Wisconsin engineer. Volume 80, Number 3 December 1975/January 1976

Madison, Wisconsin: Wisconsin Engineering Journal Association, [s.d.]

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OLUME 80, NUMBER 3 DECEMBER 1975/JANUARY 1976

wisconsin engineer

Skeleton
Heal
Thyself

Joe Nemchik battles distance and resistance...

to help provide better rural telephone service. Bell Labs electrical engineer Joe Nemchik, shown checking the performance of a circuit board, was one member of a team that tackled a major problem: telephone signals are weakened by electrical resistance in the copper wires that connect remote communities to switching offices. Up to now, reducing the resistance required costly large-diameter wires.

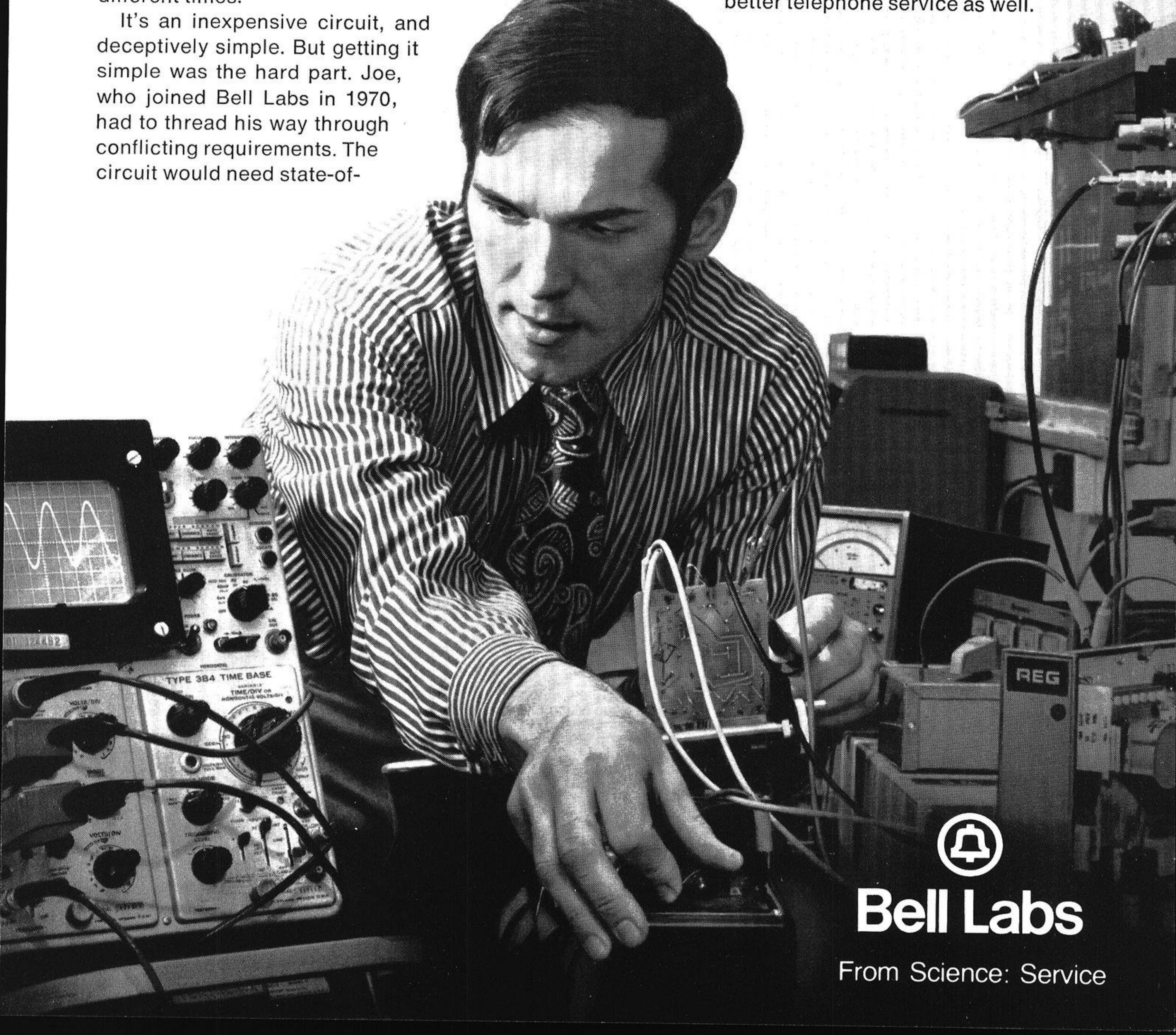
Joe and his colleagues designed a new electrical circuit that both amplifies the voice signals and strengthens the signals that set up the call's switching path by taking advantage of the simple fact that the talking and signaling occur at different times.

It's an inexpensive circuit, and deceptively simple. But getting it simple was the hard part. Joe, who joined Bell Labs in 1970, had to thread his way through conflicting requirements. The circuit would need state-of-the-art electronics and had to work with all switching equipment, some 40 years old. But high-voltage transients from older switches could damage the new electronics. So could lightning hits and power-line induction on rural telephone lines. The new circuit met the requirements.

Joe and his team worked closely with Western Electric to get the circuit to Bell telephone companies quickly. Later, Joe improved the design, cutting down the number of parts by 25 per cent.

With this circuit, Bell telephone companies can use smaller wires, helping conserve copper and saving about $15 million a year.

And provide our rural customers with better telephone service as well.



Bell Labs

From Science: Service

wisconsin engineer

PUBLISHED BY THE ENGINEERING STUDENTS of the UNIVERSITY OF WISCONSIN

Cover by Michael Wirtz

Contents

Chairman: MARSHALL H. KAPLAN, Pennsylvania State University, University Park, PA 16802
Publishers Representatives: LITTEL-MURRAY-BARNHILL, INC., 60 East 42nd St., New York, NY 10017 and 221 N. La Salle St., Chicago, IL 60601.

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Second Class Postage Paid at Madison, Wisconsin, under the Act of March 3, 1879. Acceptance for mailing at a special rate of postage provided for in Section 1103, Act of Oct. 3, 1917, authorized Oct. 21, 1918.

Published six times a year, Oct., Nov., (Dec.-Jan.), Feb., Mar., Apr., by the Wisconsin Engineering Journal Assn. Subscriptions: one year—$2.00; two years—$3.75; three years—$5.25; four years—$6.50. Single copies are 35 cents per copy. 276 Mechanical Engineering Bldg., Madison, Wis. 53706. Office Phone (608) 262-3494.

Membrane Device Lets You Breathe Easy

by Mary Peot

"What will be the impact of longer lifespans? How will we meet the needs of the elderly?"

How do we define life? When does it begin and when does it end?

If we can build artificial organs that override the natural causes of death, how will we allocate such devices, should demand exceed supply?

As artifical life support becomes an increasingly viable method of sustaining life, more and more people are finding they must answer such questions as these, listening not only to their minds, but also to their hearts.

Currently, biomedical engineering, in conjunction with the medical profession, has yielded a variety of innovations in recent years devised to promote health and save lives.

The development of artificial internal organs constitutes an important branch of this work.

Here at the University of Wisconsin, the Biomedical Engineering Center serves to coordinate and promote biomedical engineering on the campus.

Thirty faculty members, drawn from numerous departments including Nuclear, Chemical, Industrial, Mechanical and Electrical and Computer Engineering, Engineering Mechanics, as well as Health and Life Sciences and Sociology, are involved in teaching and research in this field.

Approximately 50 graduate students from five different engineering departments are focusing specifically on biomedical engineering.

Dr. Stuart J. Updike, M.D. of the Medical School faculty is currently working in conjunction with the Biomedical Engineering Center in the development of artificial internal organs. Dr. Updike, a member of the American Society for Artificial Internal Organs, is specifically concerned with the development of a new type of artificial lung.

One type of artificial lung has been used successfully for two decades. Employed in a supportive function during cardiopulmonary bypass surgery, this artificial lung is commonly known as a bubble oxygen type. Its capacity is limited because it can only be used safely for a few hours.

The new type being developed by Dr. Updike and his colleagues is a membrane device based on artificial kidney principles. Membrane devices are less toxic and can be used for several days instead of several hours. Dr. Updike's type of membrane oxygenator achieves oxygenation by transmembrane catalysis of hydrogen peroxide ($2H_20_20_2+H_20$). The device uses a dialysis membrane impregnated with a catalyst for breakdown of hydrogen peroxide. Carbon dioxide is eliminated in the form of a bicarbonate ion in the same way urea is excreted using hemodialysis.

Dr. Updike's device requires less membrane area and has the advantages of using material that is cheaper and stronger and of correcting acid/basic disturbances, among other things.

The device will be advantageous to patients who have reversible acute respiratory failures, particularly accident victims who have experienced trauma to the chest, shock lung, or who have contracted viral pneumonia. Doctors would first employ a mechanical ventilator. If that proved insufficient, an artificial lung would then be put into service. Currently, only university medical centers have artificial lung facilities.

The scope of the biomedical engineering program here at the University of Wisconsin is indicative of the increased general interest in this field. Work in the area of artificial organs has taken diverse and interesting forms. A few examples of recent accomplishments stemming from research carried out in other places includes the following:

Implantable balloon pumps for heart assist are being tested. These pumps can be removed surgically after recovery and reconnected should a relapse occur.

A prototype for an artificial endocrine pancreas is being developed using beta cells from neonatal rats. The subsequent culture continues to release insulin and remain responsive to changes in glucose concentrations. Cells cultivated in this way are protected by a membrane barrier and thus are not vulnerable to rejection.

Dr. Michael E. De Bakey of the Baylor University College of Medicine in Houston, Texas has developed an artificial heart made primarily of dacron/silicon rubber. The device is currently being tested on calves. Refinements are still needed. Installation requires a process similar to that used in transplantation.

Dr. De Bakey performed the first heart transplant in this country and was a critic of Dr. Denton Cooley who attempted to install an artificial heart in a human patient and failed.

The near future will doubtlessly see a proliferation of artificial organs. As the technology becomes increasingly sophisticated, sociological, legal, ethical, and economic questions will come into play.

What will be the impact of longer life spans? How will we meet the needs of the elderly?

Who will build these devices? How will we insure quality control?

The medical and engineering professions in conjunction with an enlightened government and public can begin to find answers.

Mary Peot *is a junior in journalism. Her main interest is in magazines. She is a former ballet instructor.*

R.I.P.

As is true with almost everything, the job market this year is both good news and bad news. The current job-hunting situation was outlined by Professor Marks, Director of the Placement Office, on an informational gathering of this semester's eager job candidates. It turned out to be that the forecast was pretty grim. The number of interviewers coming to the engineering Placement Office this semester is the lowest in about twenty years, narrowing the available alternatives. Also, electrical engineers are now suffering the consequences of the enrollment boom in this field some four or five years ago. So despite last issue's optimism, the job market is shaky and uncertain.

Of course, the situation in the Engineering Campus is paradise compared with the situation in the rest of the University. But then again, who cares? The fact is that getting a job is still relatively easy if you did your homework during the past four years, now it only takes a little more work, alertness and smiles.

Dem Bones Gonna Heal Again

(but when?)

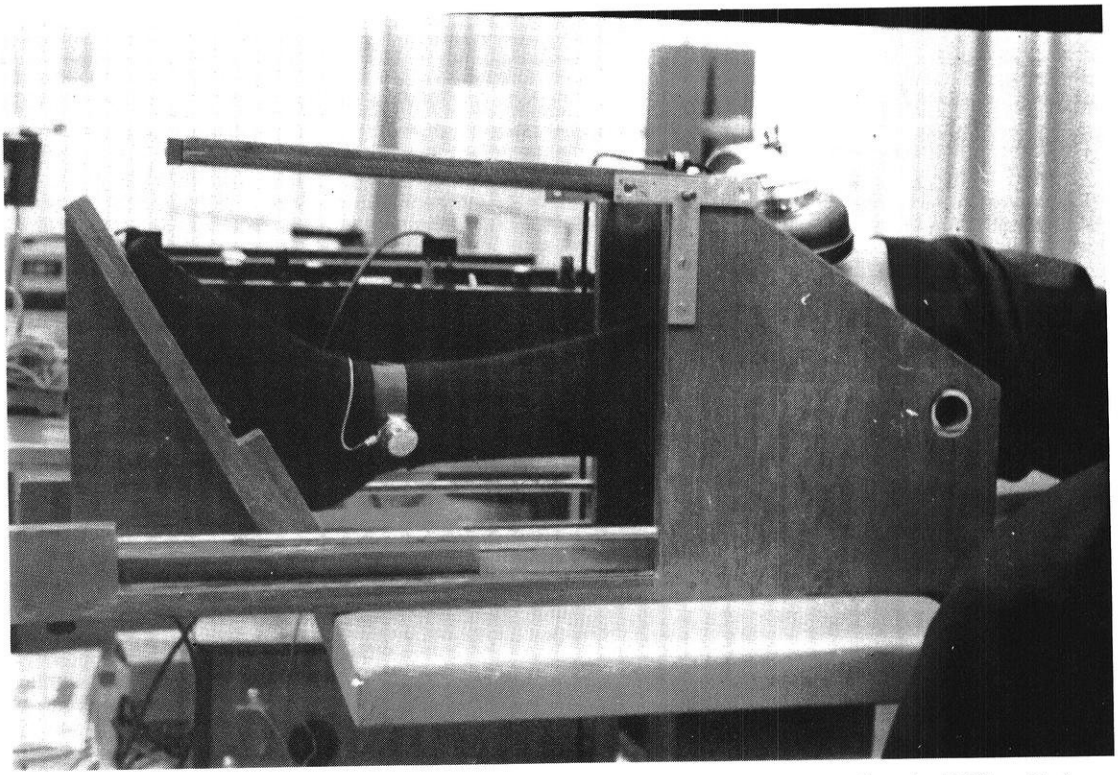


photo by William Graham

by Bill Jambois

Broken legs, the skiers' Waterloo, seem to offer by their mute, cast-wrapped presence a variation of an old theme-had God wanted man to ski he would not have made us of bones.

Apparently, skiers would rather take the risks than heed such implicit advice since, according to Paul Copello, U.S. insurance administrator for the U.S. Ski Association, six million people skied last year-400,000 of them in Wisconsin. Of these, one in ten suffered an injury.

While science is not yet able to make men better skiers nor improve a bone's ability to wholly survive a confrontation with anything so solid as a slope, it might make recovery less of a traumatic experience.

Dr. John M. Jurist, assistant professor of surgery at the University of Wisconsin Medical Center, Madison, and a bio-physicist originally trained at UCLA, is developing a technique which, for the first time, can measure precisely the extent to which a broken bone has healed.

At present, orthopedic surgeons must, with the aid of X-rays, essentially base such estimates on educated guesses.

"Conventional evaluation of healing fractures is based on clinical criteria and roentengenographic (X-ray) findings. This is a subjective evaluation and, therefore, fraught with error . . .," said Dr. Jurist in the May '74 issue of Wisconsin Medical Journal.

Such rules of thumb as "three months in a cast for broken arms" and "five months for a broken leg" are based on a long history of clinical observation, and, while having sufficed almost since the first bone was broken, traditional methods of determining bone strength are only estimates-there is no way an orthopedic surgeon can know exactly how strong a bone is, said Dr. Jurist. Until now . . .

In 1971 Dr. Jurist and Dr. Markey, a former resident in orthopedic surgery at the UW Medical Center, began to develop a technique which could measure precisely the strength of a bone.

The technique, "Tibial resonate frequency measurement as an index of the strength of the fracture union," uses a brace to hold the bone steady while a transmitter laying at one end of the bone sends sound waves through the bone which are recorded at the other end.

The resonate frequency of, for instance, a broken left tibia is compared with that of the healthy right tibia. Presumably the broken bone will not resonate as well as the unbroken bone just as a cracked bell does not ring as well as an uncracked bell. The resonate frequency is the best frequency or sound wave the bone is able to emit.

Graph 1 illustrates how the resonate frequency of a broken bone improves over a three month period. Line A shows the bone's frequency after having just been broken. Line B shows the bone's frequency after a month had passed, line C two months, and line D three months.

This supports the premise that there is a correlation between a bone's resonant frequency and the bone's strength. But, there are other methods which do essencially the same thing. And, while there is an apparent relationship between resonant frequency and strength, there needs to be a direct link. An orthopedic surgeon, after all, needs to know more than how well a bone 'rings.' Unlike other methods such as ultra-sound propagation velocity measurement, resonant frequency measurement does offer the missing link.

According to Dr. Jurist: "Consideration of the vibratory properties of uniform bars suggests that the square of the resonant frequency is proportional to the bar's strength."

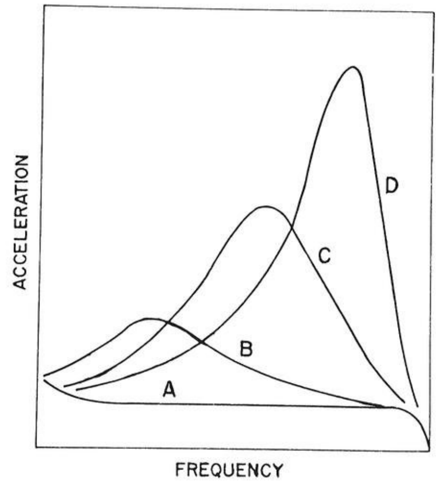
Using this theory as a premise, Dr. Jurist hypothesized that by measuring the resonant frequency of that fractured lift tibia (F_f) and using the frequency of the healthy right tibia (F_c) as a control, one could divide the broken bone's frequency by the healthy bone's frequency and achieve a ratio (F_f/F_c), which, when squared, would offer a fraction of the bone's strength.

For example, in graph 2 the point which is circled is a reading taken one month after the fracture occured. According to the formula it is 40% healed.

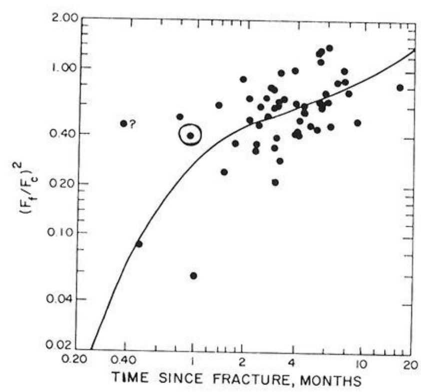
But, is the square of the frequency of a bone a true measure of its strength? Until now the theory had only been used to measure the strength of objects of uniform consistency such as iron bars. Could it be used to measure the strength of a bone?

In order to find out and develop the necessary devices and techniques, Dr. Jurist and Dr. Markey began testing the technique in 1971.

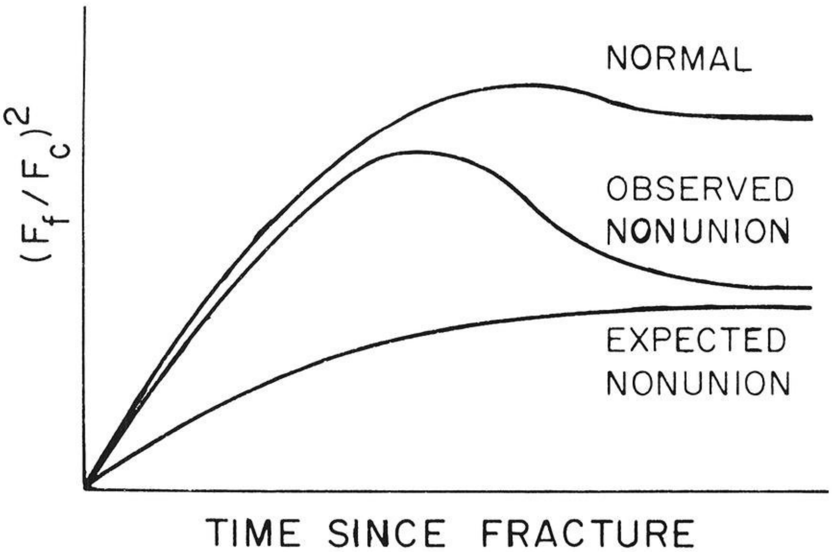
Seventy-five people were tested during the four years of testing. During this period Dr. Jurist was primarily concerned with perfecting and evaluating the technique by comparing it with conventional methods of evaluating bone union.



Graph 1



Graph 2



Graph 3

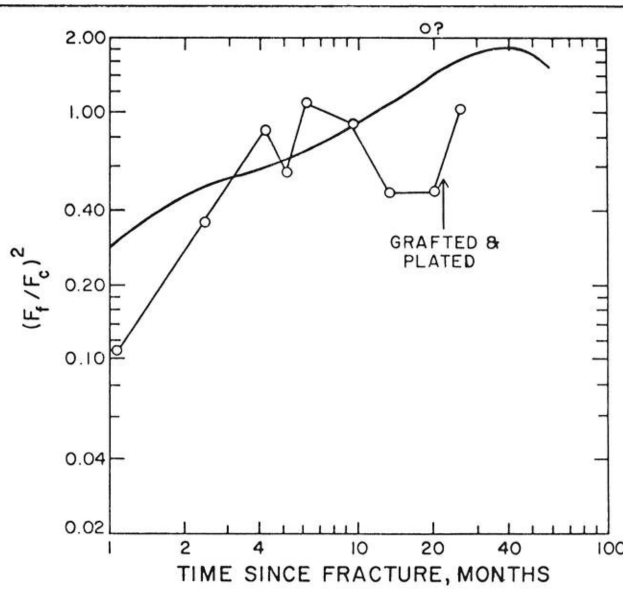
One surprise was the difference between expected nonunion and observed nonunion (fractures that don't heal). Dr. Jurist thought, before testing began, that the resonant frequency of a nonunion would produce a flatter curve right from the start, thus making nonunions predictable at an early stage of healing. But nonunions initially observed healed like a normal fracture. Thus those nonunions were not measurable until some months after the fracture occured (see graph 3).

In one case (graph 4) a 28-year-old woman that broke her leg while skiing was measured about one month after the fracture occured. Her leg appeared to be healing on schedule though at the fifth month a drop in frequency was noted. However, frequency improved by the sixth month and it wasn't until the seventeenth month that a nonunion was clearly indicated by measuring the leg's resonant frequency. Still, the technique indicated a nonunion before the traditional methods of X-ray and clinical observation had. Twenty four months after the fracture occured the woman's leg was operated on.

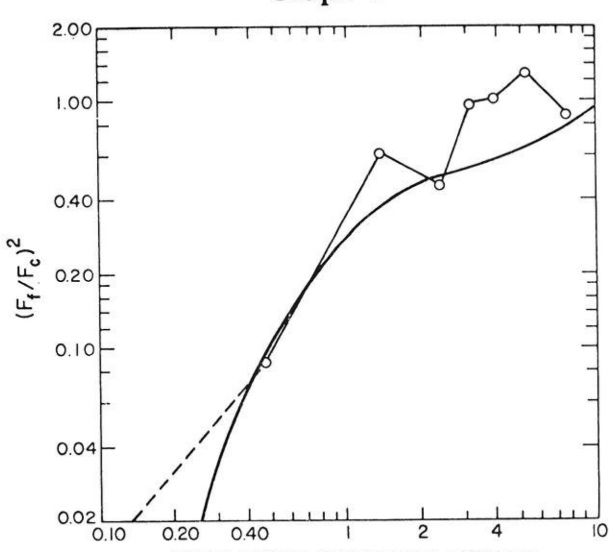
A better-than-average union, that of a 14-year-old boy whose leg was also broken while skiing, is shown in graph 5. Because the skeletal structure is still growing at this age, a fracture is expected to heal faster and this is reflected in the graph where the heavy line shows the average rate of healing for adults.

Eventually, Dr. Jurist hopes to use his technique to quantitatively measure the many different theories of promoting bone union and comparing them to determine the best ones and then improve them.

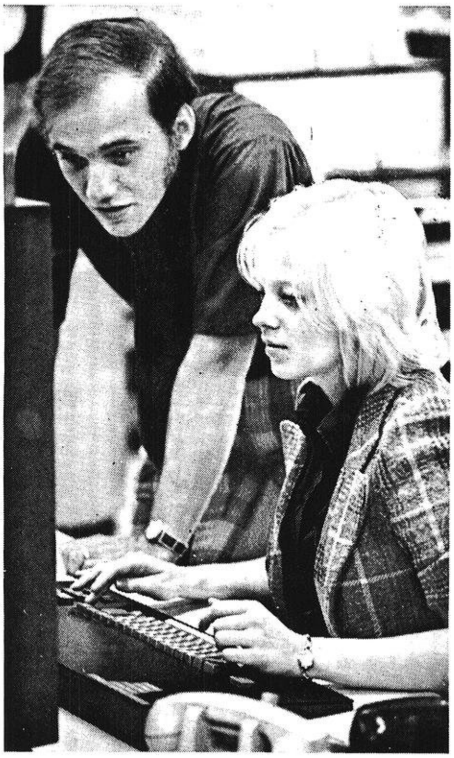
Bill Jambois *is a senior in journalism. He broke his leg a year ago in a motorcycle accident and had his leg measured by the resonate frequency measurement technique.*

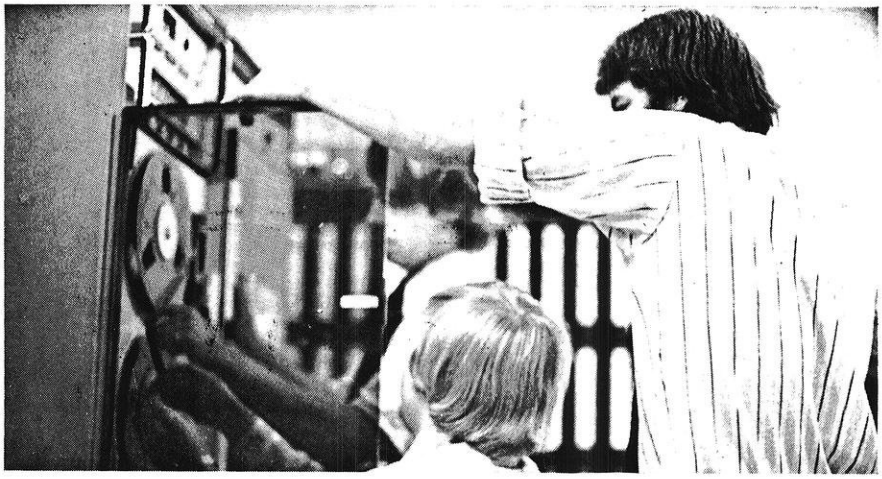


Graph 4

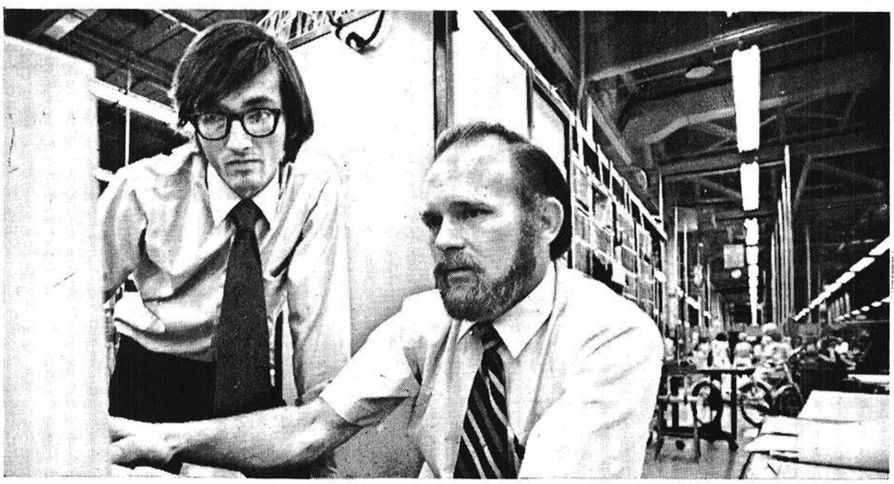


Graph 5






GTE AUTOMATIC ELECTRIC



"The time has come for you and I
To talk about the arts

Of Synthesizers

Moogs and Amps

And Razor Blades and Teknarts"

by Dan Harris

In 1967, after a long night of tape splicing and with coffee nerves still unsettled by a before—bed slug of my favorite libation, I wrote in a notebook, "what I need is more equipment." The studio whose lack of equipment I was lamenting was one I had set up in my home in New York. I use the word studio guardedly, since on the limited budget of a starving composer, I had managed to garbage six cheap tape recorders, a few broken radios, a homemade sawtooth oscillator, numerous cheap michrophones, and lots of razor blades and splicing tape. When I stand in the electronic studio which I now direct at the University of Wisconsin with its plethora of electronic gear; it amazes me that in the two years of my home studio I managed to compose so many pieces. Recently, after listening to a rather vapid student composition, produced in this equipment rich studio, I was prompted to remark, "The razor blade is still the most important tool in the electronic studio". The moral may be that the availability of equipment is no guarantee of artistic output. The software between the composer's ears and a razor blade for editing remain the preeminent studio tools.

The above ode to the razor blade is not to belittle the tremendous strides made in the realm of electronic music equipment. In the dozen years since the advent of the small modular synthesizer, not only the *modus operandi*, but also the esthetic of the medium have undergone great change. Where before once carefully guarded his catalogue of recorded sounds, now one merely flips on his synthesizer and literally makes most of his sounds. While old timers consider the synthesizer a luxury, students today expect endless numbers of oscillators, amplifiers, filters, envelope generators and voltage processors not to mention limitless tape channels. Where the older composer would have used perhaps a small number of electronic sounds in a composition, today's composer is more likely to use mostly electronic sounds. The module density of the present synthesizer has made it possible for

electronically produced sounds to be performed live while simultaneously processing the sonic output of traditional instruments or voices. The synthesizer is potentially the most powerful and versatile tool the composing/performing musician has ever had.

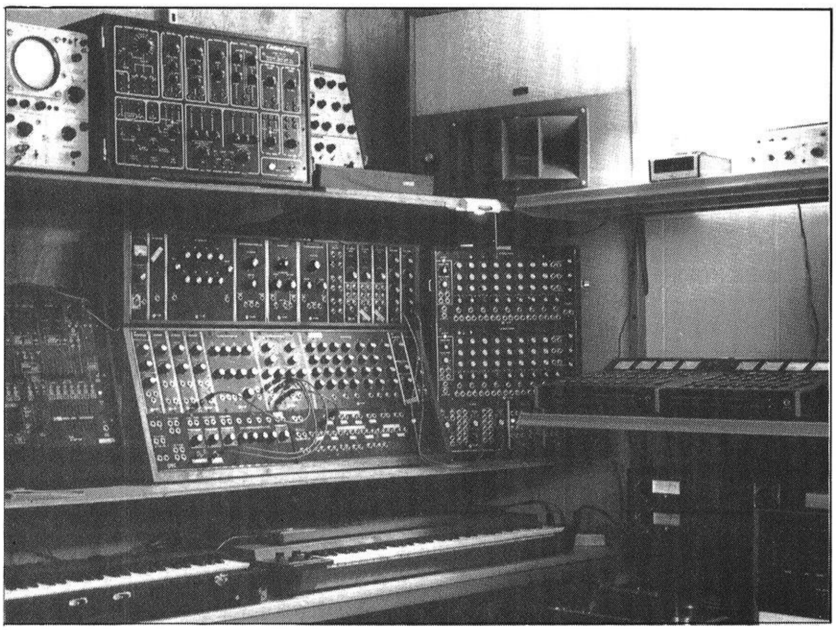
What is the substance of this plenipotentiary? A synthesizer is a voltage—controlled electronic instrument that is capable of producing, modifying and shaping sounds. In its simpler forms it contains several voltage—controlled oscillators (VCO), a voltage—controlled filter (VCF), at least one voltage—controlled amplifier (VCA) and an envelope generator (EG). A keyboard controller is usually included as an additional control voltage and trigger source. Larger synthesizers contain many more VCO's, VCA's, VCF's, EG's. In addition they may include such modules as ring modulators, frequency shifters (single sideband generators), sample and hold units, mixers, voltage processors, electronic switches, microphone preamplifiers, envelope followers, delay gates and sequencers. The packaging is such that even a unit containing all of the above modules may easily be contained in the back seat of a small automobile.

The electronic music studio at the University of Wisconsin contains four different synthesizers. They are a Moog IIc with a Complement B sequencer, an ARP 2600, a Putney VCS III, and an ElectroComp Model 100 synthesizer. Each unit has its advantages and disadvantages. The difference between the units are mainly in the logic of the system and the quality of the components. In the studio the Moog is the principal machine. It is the central synthesizing tool and is rarely used outside the studio in live, or real-time performances. The Moog contains the most elaborate filtering system (voltage controlled high pass, low pass, band pass and band reject as well as a passive equalizer), two envelope generators with a 30 milisecond to 30 second duty cycle, three VCA's seventeen oscillator outputs, a four by four mixer, envelope detector, wave shaper, 48 stage sequencer, two keyboard controllers, and a ribbon controller. All connections are made by patch cord. The ARP 2600, which is very portable, uses an internal prewired patching system with sliders. This system makes it ideal for live performance as well as useful in the studio. In addition to three VCO's, a voltage—controlled, low pass filter, two envelope generators (one linear and one exponential) and a VCA, the ARP contains three modules not present on the Moog, a ring modulator, sample and hold, and an electronic switch. The Putney and the ElectroComp are used mainly as auxiliary machines, though some users prefer them for various applications.

Since the majority of the compositions made in the studio are for tape alone, there are nine tape recorders of various formats in the studio. These are used not only as storage devices, but also as processing tools. Some of the processes for which they are used are echo, preecho, delay, octave transposition, mixing, loop playing and multitracking. One of the tape machines, an Ampex 350, has a vari-drive oscillator connected to it which will allow a speed range of barely perceptible tape movement to approximately 60 ips. The control oscillator on the vari-drive unit may be bypassed and an oscillator signal from one of the synthesizers may be used, thus allowing for rapid and programed speed changes. The vari-drive machine can also be used to create flanging and phasing effects. Tape editing is usually done on an Ampex 440 machine because of the accessibility of the heads and the provision for disengaging the reel motors. Editing may also be performed on any of the other machines, but it is more cumbersome. A TEAC 33400S four channel machine is used for bulk of the multi-track rcording.

The entire studio is interfaced through two Sony MX 16 mixers, which are wired so that there are sixteen input channels and four output channels. The outputs are connected directly to four monitor channels and a 90-pin jack patch matrix. There is a provision for cutting monitor speakers out of the system. The patch matrix provides for any signal to be sent to any tape channel or synthesizer in the studio. Signal routing is by means of a shorting plug. To pan a signal or signals, a special panning circuit is patched into the system. This circuit contains four Spectrasonic quad panpots. With this arrangement any four signals may be panned to any four tape or monitor channel. However, this operation requires at least three persons. The monitoring system consists of four Altec 9844A speakers powered by two MacIntosh MA 5100 stereo amplifiers.

Electronic music as a course of study at the University of Wisconsin had its beginnings in the middle sixties. The first synthesizer used was an early Moog I owned by Professor Robert Crane. In 1967 the School of Music purchased the Moog IIc and some tape recorders with a grant from the Graduate School. Between 1968 and 1971 the studio was under the direction of Burt Levy. In 1973 I became the full time director of the studio. Last year there were seven electronic music concerts given by the thirty members of the two electronic music classes. Members of the studio also provided incidental music for plays, sound tracks for films, music for dance concerts and several compositions for student and faculty recitals. While most of the compositional output of the studio is in the form of tape pieces or compositions utilizing tape and/or electronics and traditional instruments, a substantial portion of the output has been in the realm of mixed or intermedia. Compositions in this genre have included the use of film, slides, television, lasers, dance, cybernetic sculpture, lights, and in one instance a Philco refrigerator.



Top shelf, l. to r. - Oscilloscope, Electro Comp, Putney VCS III, Keyboards. Middle shelf - Arp 2600, Moog, Moog sequencer, mixers. Bottom shelf - Keyboards.

Current demands on studio equipment and time have led to the planning of an additional studio. This studio would be designed as a complete electronic composing system. The present studio would be used for beginning classes and as a guerrilla studio. While there are always four or five times as many students desiring to study electronic music than there is room for, there is as yet no major or minor in the field. This is due to several factors, the most important being that the field covers such a broad spectrum of disciplines: composition, electronics, recording techniques, acoustics, information theory, psychology, and computer science. There are perhaps only a half dozen places in the world that offer a comprehensive curriculum in electronic music. The diversity of knowledge needed to function successfully in today's highly tecnhical studio has spawned artists who are also technicians and technicians who are also artists.

A technician *cum* artist with whom I have collaborated on numerous projects has suggested that the new hybrid artist-technician be called an Artician. Would you believe a Teknart?

Daniel Harris, *alias Loat, was born in Chicago in 1943. He holds degrees in music from the Eastman School of Music and Yale University. He is active as a composer/performer. His compositions have been performed in Europe, the United States and Japan. Besides traditional resources his works have included the use of electronic synthesizers, interactive television, film, slides, light sculptures, lasers and assorted cybernetic devices. He is currently a lecturer in the University of Wisconsin School of Music and Director of the Electronic Music Center.*

Putting Power In its Place

by Lauren Schlicht

"Advantages of the superconductive inductor power storage will soon outweigh the economic disadvantages. They are nonpolluting and silent."

An electric generator working at maximum capacity would waste up to sixty percent of the energy produced. Running generators at a medium point would cause brownouts at peak periods of electricity use. Constant turning on and off of generators is economically impractical, but it is the only way to stay in business. If there was a way to store the surplus electricty, the raw materials going into electric generation would be conserved.

The University of Wisconsin's Nuclear Engineering Department, under the direction of Professor Robert Boom is out to solve the problem. With the use of superconductors they believe they can store electricity in a 'deep freeze'. Virtually no energy loss would occur due to decay.

One plan involves a doughnut—shaped inductor coil of superconductive material cooled to the point of -452 degrees Fahrenheit. Electricity not consumed, especially during low use, non-peak periods would be pumped into the inductor. It would then travel around the doughnut until it is needed.

Thyristorizec AC-DC inductor-convertor (I-C) units would be used to control the power flow into or out of the large superconductive inductor. Three components are essential for successful functioning of the I-C units in an energy storage system.

First, a large 3-phase power source is needed. This could be directly off the generator or at any point on bulk power lines. In this way the I-C unit connections could be made at a point where ground conditions are suitable for building the inductor.

Second, a large, superconductive inductor coil must be built. The larger the inductor the more economical it would be to operate. "A plant the size of Camp Randall and twice as high, would supply about one-twelfth of Wisconsin's power needs," states Prof. Boom.

A polyphase power converter fits the third requirement. It is an AC-DC converter with a power capacity sufficiently large enough to serve as an interface between the other two components. Using six silicon controlled rectifiers and a computerized signal pulse system, it can be used not only as a converter but also to bleed off power according to the line load.

The main problem does not lie in the lack of technology. Rather, it is one of making the plant economically practical. A feasibility study was conducted and published as a comprehensive report entitled, "Wisconsin Superconductive Energy Project, Vol. 1."

Tests were conducted to see what components could be chosen over to minimize initial and maintenance costs. TiNb was chosen over Nb 3 Sn for the superconductive wire because it is easy to fabricate. In the same way 1.8 Kelvin helium was found more suitable for cooling than 4.2 Kelvin helium because of the reduced volumes required for the same degree of heat transfer. Components are being redesigned to shave costs.

One of the major costs is one of shielding. Building the inductor underground virtually eliminates this worry. A central shaft and several sets of concentric rings tunneled into a rock formation with minimal ground water, would serve as a container for the inductor. An average-sized inductor would have tunnels 60 to 75 meters in radius, 4 to 5 meters wide and 8 to 10 meters high. Concrete would be used to line the walls.

Aluminum would be used as the solenoid. Superconductive wire would then be built up around the solenoid. A specially designed railcar would travel around the tunnels laying down the cable. Fiberglass-reinforced epoxy struts would hold up the doughnut shaped structure. The layers of superconductive wire will be insulated from each other by micarta slats. A ground level refrigeration unit would be connected to the underground helium through the central shaft.

Advantages of the superconductive inductor power storage will soon outweigh the economic disadvantages. They are nonpolluting and silent. Lack of moving parts will lead to long life and low maintenance costs. Power would be instantly available through the bridge converter. All calculations point to better than ninety per cent energy recovery the percentage increasing as the size of the inductor increases. Best of all, the system is safe. A malfunction or overload would only warm the inductor to room temperature.

Time works against engineers. The country could use such a storage system, instead of building new power plants, right now. But it will be years before such a system would be available. If funding is forthcoming, the first trial plant could be built by 1980. Testing and normal operating conditions would show if the system, as designed, will work only after five years of operation. Providing there are no design corrections to be made, the system might be commercially available between 1985 and 1990.

Lauren Schlict *is a freshman in Nuclear Engineering. She is following in the footsteps of her grandfather and uncle, both graduates from this university. She studied electronics for four years in high school.*

We're looking for engineers who know a great opportunity when they see it.

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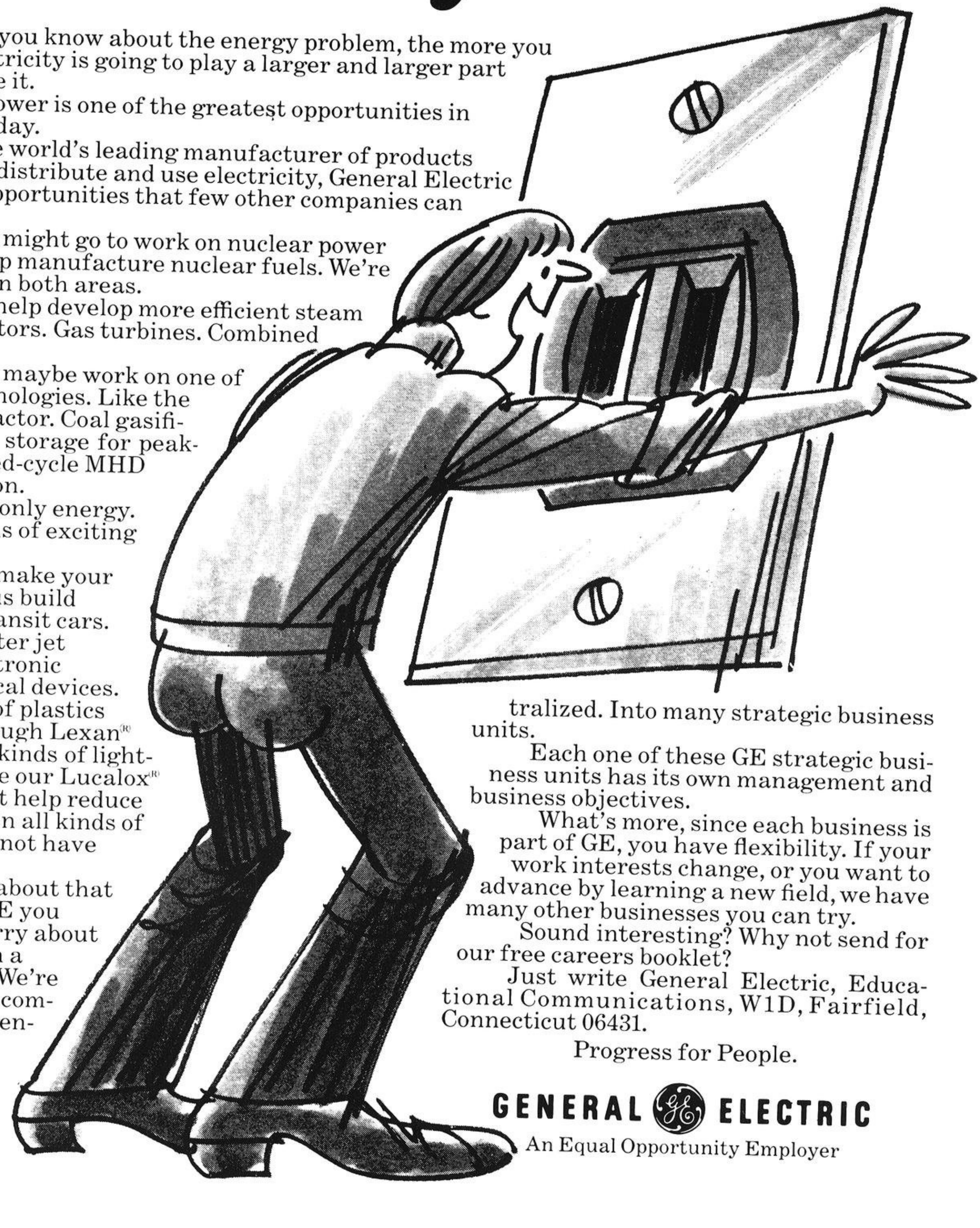
Or maybe help develop more efficient steam turbine-generators. Gas turbines. Combined cycle plants.

Or one day maybe work on one of of the new technologies. Like the fast-breeder reactor. Coal gasification. Battery storage for peaking power. Closed-cycle MHD power generation.

And that's only energy. There are dozens of exciting fields at GE.

You might make your future helping us build electric mass-transit cars. Or cleaner, quieter jet engines. Or electronic diagnostic medical devices. Or better kinds of plastics like our super-tough Lexan® resin. Or better kinds of lighting systems. Like our Lucalox® street lamps that help reduce crime. GE is big in all kinds of areas you might not have known about.

But a word about that word "big." At GE you don't have to worry about getting caught in a "bigness maze." We're not like some big companies. We're decentralized. Into many strategic business units.



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