule overruns, diminishes. As a result, we don't get an optimized design, products cost too much, and they're not as effective as they should be. We must eliminate the discrete steps of conceptual design, preliminary design and final design, as well as manufacturing training, maintenance and operations.

How do we close the gap between design knowledge and cost commitments? At NASA we're using something called Intelligent Synthesis Environment (ISE). We're not just updating tools, we're fundamentally changing the culture of engineering. The major components of ISE are human-centered computing, infrastructure for distributed collaboration, rapid synthesis and simulation tools, life-cycle integration and validation, and the cultural and educational change we need to inject into the creative process.

Human-centered computing deals with the dynamics and interfaces between the human being and the computer. Our current way of interfacing with the computer is for WIMPS (Windows, Icons, Menus, Pointing Systems). It's not the way we deal with our real environment. We interact with the world, process information and make decisions based on all of our senses. In addition, there simply isn't enough coupling of humans and computers. We need to exploit research on human biology and the brain's cognitive processes. Perhaps someday we'll talk to our computers using alpha waves or the electrical activity in our muscles.

"We must understand, appreciate, integrate and exploit biological processes and their incredible potential. Our goals at NASA depend on that, as does the future of engineering. This is something our education system must reflect."

We must also learn to discover and integrate various sources of data, using active intelligent agents to "mine" data and present it to the user in a variety of formats, including text, numbers and multimedia images. This will help us move from data, to information, to knowledge, to intelligence.

Next, we need to build the infrastructure for distributed collaboration so we can take full advantage of diverse teams around the world. We need at least a hundred- to a thousand-fold increase in computer capability to achieve the ISE vision. We need to move into nonsilicon or nonelectric computers—perhaps to optical and biological computing.

That's why we also need to increase our networking capability. The amount of information flowing through the pipeline must increase from under a gigabit per second, where it is today, to at least one hundred to one thousand gigabits per second. Tomorrow's networks must have intelligent switches and routers, or intelligent interfaces. The increased networking ability will enable us to link computers, mass storage facilities—and people—seamlessly.

Though separated geographically, scientists and engineers will be able to work in collaborative teams in the engineering design process. They will be able to work together, using the full range of human senses, even if some of them happen to be on Mars. Each team member will be able to participate and communicate from his or her own creative perspective. They will be free from the keyboard and the terminal, which are literally locking up our creativity.

The third part of ISE is rapid synthesis and simulation tools. Today, because of limitations in our models, we oversimplify the real world. We rely on separate complementary test programs to establish worst-case operating and failure conditions to guide our analyses. To account for uncertainty and to quantify risk, we must move from traditional deterministic methods to nondeterministic methods, like probabilistic approaches, neural networks, genetic algorithms and symbolic computing.

We've already achieved a high level of sophistication in numerical simulations across many disciplines, but we need to do more. Today's technology limits us to about one billion nodal connections and one billion nodal interactions per second. We need to aim for the capability of the brain, which is more than one million times more powerful. Only rapid analysis and optimization capacity near this level will close the design knowledge-cost commitment gap and enable us to go from mission requirements, to multidisciplinary analysis and design, to simulation of manufacturing and virtual prototyping, to operations and repair, to product disposal. The virtual design process will also give us, with unprecedented detail, cost impacts and risk-level assessment.

To ensure that we have analytical models to verify real-world behavior and failure mechanisms, we need to integrate analytical models development in real time with experimental testing. This approach will dramatically shorten the cycle time of product development by enabling a seamless flow from initial concept through final design and manufacturing.

To date, industry has concentrated on simulation of manufacturing, planning and processes. We have simulators of individual machines and we have real-time assessment of inventory flow control. But we need to be able to simulate an entire factory before we erect it; an entire plane before we build it; an entire mission to Mars before we launch it. Then we can begin to simulate operations, including repairs and maintenance.

That brings us to the next component of ISE: integration and validation. At this point, there are many unknowns. We don't know what fidelity we need. We don't know what scale is required. We don't know how collaborative virtual teams will work. These are fundamental issues. To address them and demonstrate and validate the future collaborative design environment, NASA plans to establish national, virtual distributed testbeds—geographically distributed computing environments that integrate hardware-in-the-loop, real-time information operating systems, and all associated engineering design tools.

At NASA, we want to focus these testbeds in critical areas such as reusable launch vehicles, next generation space telescopes, the space station as an engineering center, human exploration, and environmental modeling. To do so, we'll need broad industry and academic involvement. That's a cultural barrier, because this is not just about the aerospace industry. It is not just about technology. It's about people and how people work and communicate on a global scale to enrich our lives. Perhaps most of all, it's about education.

Back when we were using slide rules, people referred to the Three R's. Now we need the Three I's: information, integration and infrastructure.

Information: Engineers need more of it, or at least more of the right kind. Today's engineers can use the "black box," but they didn't build it. Because they didn't build it, they have trouble understanding the limiting first principle assumption of how it works, which leads to design and application failures. It's not that we have bad people; our teachers and students are the best. We're just guilty of using old approaches in a new era.

DENNIS VANDAL

Integration: We need to do more to integrate the most rapidly advancing fields in engineering education, such as biology. We are on the cusp of the Biological Revolution, and it's leaving engineering in its wake. We've seen how the knowledge explosion in the biological sciences, particularly in areas like health care and agriculture, has changed the way we live. The engineering community can't afford to sleep through this revolution.

We must take the intellectual underpinning of biology and apply it to engineering. Some call this biomimetics. I've referred to the power of the human brain. A single brain cell can carry 10 times as much information as today's most powerful computer and it is much more energy efficient. The engineering sciences need to apply this capability. We must understand, appreciate, integrate and exploit biological processes and their incredible potential. Our goals at NASA depend on that, as does the future of engineering. This is something our education system must reflect.

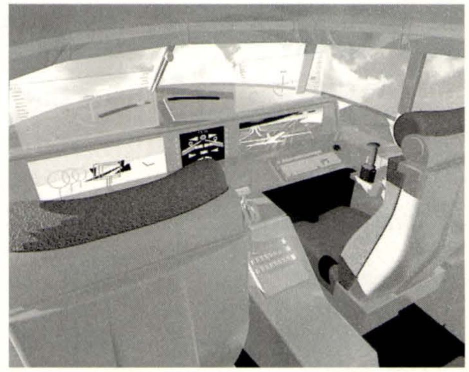
Infrastructure: Government, universities and industry must realize that our educational infrastructure can no longer be bricks and mortar; it must be bits and bytes. This means we must initiate and support revolutionary changes in our university engineering programs and create new capability for lifelong learning.

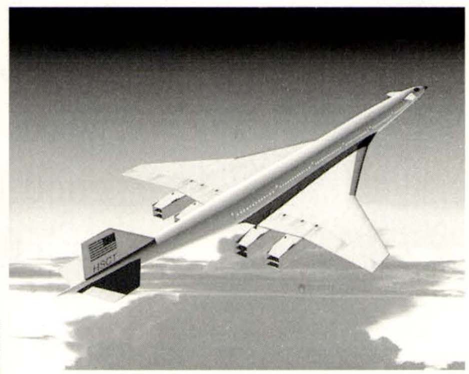
NASA and government must continue to push the envelope with long-term, high-risk research. We must work with industry to translate research concepts into workable methods and products. Most of all, we must bring in universities as fundamental, intellectual participants in the development of technology crucial for the ISE vision. NASA is already planning a program to do just that.

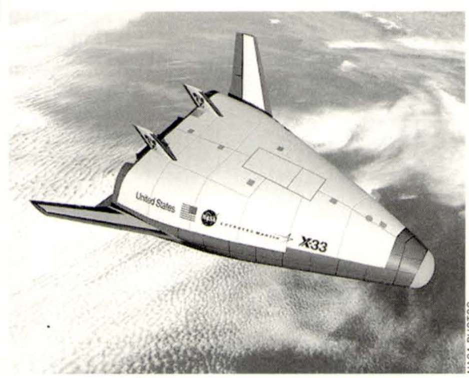
Industry must also support not just operations and near-term product development, but long-term, high-risk research and development. We'd like industry to work with us to create the workforce of the future, one that is not only more flexible, but that recognizes creativity and has a deeper understanding of the systems and tools it develops and uses.

And universities must understand this changing environment and develop new curricula and research capabilities. This is absolutely crucial because it is tomorrow's engineers who will enable everything I've discussed in this essay. With his invention of the liquid-fueled rocket, Robert H. Goddard, a 1908 WPI graduate, launched the Space Age. Future Goddards may pilot a submarine beneath the icy ocean we think covers Europa. Others may build a colony on Mars. They will have the training, the understanding and the tools. But only if we work together. So let's get to work.

—Goldin is administrator of the National Aeronautics and Space Administration (NASA). This article is adapted from Goldin's keynote address to members of the Industry/University/Government Roundtable on Enhancing Engineering Education, who met at WPI in May.







NASA PHOTOS

Smarter control systems, superfast planes that will cut in half travel time across the Pacific, and new generations of reusable spacecraft, like the X-33, are elements of NASA's 25-year plan. But Goldin told the members of IUGREEE that this plan—and the technological supremacy of the nation—will depend on the work they and others are doing to revolutionize technological education.

MAKING BIG PLANS

By
Edward A. Parrish

On Nov. 11, 1868, WPI inaugurated its first president and dedicated its first building with a long day of oratory by leaders from government and education. Among the speakers was John S. Woodman, head of the Chandler Scientific School at Dartmouth, who offered some well-considered words of advice to the leaders of the new Institute. He said a good college needs money, excellent teachers and wisdom, with the last item being the hardest to find.

"Wisdom," he said, "is needed to adjust plans and aims to means; to find the highest and best things; to aim only at just what can be well accomplished; to keep out of the way secondary, inferior and outside matters, that the money and the labor may all count upon the vigor and efficiency of the few great, central objects; and that the character of the institution may be steady, growing, and permanent."

WPI has spent the past few years in search of just that sort of wisdom. We are seeking to adjust our plans and aims, to find the highest and best things to which we can aspire, to devote our energies to the work we can do well, and to focus our imaginations on ideas and new initiatives that will help WPI grow steadily in excellence and reputation. In short, we are trying to make the big plans that Daniel Burnham talked about, and not the little plans that would result in our doing only a little better what we already do.

Big plans for WPI's future are emerging on a number of fronts. Building on the groundwork of the Strategic Planning Steering Committee of 1996-97, the Planning and Implementation Committee has been developing a number of strategic goals that it will present to the community this fall (see *The Wire*, June 1998). Concurrently, the provost has involved the academic departments in a self-study that will help identify new thrust areas that build on WPI's strengths and respond to the needs of a rapidly changing world. And the Alumni Association is drafting a new master plan that will be a blueprint for engaging, informing and serving our graduates in the decades ahead.

A STRONG FOUNDATION

All of these plans are being built on a foundation of knowledge about WPI's current position, the opportunities before it, and the threats and opportunities it faces at home and in the world beyond the campus. Here's a look at that foundation.

First, our current situation. One of WPI's greatest strengths is its excellent faculty. The faculty is the heart and soul of our outstanding education and research programs, and they bring national and international recognition to WPI as they are honored with major external awards and grants, election to fellow status in professional societies, invitations to speak at many national venues, and so on.

Provost Jack Carney and our academic departments invest a great amount of time and effort each year recruiting the very best educa-

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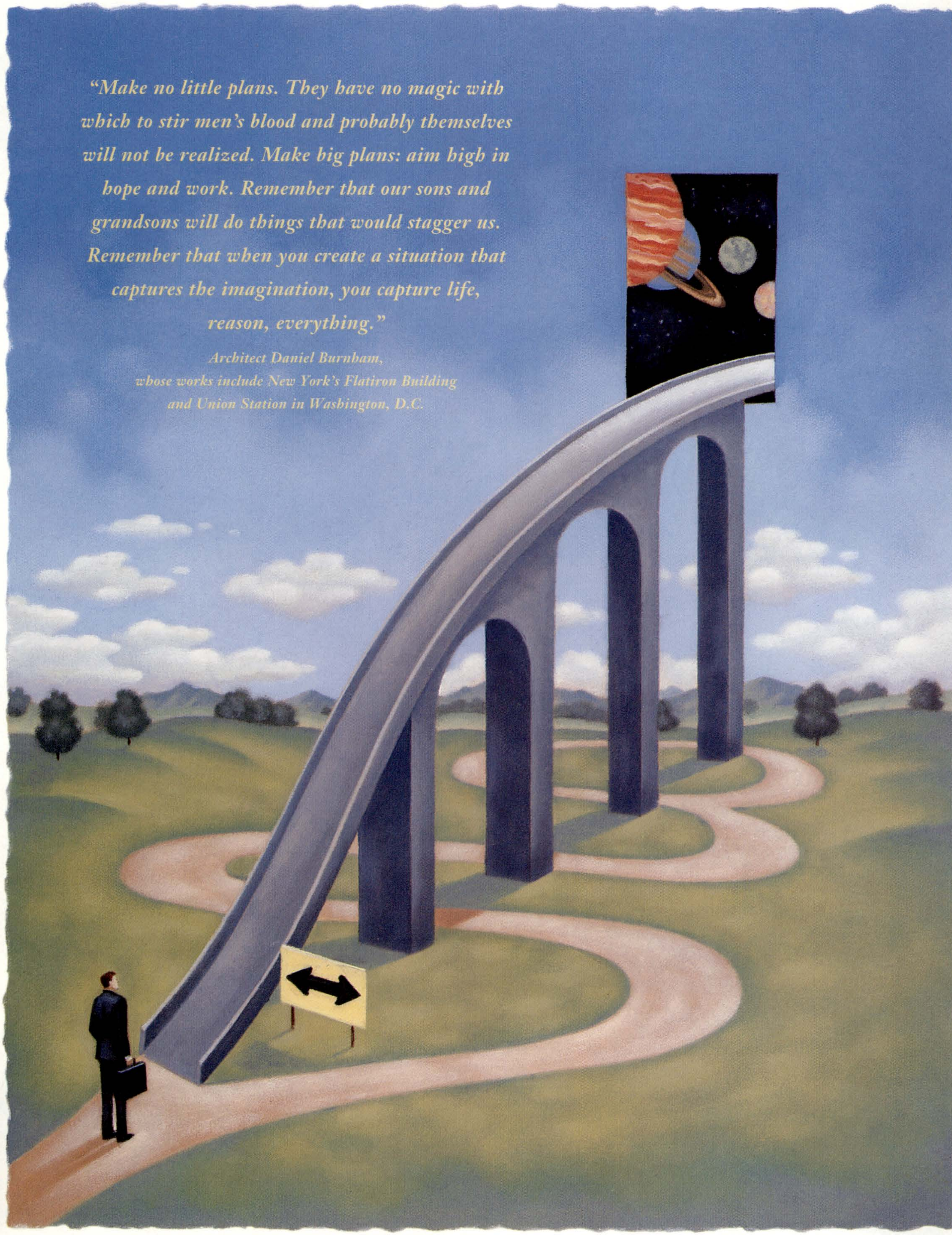
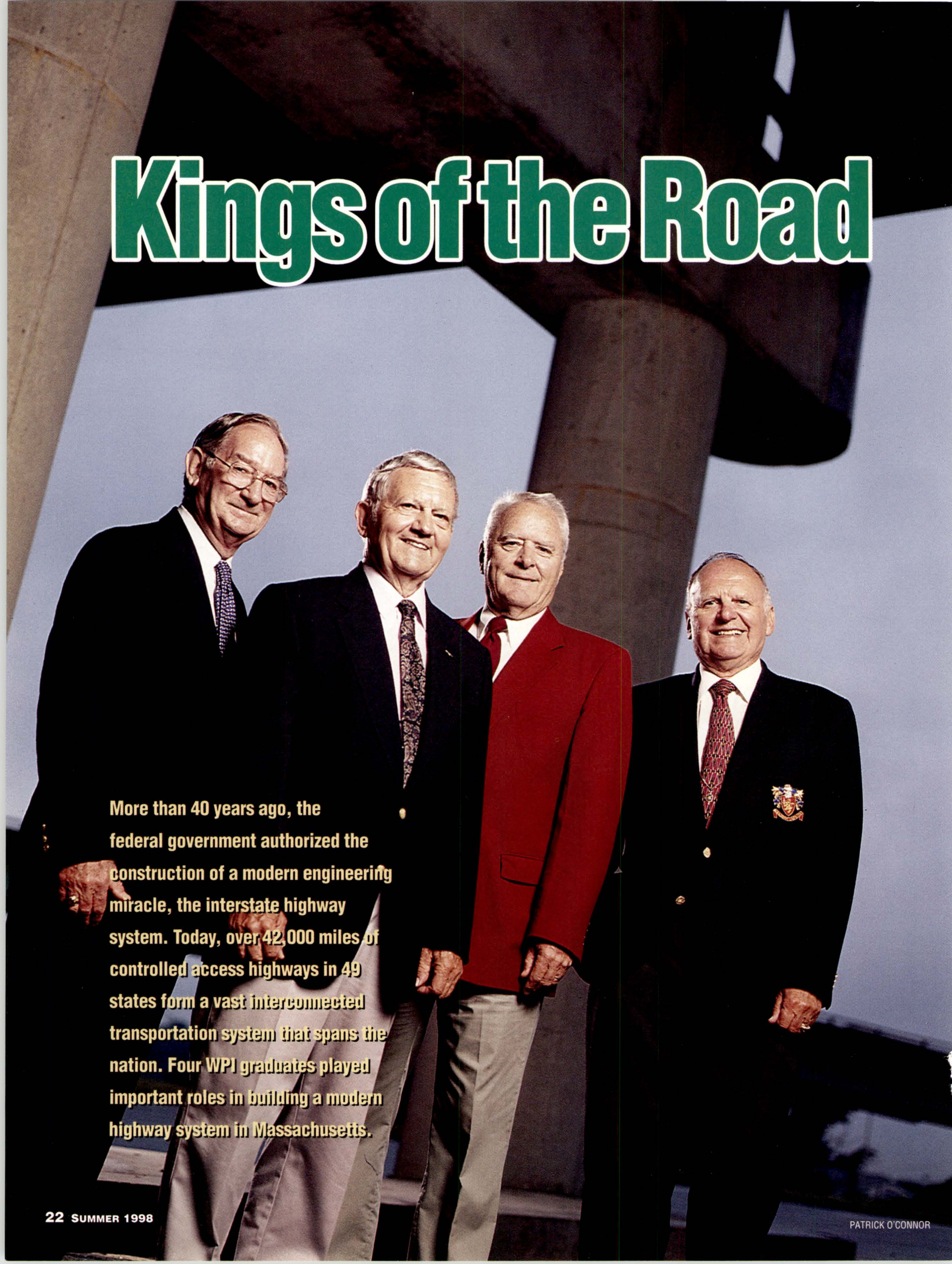


"Make no little plans. They have no magic with which to stir men's blood and probably themselves will not be realized. Make big plans: aim high in hope and work. Remember that our sons and grandsons will do things that would stagger us. Remember that when you create a situation that captures the imagination, you capture life, reason, everything."

Architect Daniel Burnham,
whose works include New York's Flatiron Building
and Union Station in Washington, D.C.

ILLUSTRATION BY FRED LYNCH



Kings of the Road

More than 40 years ago, the federal government authorized the construction of a modern engineering miracle, the interstate highway system. Today, over 42,000 miles of controlled access highways in 49 states form a vast interconnected transportation system that spans the nation. Four WPI graduates played important roles in building a modern highway system in Massachusetts.

PATRICK O'CONNOR

As early as the 1920s, it was becoming apparent that America's love affair with the automobile would give rise to a demand for a new class of roadway, one that could accommodate a constantly growing volume of vehicles and our desire to travel ever farther and faster. In the following two decades, the superhighway was born. The success of its early incarnations, including the parkways of greater New York and the Pennsylvania Turnpike, led planners to envision a national network of four-lane, divided highways to whisk motorists from coast to coast.

BY RUTH TRASK

World War II put plans for a national highway system on hold, but the return of GI's from overseas and the colossal spending spree that followed put even more cars and trucks on the road and exerted an even greater strain on the nation's aging roadways. In addition, the beginning of the Cold War placed a new focus on the need for rapid military deployment. A network of high-volume, limited access highways, it was believed, would be an ideal way to move men and equipment quickly from place to place in times of national crisis.

In 1944, Congress approved the establishment of the Interstate Highway System, though it would be another 12 years before work on the system began. On June 29, 1956, President Eisenhower signed the Federal Aid Highway Act, which called for the construction of 41,000 miles of modern highways across the country (later legislation increased that total to 42,500, and further additions brought the actual total built to 42,700). The system, eventually known as the Dwight D. Eisenhower System of Interstate and Defense Highways, would encompass every state but Alaska and take nearly three decades to complete (a few segments have yet to be built). About 90 percent of the cost of the system would come from federal user fees (gasoline taxes), with the balance coming from state coffers.

Encouraged by the ready availability of federal funds, states embarked upon an unprecedented period of road building beginning in the 1950s. Massachusetts was no exception. Working in the state's Department of Public Works, the Massachusetts Highway Department and other agencies, a number of WPI graduates helped plan, build and maintain the ribbons of asphalt, concrete and steel that today constitute the state's modern and indispensable ground transportation network. Here are the stories of four of those master road builders.

"The interstate system is one of the great engineering marvels of modern day civilization," Dean Amidon says. During the early 1960s, he was directly involved in the construction of one component of that marvel, Interstate 91, which traverses three New England states. Amidon was in charge of three projects on the portion of I-91 that passes through Springfield, Mass. "I found the projects challenging, but enjoyable," he says. "Building, making changes and seeing the results of our work made my I-91 assignment one of the high points of my career."

Amidon says construction of I-91 was fraught with obstacles. At one point, after the bridges for the project were nearly finished, the federal government forwarded new national defense requirements stipulating that bridge clearances be raised from 14 1/2 feet to 16 feet. Other change orders required that drainage and utilities and partially finished roadwork at a complicated interchange be redesigned and rebuilt. "We handled change orders right on the job as we received them," Amidon says. "There was very little delay."

Today, Amidon looks at I-91 and the rest of the interstate system with a feeling of accomplishment. "As I drive interstate highways throughout the country," he says, "I realize what a tremendous change the system has brought to people's lives, not only in terms of driving safety, but in terms of freedom of movement and choice of lifestyle. I'm pleased to have played a part in bringing those changes about."

More than a decade before he helped build I-91, Amidon joined the Massachusetts Department of Public Works as a junior civil engineer in Berkshire County. One of his earliest assignments was helping restore bridges wiped out

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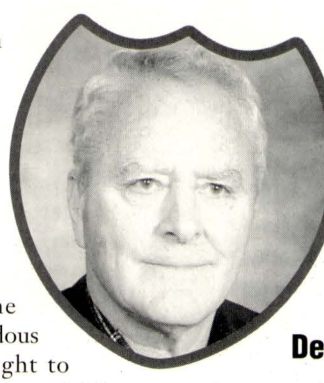

Dean P. Amidon '49

Career: 36 years with the Massachusetts Department of Public Works, three of those as commissioner; retired in 1987.

Today: Senior associate and consulting engineer at H. W. Lochner Inc.

KINGS OF THE ROAD

(Continued from page 23)

during a flood in 1949. He worked on highway and bridge construction projects in the Connecticut Valley briefly, beginning in 1955, before returning to the Berkshires, where his assignments included the construction of State Route 116 from Amherst to North Adams. For a time, he worked in Boston as the DPW's locations and survey engineer and also developed Massachusetts' implementation of TOPICS (Traffic Operations Program to Improve Capacity and Safety), a federal initiative aimed at increasing the use of traffic engineering techniques to improve the efficiency of urban highway systems.

In 1969, Amidon was named district highway engineer in the Lenox office, where he was responsible for all facets of public works in the district, including design, structures, environment, traffic engineering, maintenance, construction, administration and public relations. He was named DPW commissioner a decade later, overseeing a department with 4,100 employees and an annual operating budget of $100 million. After a three-year term as commissioner, he returned to his District One post in Lenox.

One highway project overshadowed Amidon's career in the Berkshires. Called the Route 7 or Pittsfield Bypass, the proposed limited-access highway would have relieved traffic congestion on State Route 7 between Lenox and Pittsfield. Amidon remains a champion of the project.

"New highways and bypasses are the same as jails, dumps and incinerators," he told the *Berkshire Eagle* in 1987. "We know we have to have them. Someone has to have the guts to make a decision—to say, 'Yes, it's going to hurt some people, but it's going to help more people, so let's do it.'" A final decision on the bypass project is still pending.

Highly regarded in his field, Amidon was recognized in 1975 for his engineering and administrative abilities when he received the Engineer of the Year Award from the Berkshire Chapter of the Massachusetts Society of Professional Engineers. In 1980 the American Public Works Association named him one of the Top Ten Public Works Leaders of the Year in the U.S. and Canada.

Two years later, he was elected president of the Northeast Association of State Highway and Transportation Officials, which covers the six New England States, Delaware, Maryland, Pennsylvania, New York, the District of Columbia, Puerto Rico, the Virgin Islands and five provinces in Canada. Its mission is to set standards for transportation design and construction nationally and to foster development, operation and maintenance of an integrated national transportation system. Most recently, he received the annual Outstanding Highway Official Award from the Massachusetts Highway Association.

Amidon can look back with pride at a career in which he has supervised a lengthy list of construction projects, from new bridges to road improvements to new highways. But he says his greatest thrill is seeing the products of his labor fulfilling their intended functions. "I look at a bridge or a road I've built, and I tell myself, 'That's real.' That stays with you forever."

John F. Gallagher '50

Career: 42 years in varying engineering assignments with the Massachusetts Department of Public Works and the Massachusetts Highway Department; retired in 1992 as associate commissioner.

Today: Transportation liaison between the Massachusetts Highway Department and other state and federal transportation agencies; transportation consultant for Cullinan's Project Managers in Auburn, Mass.

It's almost impossible to drive on a major highway or cross a bridge in Central Massachusetts that doesn't bear the stamp of approval of Jack Gallagher. After graduating from WPI in 1950 with a bachelor's degree in civil engineering, Gallagher accepted a post as construction engineer with the Massachusetts Department of Public Works, and went on to serve as assistant district traffic engineer and assistant project engineer in the Massachusetts Highway Department. In the latter post, he was placed on special assignment to work on the design and rebuilding of 100 bridges damaged or destroyed in flooding during Hurricane Diane in August 1955.

From 1956 to 1964, he was assistant construction engineer and a part-time project design engineer. During that time he designed Lake Avenue in Worcester and Route 122 from Tatnuck Square in Worcester to the Paxton town line. By the late 1950s and early 1960s, the road building boom had created a need for young engineers skilled in highway design and construction. To help fill the need, Gallagher and several other WPI alumni taught courses in highway engineering, fluid mechanics, reinforced concrete design and related topics at the former Worcester Junior College.

In February 1968, Gallagher, having risen to the post of assistant chief engineer, found himself speaking before citizens' groups about Interstate 190, a new route designed to reduce travel time from Worcester to Leominster and other points north. "There was some concern in West Boylston," he recalls. "People were afraid that the new superhighway would seriously divide the town, though it didn't."

Ultimately, I-190 became part of what is sometimes called the North-South Freeway, one of the state's most important traffic arteries. Also consisting of portions of I-290 and I-395, the freeway joins Fitchburg in the north and Webster in the south.

The I-290 project, also called the Worcester Expressway, was the site of a major construction accident in 1968, Gallagher remembers. In April, a bridge being built over a section of Southbridge Street in Worcester collapsed, killing three construction workers and injuring eight. Media reports noted that only one end of the steel girders had been fastened to the concrete abutment, but Gallagher told reporters the technique is standard practice to prevent expansion and contraction of the beams from ripping out the bolts. A general inquiry into the collapse ruled out negligence, but was unable to pinpoint a specific cause, Gallagher says. Just five months after the bridge disaster, the southern leg of the expressway, from Brosnihan Square to Route 20 in Auburn, was opened.

Beginning in 1970, Gallagher took a three-year post as assistant director of the newly established Massachusetts Bureau of Solid Waste before returning to the Highway Department as project development engineer. In that capacity, he worked with officials in towns along the route for the proposed I-395. In Webster, he helped win approval for a ramp to connect the town to the highway. In Auburn, he discussed possible routes the road might take through town and made sure residents had a voice in planning for landscaping and sound-reducing barriers. A former chairman of the Auburn Planning Board, Gallagher also urged the town to use zoning as a tool for planning for the growth the new highway would bring.

Promoted to deputy chief engineer of highway maintenance in 1987, Gallagher supervised a staff of more than 250, as well as another 1,000 workers who completed work for the department. For the next five years, until his retirement, he was responsible for the upkeep of 13,000 lane miles of highway and more than 2,800 bridges. "Fighting for maintenance funding was my biggest concern," he says.

"In my present consulting work, I haven't lost contact with the state highway department," he adds. "I still enjoy meeting with city and town officials to advise them on transportation problems. I'm proud to have been part of building and maintaining the interstate highway system, a part of my career for which my WPI education and the excellent WPI professors prepared me quite well."

Back in 1953, a reporter for the *Boston Sunday Globe* took a jeep ride with Norm Diegoli through the wilds of Cape Cod near Provincetown, where the state was building a section of the Mid-Cape Highway. Noting that Diegoli steered the vehicle deftly "through this wilderness of near-rootless scrub pines, stunted bushes and pure sand," the writer observed that Diegoli could make the jeep do everything but wait on tables. That's also a good summary of his varied career with the Massachusetts Department of Public Works and the state Highway Department.

After earning his degree in mechanical engineering (he would later graduate from Stanford University under the U.S. Army's Specialized Training Program for Advanced Engineering), he started out working on the design, construction and maintenance of the state highway/interstate highway network. His initial assignments included the construction of several sections of State Route 6 from the Cape Cod Canal to Provincetown, State Route 24 from Taunton to Fall River, and State Route 3 from Duxbury to Hanover.

During the early years of his career he was also "on loan" to the U.S. Navy for bridge construction at the Hingham Navy Yard and to the State Division of Beaches for the construction of Scusset Beach Reservation at the east end of the Cape Cod Canal. In 1968 he was transferred to the Bureau of Transportation Planning and Development, where the corridors for Interstates 495, 190, 391 and 392 were worked out.

Promoted to deputy chief engineer of the Division of Waterways in 1974, he oversaw the rebuilding of state piers in Plymouth, Fall River, New Bedford and Gloucester. During his watch, the canopy that encloses Plymouth Rock was extensively refurbished and a number of state harbors and waterways were dredged.

Diegoli was the last deputy chief engineer for the Division of Waterways, as the division became part of the Office of Environmental Affairs in a 1977 reorganization. He transferred to the state Highway Department as deputy chief engineer in the Division of Maintenance and Equipment, and had barely settled into his chair when state employees launched what would become a three-day strike. From his command post in the Communications Office, he saw to it that drawbridges continued to operate, traffic lights were in working order, and emergency highway repairs were performed, despite the walkout. "We were grateful," he says, "for the help given us during the crisis by sympathetic contractors, municipal electricians and faithful state employees who used their own vehicles to render services after dark."

Another, more daunting crisis arrived the following year. On Feb. 6, 1978, New England was hit by one of the worst blizzards of the century. Diegoli says the day took on a note of tragedy even before the storm hit when a passing motorist on Route 1 in Dedham struck and killed a state maintenance worker. That afternoon, the snow started and conditions on the state's roads quickly deteriorated. For the next two days, most highways were impassable.

Diegoli says 2,800 vehicles were stranded on just one stretch of Route 128, between Route 9 in Wellesley and Route 138 in Canton. With crews from Vermont, New Hampshire and the U.S. Army assisting, clean-up operations continued around the clock until Feb. 11, when the last section of Route 138 in Stoughton opened to traffic once again.

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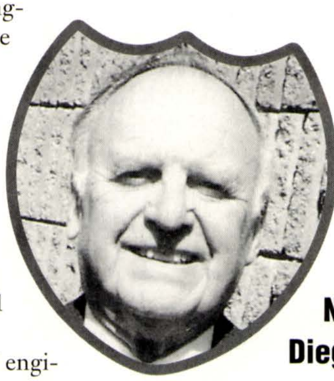


Norman L. Diegoli '48

Career: 34 years with the Massachusetts Department of Public Works and Massachusetts Highway Department, including a term as deputy chief engineer for the DPW's Division of Waterways; retired in 1983.

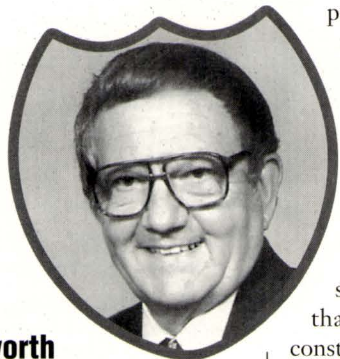
Today: Senior interstate representative for Bartlett Consolidated Inc., a maker of traffic signal devices, highway signs and guard rails in Plymouth, Mass.

KINGS OF THE ROAD

(Continued from page 25)

The snowy winter of 1978 was followed by a long, hot summer that found Diegoli in Cape Canaveral, Fla., overseeing the completion and testing of a high-speed hovercraft commuter boat. "That fall, the hovercraft was put into service between Hingham and Boston," he says. "But soon, service had to be curtailed because the craft kept running into floating debris, causing accidents."

Late in his career, Diegoli put his skills as a first-rate problem-solver to work on yet another challenge: cutting red tape in his own department. "I designed a program in which insurance companies pay for repairing damage to state highway property caused by motor vehicles," he says. "The program ensures that repairs are made quickly even during times of severe budget cuts and resource restrictions."



Ellsworth M. Sammet '49

Career: Four decades with the Massachusetts Department of Public Works, including two stints as district highway engineer; retired in 1989.

Today: Enjoying retirement in Pittsfield, Mass.

During a career spanning 40 years, there is bound to be at least one assignment that stands head and shoulders above the rest. For Sam Sammet, that special assignment was working on the construction of Interstate 91, a highway that now carries motorists from New Haven, Conn., to the Canadian border in Vermont. As assistant district construction engineer in District 2 in Northampton from 1965 to 1970, Sammet supervised resident engineers working on sections of I-91 from Greenfield, Mass., south to Chicopee and Springfield, including the link between I-91 and Interstate 291 in Springfield.

"Construction of I-91 along the Connecticut River Valley was especially challenging because many sections required construction in two phases," he says. The unusual technique, he notes, was necessary because of the thick layers of clay and silt along the river. In the first phase, embankments were built several feet above their final grade and allowed to settle for 18 to 24 months while the elevation of the road was monitored using settlement platforms and piezometers (instruments that measure pressure and compressibility).

To add to the complexity of the project, construction of drainage culverts had to reflect the anticipated settlement and bridges could not be constructed until the roadways had reached their final grades. "Building I-91 was one challenge after another," Sammet says. "But in the end, it was worth it."

Sammet joined the DPW in 1950 as resident engineer on highway and bridge projects in District 3, which encompasses Worcester County. He remained in that post for 15 years, working principally on sections of State Route 2 in Westminster, Gardner, Phillipston and Athol. After I-91 was completed in 1970, he was promoted to District 2 maintenance engineer in charge of all district highways and bridges.

At the time, plans were being made for the $90 million Route 7 Bypass project in Pittsfield. Expecting that construction would start in 1972, Sammet accepted the post of District One construction engineer and moved to Pittsfield in 1971. But the project never got off the drawing board. Sammet says he believes the price tag for the project has grown so high that it is unlikely to be built any time soon, especially since the "Big Dig" in Boston is siphoning off most new construction funds.

One of the factors that helped sidetrack the bypass, Sammet says, was the opposition of hundreds of homeowners in its path, who would, of necessity, have had to give up their houses. The District One construction engineer found himself caught in the crossfire between irate homeowners and the administration of Governor Michael Dukakis, which had pushed for the funding for the bypass and wanted it built. While he sympathized with the homeowners, the proposal had been on the table for 40 years and he felt it was time to build it to improve the regional transportation system.

As district chief, Sammet also monitored millions of dollars allocated by the state for highway building and maintenance in Berkshire County and eight contiguous towns, an assignment that entailed coordinating with 38 diverse boards of selectmen and two mayors. Commenting on the even temperament Sammet needed to do his job, one local reporter wrote that he was "a chief engineer with a bedside manner."

When Dean Amidon '49 was named commissioner of the State Department of Public Works in 1979, Sammet assumed the post of district highway engineer, a position he held until Amidon returned to the district in 1981. For the next six years, Sammet served once again as district construction engineer, taking on the additional duties of assistant district highway engineer. With Amidon's retirement in 1987, Sammet returned to the district highway engineer's chair until his own retirement in 1989. At his retirement luncheon, it was noted that Sammet was responsible for the substantial progress that had been made in updating, reconstructing and rehabilitating the state and town transportation system in his district.

As he looks back over a "very satisfying career in civil engineering that was launched at WPI," Sammet says he is particularly proud of the many miles of highways and the more than 100 bridges that exist today, in large part, because of his supervision. "Although highways and bridges often bear the names of politicians who helped fund them," he says, "the real imprint is that of the engineers and contractors who designed and built them." ■

—Trask, former alumni news editor for WPI, is now a freelance writer and a frequent contributor to the Journal *and* The Wire.

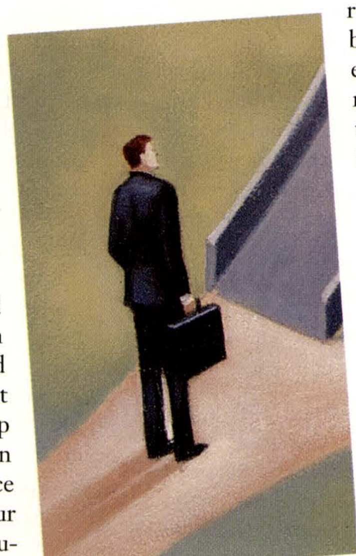
Making Big Plans

(Continued from page 20)

tors and researchers. Their labors, coupled with WPI's growing reputation, have enabled us to attract some outstanding new faculty members to our campus in recent years. This fall, we welcome 17 faculty members, including new chairs for the Chemical Engineering and Computer Science departments. In addition, Malcolm Ray, the first recipient of the White Family Endowed Professorship in Civil Engineering, a gift of Leonard H. White '41 and his family, will arrive in January. I am impressed by the extraordinary credentials of this group of educators and scholars who come to WPI from many of the nation's finest universities.

Of the tenure-track faculty who've just joined us, two are in computer science and three are in mathematical sciences—areas where average class size has been large enough to get in the way of the close student-faculty interactions that are the hallmark of our programs. We are committed to adding still more tenure-track faculty in the years ahead.

There are many factors to consider when hiring new faculty members. We seek excellent educators with a commitment to students, accomplished researchers with interests that make a positive contribution to our overall research program, and individuals who will thrive in our particular environment. Recognizing that our faculty members can be powerful role models for our students, we also want a faculty that reflects the diversity of our student population. While there is more work to be done, we are pleased that of the 44 faculty members hired over the past 3 1/2 years, 11 are women and 14 are minorities.



We also have a dedicated staff and we have bright students, enrolled in about the right numbers and supported by several strong student services that promote retention, wellness, leadership and career planning. We have been working over the summer to enhance some of those services. Recognizing our obligation to support the growing student interest in overseas projects (see below), we have created more elbowroom in the Project Center for the Global Perspective Program. Since oral and written communications are such critical elements of project work at WPI, we've moved the Writing Resource Center to the Project Center. We've also created the Learning Center, whose mission is to help students develop positive learning skills.

One of WPI's most critical support services is the George C. Gordon Library. For the past three decades, our library has served well the needs of our students and faculty. Today, with nearly 350,000 bound volumes, more that 1,000 current journal subscriptions, hundreds of electronic resources and databases, and links through the Internet to information resources throughout the world, Gordon Library is a well-equipped research facility. But it is under two serious constraints. The first is space. The growth in the library's holdings and in the demands placed upon the facility by active research and project programs has left it in need of additional room. The other constraint is money. Rapidly rising prices for journals—print and electronic—have outpaced the growth in the library budget. Eliminating underused titles has helped, but we are still fighting an uphill battle with journal prices. In the short term, we've increased the library's journal budget for this year. With the aid of our strategic planning process, we hope to find long-term solutions to the space and money crunches.

WPI also has a well-maintained physical plant soon to be expanded through the construction of a 71,000-square-foot campus center, a 41,000-square-foot academic building, and an adjacent parking garage. In recent months we have enhanced our physical facilities through a multitude of construction projects. For example, we completely renovated Daniels Hall. The project is part of a $14 million program to refurbish and modernize four of WPI's residence facilities by the fall of 1999. Renovation and construction projects provided new and enhanced facilities for research in biology and biotechnology, biomedical engineering, chemical engineering, chemistry, and electrical and computer engineering. We made some of our academic buildings more accessible to the handicapped, spruced up the properties we own in the surrounding neighborhood, and remodeled the first floor of Boynton Hall and the entrance to the Admissions Office to provide a more attractive entryway for visitors.

"We seek excellent educators with a commitment to students, accomplished researchers with interests that make a positive contribution to our overall research program, and individuals who will thrive in our particular environment."

But one of the most exciting projects involved renovations to our classrooms. In recent years, WPI has created a number of state-of-the-art multimedia classrooms with computers, video technology and satellite links. Over the summer, we added another, Stratton Hall 203, which was transformed into a computer classroom for mathematics education. Six other classrooms in

(Continued on page 28)

Making Big Plans

(Continued from page 27)

Stratton were renovated and outfitted with new seating, ceilings, lighting and carpeting. Two classrooms in Salisbury Laboratories were also renovated, and new seating was installed in classrooms in Higgins Labs and Olin Hall.

Creating well-equipped, networked classrooms is just one aspect of WPI's commitment to giving members of our community the information tools and resources they need for teaching and learning. We've made significant investments over the past few years in our information infrastructure, for example, placing network connections in every residence hall room and installing wireless network links to our fraternities and sororities. This summer we increased the speed of our residence hall connections from 10 megahertz to 100 megahertz to help resident students keep pace with the growing multimedia capabilities of the World Wide Web. We also upgraded network connections in 11 academic buildings.

"The gains in maturity and self-confidence students realize through their global experience are among the important characteristics that distinguish overseas projects, as a group, from those completed here on campus."

WPI has many other strengths, of course. For example, the market value of its endowment and similar funds is now $254 million, and this fall *U.S. News & World Report* ranked the University No. 51 among the top universities in the nation and 18th in terms of the quality of educational programs based upon cost of attendance. But some of our most significant assets as the end of the 20th century approaches may well be the remarkable opportunities that lie before us.

A Unique Moment in Time

The University is slowly gaining a national reputation and is experiencing a gradual increase in prestige. We have an established product that is in high demand and an undergraduate academic program, the WPI Plan, that anticipated by 25 years a number of national initiatives in technological education reform. In addition, our unique society and technology project (the IQP) and the potential applicability of the WPI Plan to graduate education are strong advantages.

WPI has taken a significant lead in providing students global opportunities; we have also realized great success over the past year in marketing our remarkable Global Perspective Program to our own students. Last year the Global Ambassadors, students who are veterans of overseas project work, took advantage of every opportunity to tell other students about the academic, professional and personal benefits of working on projects in other cultures. Largely as a result of their efforts, interest in the global projects program ballooned. This year we are taking steps to accommodate the many students—about half of our junior class—who wish to complete projects at our overseas sites. Our project center directors have been working with current and potential project sponsors to identify new projects. We have also been expanding our operations at some centers and working to create new ones. We will inaugurate centers in Boston, Copenhagen and Melbourne in 1998-99 and offer project opportunities in Zimbabwe next summer.

We are bolstering our efforts to prepare more faculty to serve as overseas project advisors. This is arguably one of the most demanding jobs our faculty do. Overseas advisors are on duty around the clock for seven weeks straight, dealing with the academic and social needs of students who are often thousands of miles from home and familiar surroundings. The job is not without rewards, of course, the greatest of which is seeing the remarkable personal growth students undergo at these centers.

The gains in maturity and self-confidence students realize through their global experience are among the important characteristics that distinguish overseas projects, as a group, from those completed here on campus. One of our priorities as an institution is to find ways to give students who complete their required projects locally the opportunity to realize the excitement, educational benefits and personal rewards of off-campus project work. Toward that end, we will work this year to establish and raise funds for the Worcester Project Center, where students will conduct IQPs with local agencies. The center will have as part of its mission consolidating and enhancing the services our students perform for the local community—through their projects and as volunteers. We believe that this exciting new program will enrich our educational programs and make a positive contribution to the city WPI has called home for over 130 years.

Along with those opportunities comes a host of threats that we must take quite seriously. For example, national engineering reform efforts, supported by more than $120 million in federal government funding, could remove our competitive advantage and erode the value added by the WPI Plan. Just as important, the high workloads of WPI faculty and staff make it difficult to continuously improve, which we must do to remain competitive, and even threaten our current quality.

The fact is, we've reached an inflection point, a time where we will need to decide whether we climb up, or slide down. I believe it's time to make a change—time for a great leap forward that will enable us to scale new heights of recognition and success. Historically, change occurs inadvertently; you don't see it coming. But we must either shape change, or it will shape us. British novelist Graham Greene spoke of a "unique moment in time when the door opens and lets the future in." I think we've arrived at such a moment.

REALITY VS. PERCEPTION

Our great leap forward should also help address WPI's image problem. The quality of our program is high, but our prestige is not commensurate with that quality. For example, while *U.S. News & World Report* ranked WPI among the top 51 universities in the nation, it also said our academic reputation, while improving, was among the lowest of those 51 schools. Academic reputation is about prestige, not quality.

We need to make a change that will increase our quality *and* prestige, and we need to do it while we are still in the national spotlight. The spotlight is on us for a number of reasons. One, of course, is our *U.S. News* ranking. Another is our selection as one of the first two universities in the nation to have their engineering programs accredited under the new outcomes-based criteria adopted by the Accreditation Board for Engineering and Technology. The criteria will soon apply to every engineering program in the nation, so there are hundreds of colleges and universities that want to know about our experience and our academic programs. Another reason for the spotlight was the decision of the Industry/University/Government Roundtable on Enhancing Engineering Education to hold a major meeting at WPI in May, its first meeting ever on a university campus. [NASA Administrator Daniel Goldin was the keynote speaker—see page 16 for his remarks.]

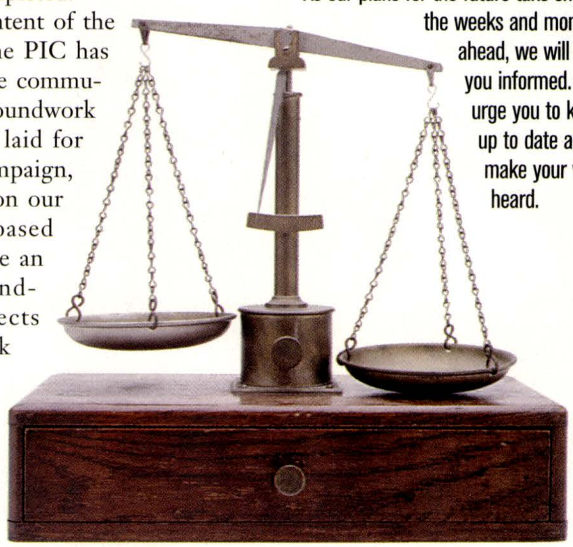
This is the right time to make a leap. Interest in WPI is at an all-time high. Our academic programs are in demand and we're attracting record applicant pools, and our applicants require less financial aid than in previous years. Our new class, the Class of 2002, is a good case in point. Starting with the largest applicant pool in the University's history, we expect to enroll between 680 and 690 students, comfortably above our target of 675. As I write this article (before students matriculated), the class includes 22 valedictorians and 12 salutatorians. A total of 46 percent are in the top 10 percent of their high school classes. Twenty-two percent of class members are women and nearly 6 percent are minority students.

Just as we have had great success in attracting outstanding students to our campus, our graduates are finding the kind of employment for which they've prepared. The economy is strong. The jobless rate is at a 24-year low, and twice as many high-paying jobs are being created as low-paying jobs. There is an especially strong demand for employees in engineering, management and computer services—our programs. In fact, Congress is so concerned about the lack of technical skills in the U.S. workforce that it is thinking about increasing the quota for immigrants with technical skills from 65,000 to 105,000 a year to fill the void. I'd like to help fill that void with our graduates.

MAKING THE LEAP

So, just what will constitute the great leap forward I've alluded to? The answer to that question is gradually emerging and will become clear when the Planning and Implementation Committee makes its final report to the community in late October (culminating a planning process that has involved dozens of faculty and staff members, students and alumni) and as the self-study being conducted by the provost and academic departments is completed.

Judging by the content of the draft initiatives that the PIC has already shared with the community and the initial groundwork that has already been laid for WPI's next capital campaign, the leap will build upon our trailblazing project-based curriculum and involve an expansion of our trend-setting global projects program. It will seek to revitalize and expand research at both the graduate and undergraduate levels, while redoubling our emphases on teaching and learning, lifelong learning, and outreach programs. It will include the exploration of new ways of integrating learning and living through innovative residential communities, as well as the strategic expansion and renewal of our campus, including the construction of the new campus center, academic building and parking facility.



Making a significant leap forward will take considerable resources. Much of this fiscal fuel will come from the upcoming campaign. Many institutions use their campaigns to make incremental changes. But if WPI takes that approach, I believe it will become a traditional institution and will lose its edge in project-based programs, in global programs, and in the other features and characteristics that make this university distinctive.

This is an opportunity that occurs rarely in the life of an institution. The prestige we will gain and the immediate and much-needed investments we will make will help WPI become a true national university—and sooner, rather than later. ■

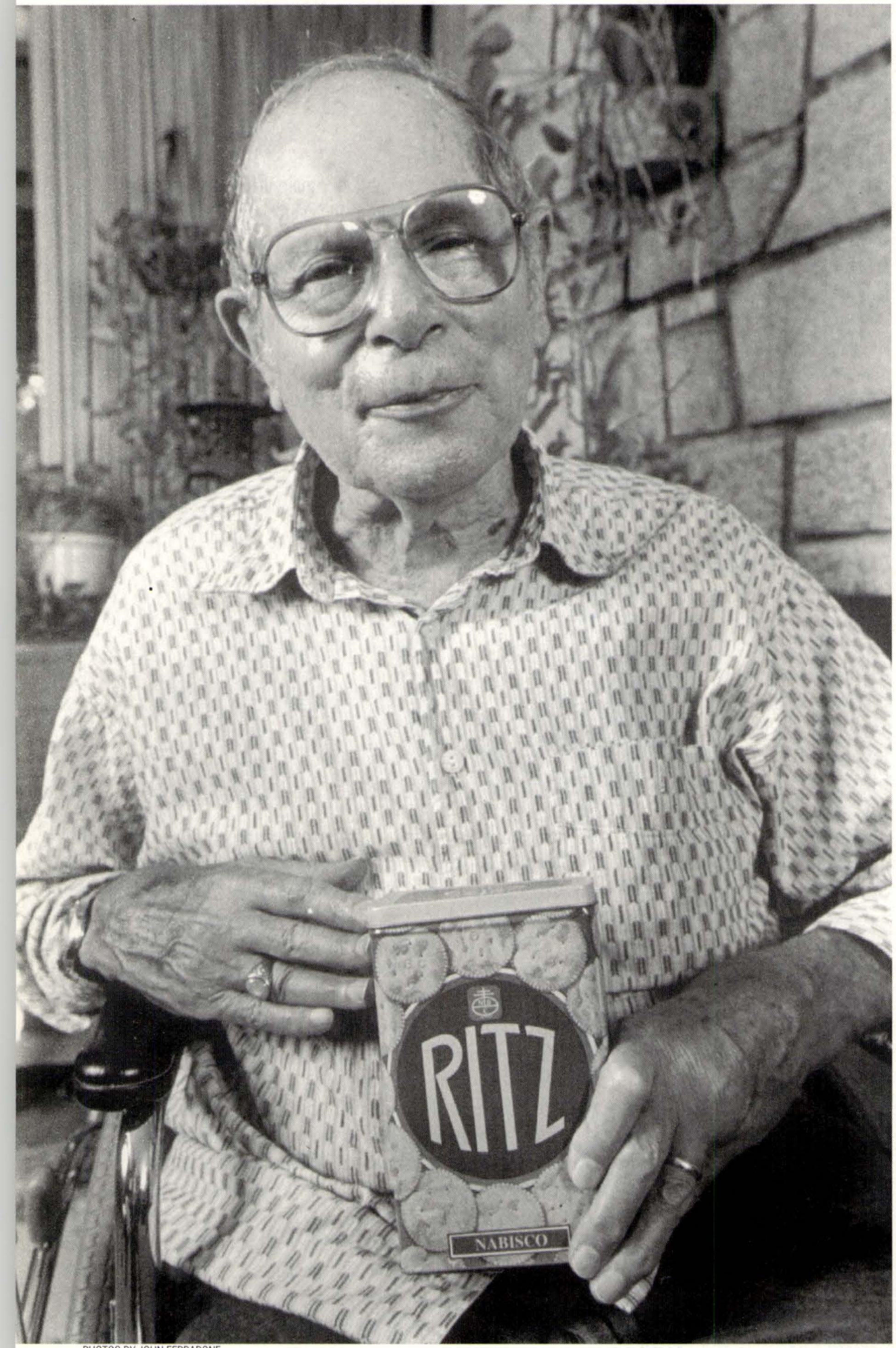
—This article is based on the State of the University *address that President Parrish delivered to the WPI community on March 11, 1998, and on his recent progress report to the WPI faculty, staff and students.*

Make Your Voice Heard

It will take more than money to propel this institution forward. It will take the interest, involvement and support of all sectors of the greater WPI community. As our plans for the future take shape in the weeks and months ahead, we will keep you informed. I urge you to keep up to date and to make your voice heard.

An important opportunity to speak out is coming up quite soon. Starting in the last week of October and continuing to mid-November, you will have the chance to register your opinion on the PIC's proposal and indicate how you would prioritize the committee's recommended goals. To cast your vote, visit WPI's strategic planning Web site (www.wpi.edu/Stratplan/), read the final PIC report once it is posted, and take part in an innovative Web voting system. If you are unable to use the Web, call the Communications Group at 508-831-5305 and a paper ballot will be faxed or mailed to you. The Planning and Implementation Committee very much wants to hear from all sectors of the WPI community, so please take part.

A Grand Tradition



PHOTOS BY JOHN FERRARONE

BY CHET WILLIAMSON

The gift that keeps on giving can arrive in many forms and have many meanings. For 82-year-old Henry M. Ritz '38, it was a music box he received a half century ago. From that first magical, mechanical device has grown an impressive collection that numbers more than 150 music boxes from around the world.

"It was something that just grew on me," says the retired president, treasurer and CEO of R&R Plumbing Supply Corp. in Worcester. "When R&R moved from Mechanic Street to Worcester Center Boulevard, I received a cigarette holder that played music. That started me off. Thereafter, on my birthday or Father's Day, my friends, my relatives and my children would give me music boxes."

The bulk of the Ritz collection is housed in a large, lighted cabinet in the basement of his home. Music boxes of every shape, color and nationality are crowded yet neatly arranged on shelves behind a glass encasement. A trolley car clangs out "I Left My Heart in San Francisco." A miniature Russian church plays the ancient folk song "Troika." A tiny gramophone twinkles "The Way We Were," and a Parisian kiosk plastered with French posters renders "La Moulin Rouge."

There are music boxes disguised as pocketbooks, radios, wristwatches and musical instruments. There are many wine and liquor bottles: an amber one plays "Little Brown Jug," while another spills out "How Dry I Am." One box, designed to look like a package of Ritz Crackers, has no doubt launched a thousand conversations at the Ritz household as it tapped out "Puttin' on the Ritz."

Other boxes set in motion twirling dancers, chirping birds and blowing whistles. There are musical buildings, alarm clocks, pin cushions, cigarette lighters, perfume atomizers, makeup cases, baseballs, footballs and banks. A birthday cake, in celebratory fashion, tinkles "Happy Birthday."

It's been said that when a music box is played in a room full of people, "everything else will stop." Ritz agrees. "It has a special tone," he says. "You can turn on a radio and people won't stop. A CD? People won't stop. But a music box? They do. It's like you are going to a circus and hearing a calliope."

"Music box," according to the Musical Box Society, an international educational organization, is a popular term "covering all types of automatically played musical machines, from small tabletop instruments that use a cylinder or disc to play tunes on a steel musical comb, to large orchestrions [mechanical band pianos] and carousel organs which have the musical capability of a symphony orchestra or a military brass band!"

The Encyclopedia of Collectibles dates the oldest music boxes to the last quarter of the 18th Century, "when watchmakers, mostly in Switzerland, began installing small spring-powered musical movements in watches, snuff boxes and other baubles. The bells that were the principal sound component in the earliest objects were relatively bulky; it was to afford greater miniaturization that combs of tuned steel teeth were developed as the basic musical element."

The oldest music boxes have their tunes inscribed on metal cylinders. In the late 19th century, cylinders were superseded by metal disks, which could be stamped out by machine and were, thus, less expensive to produce. Ritz' collection contains both kinds of boxes, as well as orchestrions and carousel organs.

The international look of the collection is a result of the many overseas trips Henry Ritz has made with Roslyn, his wife of 58 years and daughter of Jessie Morton Schorr '16. The couple have three children and five grandchildren. "Every place we went, I would buy a music box representing the country we visited.

"A lot of people ask me: 'What do you think it is worth?'" Ritz says about the collection. "That answer is: 'What is it worth to you?' It may be worth $20 to you and $100 to me. Take the antique box. I wouldn't sell that for several thousand dollars. Now, whether anybody would pay that much is problematical."

In fact, the antique box is one of Ritz's favorites. He keeps it upstairs in the living room along with a few other choice pieces. He found it, not in Europe, but in a secondhand store in Worcester. Made sometime around 1890, it plays six different French tunes. A hand-written label still clearly lists each piece. When Ritz found this rare mechanical music box it was sorely in need of repair. He fixed it himself.

"I used to take them apart and put them together again," Ritz says. "They always needed fixing and lubricating. I was able to do that."

Ritz is no longer able to work on his beloved music boxes. Having suffered strokes in 1981 and 1988, he must use a wheelchair to get around. Still, he remains active and his spirit is undiminished.

"You are looking at an inspiration," Roslyn says, placing her hand on her husband's shoulder. "Even though it is 10 years now since he had his second stroke, he tries everything he can to live a normal life. He advises others who have had a stroke. He will write a letter to someone and tell them not to lose faith, to keep on trying as hard as they can, to do their therapy, help themselves, so that they can live a productive life."

Living a productive life is something Henry Ritz has always tried to do. Born in Worcester in 1916, the son of Samuel and Minnie Ritz, he graduated from Worcester's Classical High School in 1934 and the following year enrolled as an electrical engineering major at WPI.

"I lost my father in my senior year and I had to quit school," he says. It was a time when R&R's annual sales were, as Ritz puts it, "equal to what we do in two days now." For five years, he worked at R&R during the day and took courses at night at a satellite campus of Northeastern University in Worcester, earning a degree in business and engineering.

Started in 1905, R&R took its name from its founders, Samuel Ritz and Joseph Rutman, father of Walter Rutman '30. The company started out on Water Street and moved to Mechanic Street in 1929. In 1950, it moved to Worcester Center Boulevard, where its brightly colored neon sign, with its dripping faucet, become a local landmark. Three years ago, the site was taken by the city to make way for the massive Medical Center project now under construction in downtown Worcester. Since then, R&R has called Chandler Street home.

In 1987, at the age of 71, Henry Ritz turned the company over to his son Jesse. "Jesse's doing very well," he says. "I'm very proud of him. He was just selected president of the Jewish Community Center in Worcester."

Ritz says he also plans on turning the music box collection over to Jesse. "He has the room for it," he says. "You have to have a lot of wall space to show all those music boxes. He is the only one of the three children who has the proper space."

The more than 150 music boxes in the collection of Henry Ritz '38 include some rare and unusual specimens. A box made to look like a box of Ritz Crackers plays "Puttin' on the Ritz." The antique box in the lower photo is among Ritz's favorites.

After nearly a half-century of amassing his collection and enjoying countless hours with his music boxes, Ritz is now a collector who wishes only to give and not receive. "I have no place to put them," he says, laughing. "I give them as gifts to grandchildren for birthdays. I would buy surplus ones and give them out as gifts: keychains, cigarette lighters, dolls, animals...."

It's obvious how much pleasure Ritz finds in sharing the joys of music boxes. "I can't tell you how pleased Ray Morin was when I gave him a cigarette lighter that played his theme song," Ritz said, referring to the late dean of Worcester music critics whose music box played, "Für Elise" by Beethoven.

Through the years Ritz has given many lectures about his music boxes. He's spoken to many Worcester social groups and on occasion has placed his collection on display at the Worcester Public Library and similar venues. In his talks he would often note how the royalty of Europe took great pride in their music boxes. It was a form of appreciation to give each other such enchanting gifts. In his own way, Henry Ritz has continued this grand tradition of giving gifts for the generations.

—Williamson is a freelance writer and musician living in Worcester.

Sharing the Secrets of the Universe

BY JOAN KILLOUGH-MILLER

Imagine a classroom powered entirely by enthusiasm, and you'll get the general idea of the Solar Energy Education Center at St. Mary Central High School in Neenah, Wis. If the love of learning is a form of energy, then teacher and Solar Center Director Allan Clarke '77 is the source. His excitement is captured by his students, who transmit it through the school and out into the larger community.

"I love the way kids come into a classroom so expectant, and they absolutely energize you," he says. "It may sound corny, but it's so real. It's like—Wow! For 45 minutes, you can share with them some of the secrets of the universe!"

Words like "wow" and "whoa" and "awesome" crop up a lot when Clarke talks about the Solar Center, which broke ground in January and was dedicated in May. Housed in a converted storage garage on school grounds, the center boasts a 1,000-watt photovoltaic system, a 900-watt wind turbine, and solar energy demonstration equipment that would be the envy of many colleges. The center is home base to St. Mary Central's "Solar Team," keepers of two beautiful electric vehicles—a bright red dune buggy called the Solar Spirit and an electric-blue go-cart called Zephyr Lightning.

Teacher Allan Clarke with the Solar Spirit at the Solar Energy Education Center he directs at St. Mary Central High School in Neenah, Wis.

Clarke still can't get over the generosity and good fortune that brought the center into being. "The solar center is a visible manifestation of things I've always believed in and I've tried to do in the classroom," he says. "I don't know how I did it before. How could I possibly teach solar energy operating out of a filing cabinet in my classroom, where you can only have things out for a day, then you've got to put it all away?"

Inside the solar center, students can feel hot air blowing in from the solar heating panel, even on a Wisconsin winter day. They can pedal the "Energy Cycle"—a stationary bicycle that generates electricity—until they've made enough juice to light a light bulb or run a hair dryer. "When they see, for example, that it takes 100 hours of cycling just to heat up your bath water, they begin to value resources differently," says Clarke. "And when they connect it with burning natural gas, oil or coal, they start to understand that there's got to be a better way."

"There are so many ways you can teach energy," he continues, "from lighting a match, to bouncing a ball or shooting a rocket. I've always been a hands-on, involved teacher. I love deep theory, and I love to teach it. But it doesn't have to be heavy or dry. When kids can touch something that's real, it just sticks with them."

At community picnics and fairs, the Solar Spirit and the Zephyr Lightning draw a crowd faster than you can say "solar assisted vehicle." Kids are flabbergasted by a quiet engine that uses no gas and creates no fumes. The Zephyr Lightning, built by St. Mary Central students in 1994, impressed the local Community Foundation so much that it funded construction of the Solar Spirit, and later donated funds for a trailer so the cars could be displayed throughout the area. Enthusiasm and donations snowballed from there. In 1996, Clarke formed a partnership with the Fox Cities Children's Museum in nearby Appleton, and together they obtained a $20,000 grant for students to build a working photovoltaic exhibit for the museum.

As the solar team grew, Clarke dreamed of establishing a permanent home, where students could work on long-term projects, consult with professionals, and expand outreach to other schools and community groups. In the fall of 1997, Clarke learned that Wisconsin Electric Power Co. was offering a $15,000 photovoltaic system to the most deserving school or group in the state. With the deadline only weeks away, he and his wife, Ann, worked round the clock and pulled together a winning proposal.

A large local construction company, Miron Construction, volunteered its services for the $50,000 job of converting a storage garage to a solar education center. Other supporters rallied to the cause. The teamwork was documented in a video, which was shown at the dedication this spring.

Although Clarke is justifiably proud of the physical apparatus—the likes of which many college students never see—it's the humbling challenge of reaching young minds that matters to him. "The Solar Center is really just a model for education," he says. "This center could have been devoted to robotics, it could have been for telecommunications...it just happened to be on the vital topic of energy. What I'm discovering is that most people have a deep thirst for knowledge. It's just a matter of how you turn that on and off."

In fact, it was at WPI that Clarke discovered his love of learning and his desire to teach. He was inspired by the "Comps"—Comprehensive Exams taken by seniors in the early years of the WPI Plan. To prepare for the exams, Clarke spent time with each of his professors, asking the questions that he never understood in class. He realized that he loved learning. But a number of his fellow seniors—some of whom had spent the winter break skiing or sleeping off the previous semester—had failed the exams and would not graduate. At Commencement, Clarke says he was filled with empathy, and a growing desire to go into teaching.

After a few years in research and development with Procter & Gamble and the former American Can Co., he earned his teaching certificate in high school science and mathematics at Lawrence University in Appleton in 1982 and accepted a position at St. Mary Central that summer. "WPI prepared me for teaching very well," he says. "It trained me not to just fill a slot but to create new opportunities. If there are needs, don't complain—fill them. If you see problems, fix them."

At St. Mary Central, students are beginning to consider it cool to be part of the Solar Team. Being elected a co-director is even cooler. "We're working hard at making it an awesome thing," says Clarke, "and what we're seeing is a new breed of leadership." He has some choice words to describe the type of students who manage the solar center: respectful, cordial, quiet, mature, modest. The co-directors take on responsibility without being asked, and never miss a meeting without prior notice.

"But we never forget that they are high school students," he asserts. "We don't want to fast-track their lives." Not all of the students are interested in technology: there are roles for artists and writers, fund-raisers, and would-be entrepreneurs. "They don't realize they're getting leadership, management and research practice, along with a chance to develop their people skills," adds Clarke.

"There are so many ways you can teach energy, from lighting a match, to bouncing a ball or shooting a rocket. I've always been a hands-on, involved teacher." —Allan Clarke '77

The solar team's next step will be to bring electric vehicle racing to Wisconsin, with the goal of holding an "electrathon" in the year 2000. Clarke envisions having the electrathon vehicles lead the runners in the Fox Cities Marathon. He would also like to start an Explorers scouting post devoted to energy, to give students from the surrounding towns a chance to use the solar center's facilities. This fall he will be teaching the state's first high school course on solar technology, and he is excited about the interest from educators from other parts of the country, who seek guidance in starting alternative energy centers of their own.

With all the plans and progress, Clarke is still filled with wonder over the simple phenomenon that makes it possible for the sun to create electricity through a flow of electrons. "The science behind solar energy is absolutely beautiful," he exclaims. His voice swells with joy as he compares the rhythmic motion of electrons to a symphony orchestra, or describes the peaceful whirring of a wind turbine. This technology holds the power to transform the world, says Clarke, even beyond the invention of the wheel.

Three generations of the Clarke family are invested in the Solar Center and the future of alternative energy. Allan's father is Edward N. Clarke, a pioneer in the semiconductor field, who is professor emeritus of electrical engineering, former associate dean of graduate studies and director of research, and former head of the Center for Solar Electrification at WPI. A principal donor of the solar center, he was invited to speak at St. Mary Central's convocation and the dedication of the center.

"It was exciting, as a father and also as someone interested in solar energy," he says. Sarah Clarke, Allan's daughter, is currently one of the center's five co-directors. They all agree that the best way to ensure the future of renewable energy is to put the developing technology into the hands of young people.

Allan Clarke observes that kids may be more open to new technology than adults, who are often locked into the status quo. But when adults see the kids getting excited, they tune in and start paying attention. Clarke thrives on these interactions, when his students have the confidence to show visitors around the center and answer questions.

"The kids become the teacher, and I just sit back, loving all of this, because my role is to get people teaching each other. That's when I feel like my dreams have come true. It's just really, really, awesome. All because the sun can create electricity through a flow of electrons! You know, technology is a wonderful thing."

Allan Clarke's daughter Sarah, a co-director of the solar center, tries out the Zephyr Lightning, a solar-powered go-cart built by St. Mary Central students in 1994.