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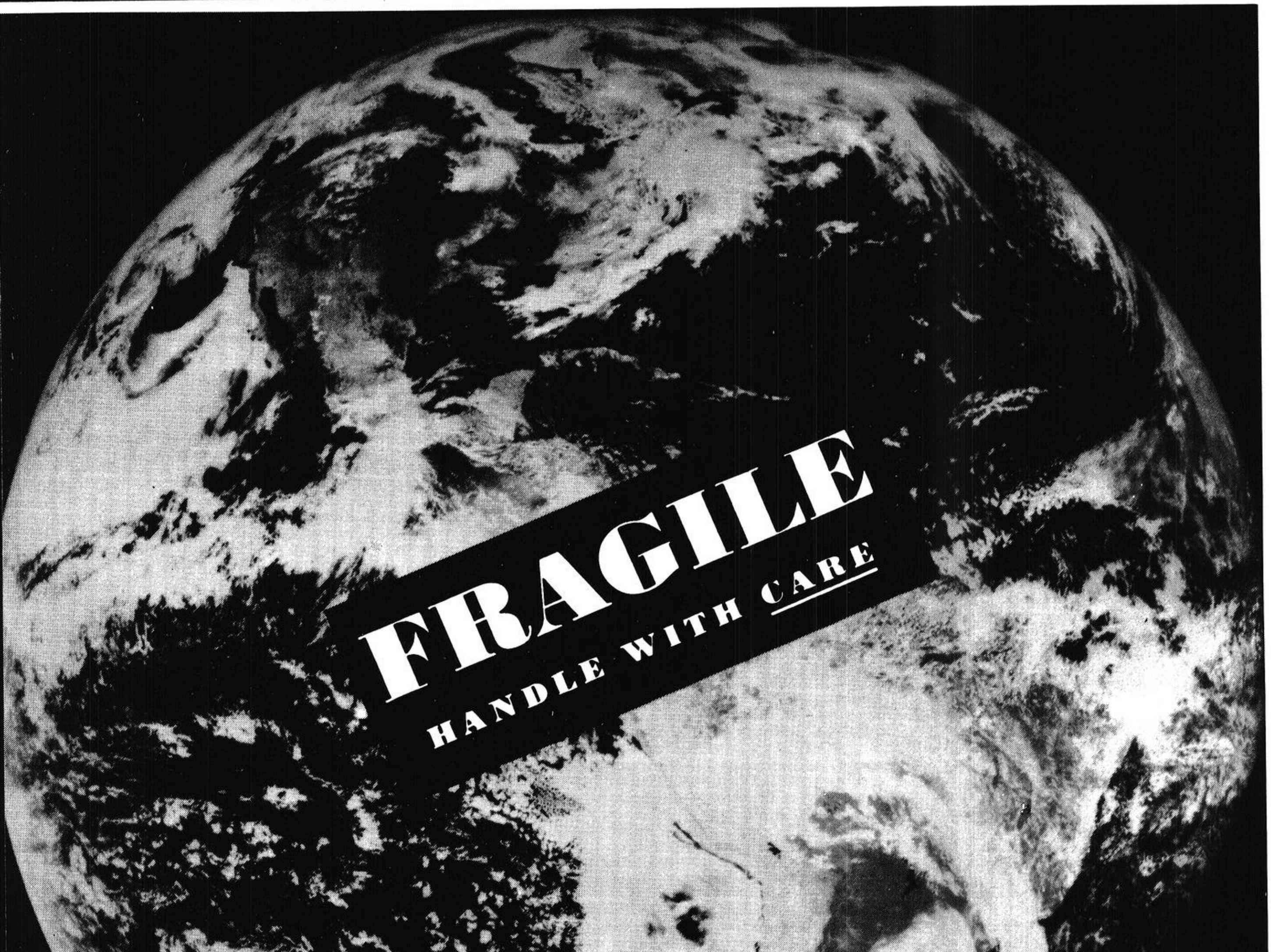
wisconsin engineer



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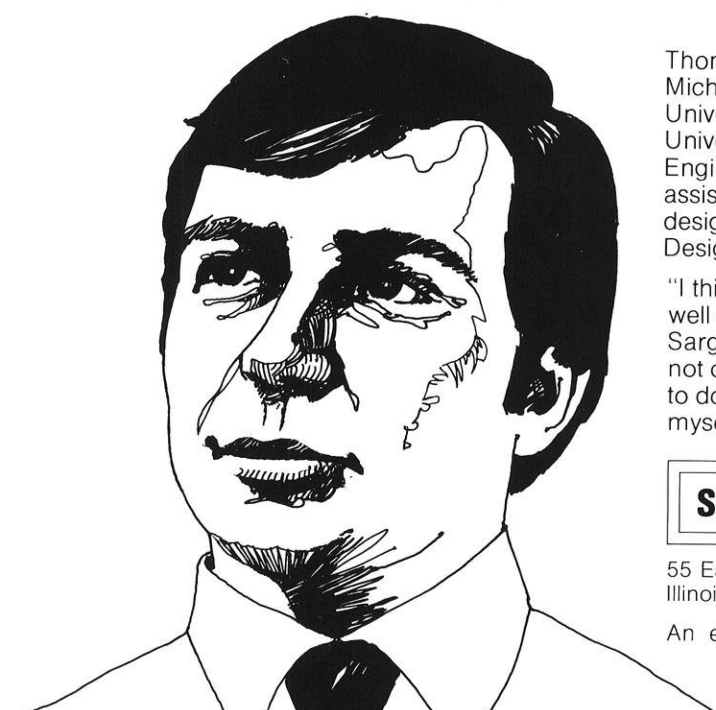

Thomas G. Longlais, B.S., 1969, Michigan Technological University; M.S., 1972, University of Wisconsin, Civil Engineering. Presently, assistant chief structural design engineer, Structural Design and Drafting Division.

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wisconsin engineer

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— Smile — You're a Model

by Dr. Edwin Lightfoot

Each of us is interested in the workings of his own body, and in recent years the trend to institutionalize our activities has been all but irrestible. Bio-engineering is a natural result of these two factors operating on the engineering profession, and it has received a lot of publicity in the last decade. I would like here to review briefly one aspect of this field, the quantitative modeling of living organisms.

Bio-engineering is really nothing new if we include all physical scientists with engineers, and in this sense the French mathematician Rene Descartes was a pioneer: he wrote the first "modern" physiology text (*De homine*, published posthumously in 1662). Though important, this book failed in essential respects because Descartes did not recognize the existence of chemical transformation (ECE's please note). The same was true of clockwork models, as in figure 1. It was once suggested that we operated on the decrease of potential energy of food passing through our systems.

Modern models are more solidly based in physics and chemistry, and, most important, physiology. Comparative physiology is particularly useful for putting us in our place, and it may be seen from figures 2 and 3 that this place is not so special. Both our shape (as evidenced by fractional lung volume in figure 2) and activity, as metabolic rate, are unremarkable functions of size. Similar correlations for various sizes of humans aid doctors in diagnosis.

Scaling based on generalized correlations are also useful in medical research. Figure 4, which shows a scaled correlation for the retention of the anti-cancer drug methotrexate in five different species, is helpful in setting dosage schedules for this highly toxic drug.

One can do even better if starting from a more detailed model, and the first step is to "lump" the enormous detail of a body, suggested in figure 5, to produce something manageable. The lumped-parameter **pharmacokinetic** model of figure 6 has proven particularly valuable and can often be further simplified. A particularly useful example is the two-compartment dialysis model of figure 7. this model, which contains only four parameters, is capable of predicting dialysis schedules days or even weeks in advance. This is shown in figure 8 which compares model prediction (curve) with data (points). The sharp drops represent dialysis, and the rise regions the intervening periods of toxin accumulation.

Sometimes more detailed knowledge is needed, and this requires distributed-parameter modeling. One such case is oxygen supply to the brain, one of the most difficult supply problems we face. Here one uses an approximation to existing geometry, for example the parallel capillary model of figure 8, and solves the appropriate microscopic transport equations, here the diffusion equations, for it. This process is frequently quite successful, as indicated in figure 9. Here venous oxygen tensions are shown as a function of arterial tension for two different carbon dioxide concentrations. Numerical predictions are seen to agree well with observation.

Modeling efforts of these general types are carried out in many areas of our university, both at the clinical and research levels; UW Madison is in fact a leading institution in this and other respects.

Applications include diagnosis of malignancies and pulmonary disease, setting of dialysis schedules, and the estimation of fetal oxygen supply in pregnant women. This activity is spread over many departments; medicine, physiology, radiology, and most of our engineering departments.

Dr. Edwin Lightfoot *has been a professor in the Chemical Engineering department since 1953. His major interest is in the medical application of chemical engineering. He has written a book in this area, Transport Phenomena and Living Systems.*

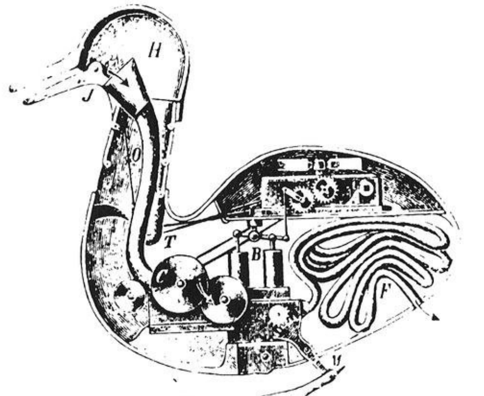


Fig. 1

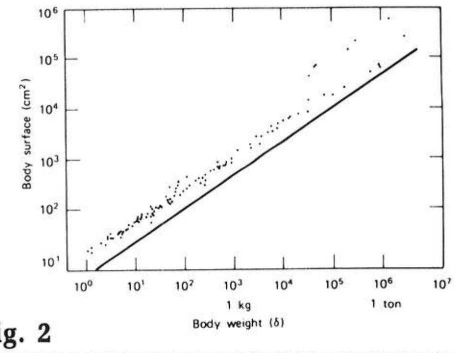


Fig. 2

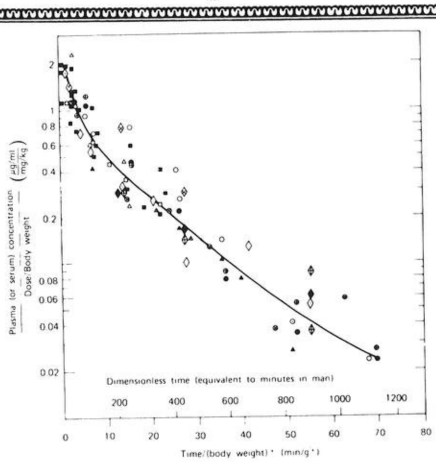


Fig. 3

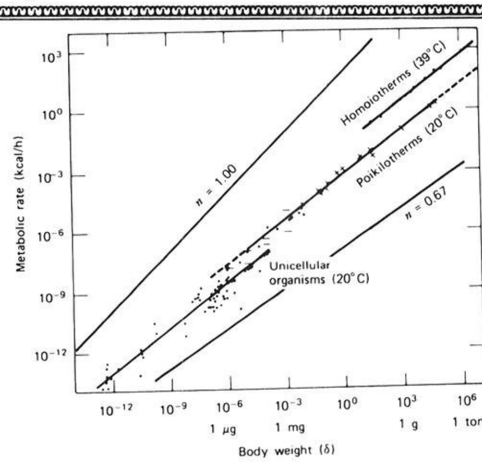


Fig. 4

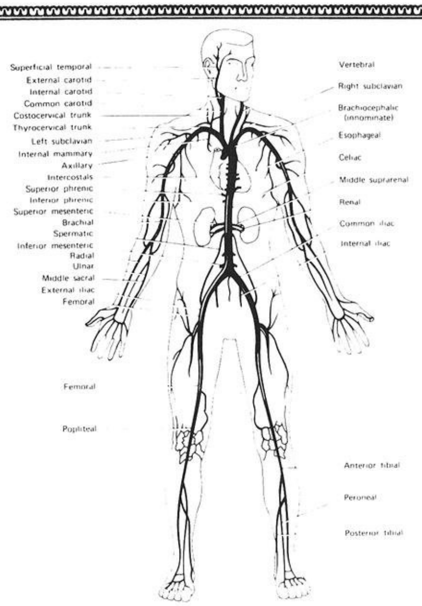


Fig. 5

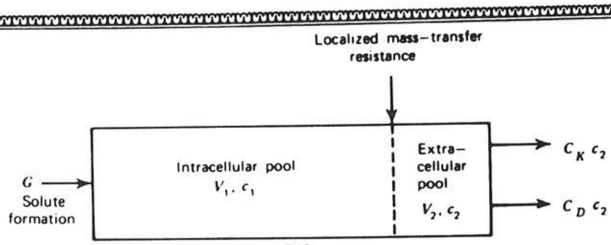


Fig. 6

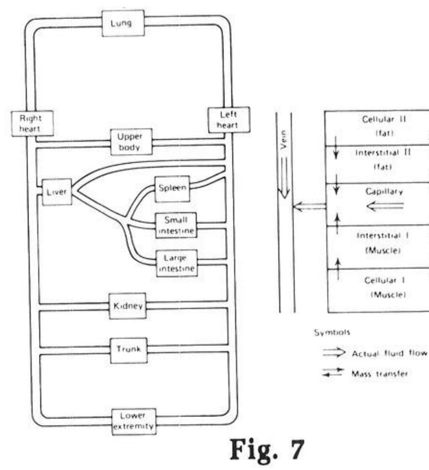


Fig. 7

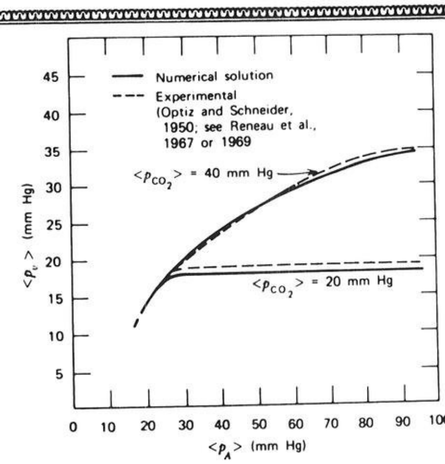
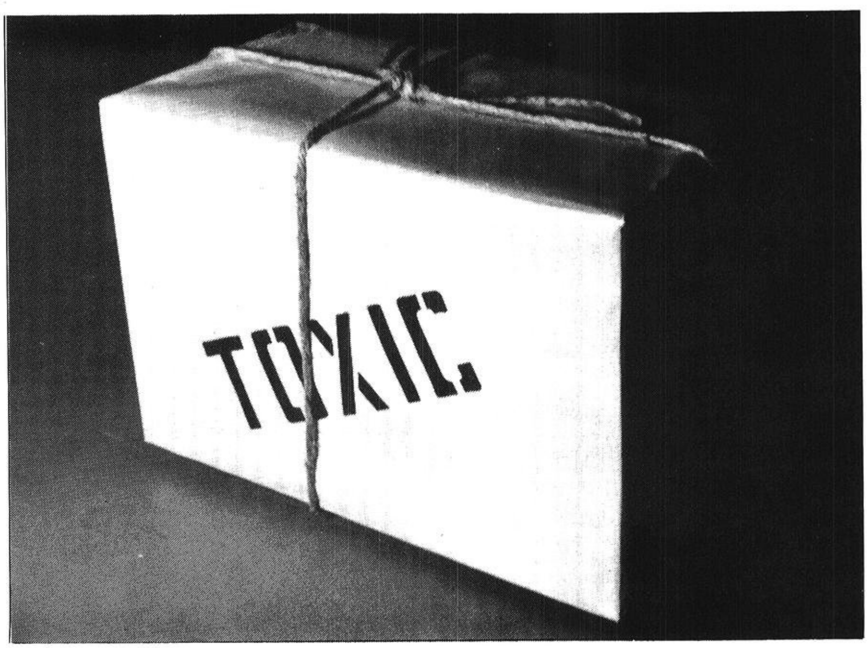


Fig. 8

Both Sides — Now!

Pro, Con, Indifferent
It's Time to Take a Stand
On Nuclear Power

by Joe Fumo



Who is being more dishonest with themselves-nuclear engineers or environmentalists? Those pushing for nuclear power or those against it? Each side has made good points, but good points must be accompanied by good solutions. It is time for you to decide which long-range energy goals the United States should opt for. Here are the facts provided with some background to help you reach a conclusion.

Proponents of the expansion of nuclear power see the future in three steps: (1) continue building today's light water reactors-there are 56 in operation, with 63 under construction and 101 on order, (2) develop the breeder reactor by the 1990's to replace present reactors which will then become obselete, and (3) use the breeder until nuclear fusion is developed-the fusing together of two hydrogen atoms, a process responsible for the sun's energy.

The breeder, which will utilize much more of the uranium required to fuel a reactor, will expand world uranium reserves to last 80,000 years, according to Prof. David Rose of the Massachussettes Institute of Technology (MIT). It is generally agreed today that the world's uranium resources will be depleted in 25 to 30 years. This is so because today's reactors utilize less than one per cent of a given chunk of uranium—only the U-235 isotope. Most of the remainder is U-238, which cannot undergo fission, but can be used by the breeder to foster plutonium-239 fission reactions. (It is when atoms undergo fission, by picking up excess neutrons, that large amounts of energy are produced.)

Proponents justify nuclear expansion because there are no immediate viable solutions to meet energy demands, which they claim will not be met without nuclear or coal-powered plants. Nobody wants to see beautiful regions of the Western United States strip-mined for coal, and the problems of world wide gas and oil shortages are well known.

Nuclear opponents point out two flaws in the above statements: (a) society will never be completely safe from the highly radioactive fission by—products, and (b) it is possible to bypass the breeder stage with increased funding for research of pollution-free forms of energy. Included are fusion, solar, geothermal, wind and ocean power.

"Both sides admit that if a significant amount of fission by—products reach the environment, over a thousand people could die."

Critics believe reaction waste products cannot adequately be protected against sabotage and theft. They say that because so much effort and money has already gone into the industry, the nuclear "bureaucracy" refuses to slow down and consider if their programs are justifiable.

Safety study

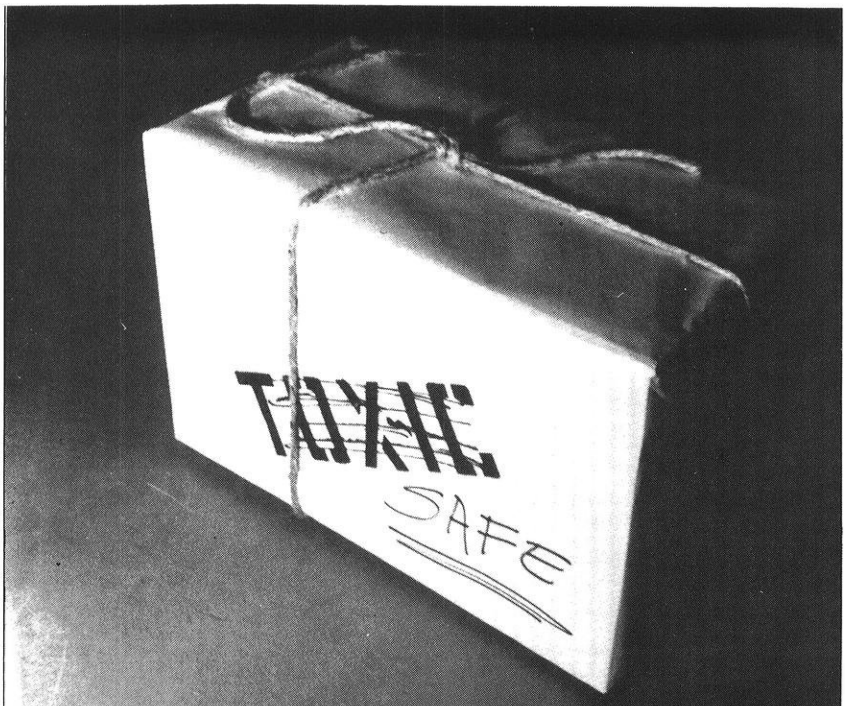
In order to settle the safety dispute, the Atomic Energy Commission (AEC) conducted an intensive study, The Rasmussen Report, on this topic. Released in August, 1974, the study concludes that emergency core cooling systems, designed to prevent the fuel core from melting and seeping into the environment, are safe.

The study describes that the chance of all systems failing simultaneously with a resulting catastrophic accident is as likely to happen as a severe earthquake occuring during a major volcanic eruption in the midst of a hurricane.

The report is the nuclear proponents' chief weapon in combating attacks on nuclear growth. It appears to answer favorably all safety problems except for theft and sabotage of nuclear materials. Nuclear critics also have a weapon.

The AEC, in one of its final actions (before being split into two separate agencies in January) issued the Proposed Final Environmental Statement on the breeder last December. The AEC consistently found that the program benefits outweighed the costs. The Environmental Protection Agency (EPA), however, ruled that the statement was inadequate primarily because of deficiencies in the AEC's cost-benefit analysis.

The environmentalists' main concern, simply, is what would happen if things went wrong, not what is the likelihood of such a catastrophic accident. Both sides admit that if a significant amount of fission by—products reach the environment, over a thousand people could die. There is no disagreement that plutonium is the most toxic element known. One particle lodged in the lung will cause cancer—no questions asked.



Introduction of Atomic energy in U.S.

Nuclear opponents argue that since its creation in 1946, the AEC has acted in arrogance and secrecy. It seemed to take the father-knows-best-so-don't-ask-questions attitude. Even proponents can understand why people got so upset when they finally realized what was going on. (There were only six nuclear plants in operation in 1965, compared to 56 now).

Though it may be surprising to some, nuclear power has been a safely-operated industry. *Forbes* magazine, July, 1975, said the industry's safety record is "far better than that of the railroad in its early days or the airplane or even of coal generation of electricity." Nobody has ever been killed or seriously hurt by a nuclear reactor, a good record for a new industry.

Delaying construction

There has also been concern over the cost of the breeder program—it keeps increasing. The original estimate in the late 60's for the total cost of development was $2 billion. It has been adjusted this year to $10 billion.

A key breeder demonstration reactor project near Oak Ridge, Tennessee has also soared in cost predictions. It is expected to cost $1.7 billion and be completed in 1982, rather than the $700 million figure given two years ago when the project was set for a 1980 completion date.

Higher cost of materials and labor have been cited for the rises in each case. Proponents blame these results on schedule delays. The longer you wait—the more a project will cost.

"Nuclear fusion could offer a cheap, virtually unlimited supply of clean energy for all the nation of the world by the year 2000. . ."

One of the basic differences between opponents and proponents is the notion that breeder development can be put aside for a number of years without totally annihilating the program.

In Wisconsin, Senate Bill 127 calls for a five-year moratorium of nuclear power plant construction so that safety & economic questions can be answered before the state makes a sizeable committment to the nuclear industry. The bill's author, Sen. Dale McKenna (D-Jefferson), defended his legislation at a public hearing in September: "We spent two years debating the $5 billion SST (Supersonic Transport) program but we haven't spent a week in Congress or in this Legislature debating a $500 billion committment to nuclear power."

The EPA also thought debate was the best immediate solution, suggesting that a delay of four to twelve years in breeder development wouldn't significantly reduce the uranium conservation value of the breeder.

Even Prof. Rose, an outspoken lecturer supporting nuclear power, suggests we can afford to think things out before acting. He wrote in *Science* magazine recently: "I estimate that the breeder will almost surely be attractive when uranium oxide, the processed fuel which makes up the core, reaches $50 a pound in 1974 dollars. That will not happen in the first few decades of the twenty-first century. In the meantime, nuclear power is in no danger of losing out to other fuels, and there does not need to be a crash breeder program."

Research Funding

Nuclear critics have a legitimate gripe when it comes to analyzing how the federal government assists various types of energy research.

The Energy Research and Development Agency (ERDA) in February requested a 1976 budget to include $1.66 billion of direct energy research and development. Nearly a half billion of that amount would go to the breeder project. Fossil fuel research would get $311 million worth of attention, while solar energy would receive only $57 million, and geothermal, $28 million. Without money, critics cry, how can non-fission alternatives be realized?

"Nuclear fusion could offer a cheap, virtually unlimited supply of clean energy for all the nations of the world by the year 2000," says the National Wildlife Federation. "Although top scientists say this process is feasible, the most promising technology is 30 years away, partially because of low budgetary priorities."

Solar power is also on a low budgetary priority, and in 1970 it received only one million dollars of federal aid for research. solar power researchers at the Universities of Arizona, Minnesota & Houston predict solar power can begin to play a significant role in the nation's energy production before the end of the century with "reasonable" support.

A major criticism of solar energy, however, is that it would require large mirrors to be placed on vast areas of open land in order to receive the necessary sun rays. Even if the technology becomes available, environmentalists might end up against such "solar farms."

Geothermal power—power given off from natural steam within the earth—is pollution-free but probably could only be used in the West, where most geysers are. California has had success in its limited efforts to generate electricity from geothermal power. Wind and ocean power may also be regional and not worth top governmental priority.

Now it's time for you to make up your mind. Do you want the fission process bypassed until fusion or solar energy are available, or will that be too long to wait?

Joe Fumo *is a senior in journalism. He has been writing about nuclear power and related environmental issues for the Badger Herald and Daily Cardinal since 1973.*

STARTREK *
Cancelled By Popular Demand

by Phil Blackman

```
0090 PRINT ' THIS PROGRAM LIST. THE RULES FOR STARTREK'
00100 PRINT
110 PRINT
111 PRINT '        T H E   S T A R S H I P   E N T E R P R I S E '
112 PRINT '        = = =   = = = = = = = = =   = = = = = = = = = = '
113 PRINT
114 PRINT
00120 PRINT
00130 PRINT '    =//////////////////////)                     / \'
00140 PRINT '      -----------    ---              /////////      \\\\\\\\\'
00150 PRINT '                        [ ]              \\\\\\\\\      /////////'
00160 PRINT '                        [ ]               /    /   ++++>'
00170 PRINT '                        [ ]             /    /'
00180 PRINT '                  //++++++++++++/      /++'
00190 PRINT '                   (           . .. .  >(-'
200 PRINT '                    +++...          +'
00210 PRINT '                              ++++//'
00240 PRINT ''
241 PRINT
242 PRINT
243 PRINT
00250 PRINT '          THE GENERAL BACKGROUND AND SITUATION   '
00260 PRINT '          === ======= ========== === =========  '
      PRINT
```

Five years ago, when the Star Trek television series disappeared from the screen, it had the distinction of being one of the most loyally followed series ever to die an unnatural death.

Now a namesake of the show, a computer game that reached fad proportions at the University of Wisconsin this fall, has outdone the television series in the art of paradoxical demise. It has been removed from the program file of Access, the university's free computer time program, precisely because of its popularity.

According to Larry Travis, the director of the Madison Academic Computing Center, the game was being played by so many engineering and technical students on campus that people couldn't get to the terminals for "more serious" programs.

Travis, who made the comment in his plush office on the second floor of the Computer Sciences building, was obviously choosing his words carefully. He spoke slowly, leaning back in his leather chair, and touching together the outstretched fingertips of his hands as if he were counting the words as he spoke. A thousand or more STARTREK* fans were not something to be taken lightly.

"STARTREK* was taken out of the library," he said, "because there was a widespread complaint from people—many of them students—who were not able to get onto the computer."

"We were not happy about doing this," he continued. "It went against the philosophy of the system, which is that Access should be available for anything a student wishes to do with it."

"But when you are in a position where you don't have enough computing time to go around, it is difficult to justify using it on a game of the sort played in a pool hall," he said.

While the computing center may never have had quite the atmosphere of a pool hall, notes taken by the author in that room during mid-October, when STARTREK* was at its apogee, show that the room was a different kind of place from what it is now.

On October 13, those notes show that four of the ten terminals in the room were being used by STARTREK* fans. Two enthusiasts who could not get terminals were left floating from one console to another helping other students log on.

"I dialed the access number and got a busy-signal," a student at one terminal complained. "What do I do?"

His busy signal buzzed from the speaker under the terminal. While he talked another busy signal started at the terminal beside his.

"Just keep dialing 3-1400," one of the floaters told him.

"Should I wait for the line to clear?" the student asks.

"No," he is told, "just keep dialing, there are ten lines and people are getting on and off all the time. If you just keep at it you usually get on within ten minutes."

From the terminal next to that student, the low purr of a ring sounded, then a high-pitched beep.

"I'm on," the student at the terminal announced.

He searched out the letters U-Q-R-B, then, after a splatter of printing from the computer he typed a school code, and "OLD: STARTREK."

"NOT FOUND IN PROGRAM FILE," the computer replied.

A voice from over his shoulder advised him and he tried again. "OLD: STARTREK* he typed this time, punching the final asterisk with a flourish.

This time the type-cylinder in the terminal began to jump.

"WELCOME ABOARD CAPTAIN," it printed. "PLEASE ENTER YOUR NAME IN THE LOG."

He typed "BETHE," his last name, then a "three", indicating that he wished to play the game in the Apprentice classification.

The cylinder began to jump again, and the game began in earnest:

"...CAPTAINS (sic.) LOG....STAR DATE 5091 .2966

THE USS ENTERPRISE IS ON PATROL IN THE ACTURUS SECTOR

OF THE GALAXY NEAR GAMMA TRISKELLION I

MR. SPOCK PICKS UP THE NEUTRON SIGNATURE OF A

KLINGON HEAVY CRUISER AND TENTATIVELY IDENTIFIES IT

AS KHC-59

KLINGON ATTACKING...RED ALERT

SHIELDS ON CAPTAIN BETHE—READY TO ENGAGE ENEMY

The computer printed out a chart giving, for the Enterprise and the Klingon, a position in the Cartesian coordinate system, a bearing, and a "warp speed." The warp speed was the log of the speed in kilometers per turn.

The game was a two-dimensional, inter-stellar "dogfight."

The computer offered a choice of tactics that included stopping, changing course, or firing either of the ship's weapons, phasers or photon torpedos.

Bethe pursued his prey, keeping track of the positions of the two ships with a coordinate system penciled on an old printout. He scored a hit with one phaser shot, then another.

The Klingon ship was limping into the fourth quadrant now, with damage the computer estimate at 50-70%. His curly head bent low over the terminal, Bethe scratched out his next maneuver. The half-hour access limit was closing in fast.

He gave a number two order; an evasive maneuver followed by a shot with a phaser.

"ENTERPRISE PHASER HITS KLINGON," the computer printed.

He studied the chart, and opted for Order Type 10, an intelligence report.

Spock told him that the Klingon favored order Type One, retreat. Bethe chose Type Two and homed-in.

"KLINGON DESTROYED," the terminal printed out, and Bethe was given the approval of half a dozen on-lookers.

Action like that can't be found in the terminal room now.

A visit made at four in the afternoon like the one above would find no one using UQRB. Since October 30, the UQRB system has been closed down between 11:00 a.m. and 6:00 p.m.

We make our visit at 9:00 p.m. We find one terminal being used for Access with a program printing graphs, one terminal lies idle, and most of the rest are being used for homework assigned in various computer science classes.

One student S. Singh says that he was a "big STARTREK* fan." He remembers that he used to try to screw up the game.

"I use to try all kind of crazy things to make the program blow up," he recalled with a smile. "Like one time I just took off at warp 9 on the x-axis. Warp 9, just keep going.

"It wouldn't screw-up," he said. "After awhile it printed, 'approaching energy field' and 'Mr. Spock say turn back' and all kind of crazy things like that. Then the ship just disappears.

"Another time I try going warp 9 in one direction then make a 180 degree turn and warp 9 in the other direction," he continued. "It prints out 'Mr. Spock says there will be structural damage.' I say 'go on, do it anyway.' I think it's something like 30% damage."

Another student, Jan Clairmont, remembers how he learned about STARTREK's demise on the same day it was removed from the system. That was Wednesday, Oct. 8.

"I logged on and typed 'OLD:STARTREK,'" Jan said. "The computer said 'THAT PROGRAM NO LONGER EXISTS' and then started printing a list of every program in Access—must have printed for five minutes. Boy, was I pissed."

Jan talked with interest about a rumor that there was a new Startrek program in the Access file with a name that is a five-letter abreviation of the old one.

The existence of that particular program can not be varified, but the Director of MACC admits that STARTREK*, like its television namesake, is not going to die quietly.

"There are bootleg programs already available in the Access system," Travis said in the interview at his office. "If those programs are too widely used we may have to take action again."

Almost without being asked he went on.

"In fact I believe there may still be a Startrek program in the main system that could be adapted for Access," he said.

"Of course to do that a student would have to learn something about files, learn the differences between regular and QRB Basic, and perhaps learn something about paper tape," Travis said.

"But," Travis added, smiling over the top of his touching fingertips, "learning those things is what the Access program is all about."

Evaluate complicated functions.
Calculate transcendental functions.
Find the roots of: F(x) = 0.
Find numerical solutions to ordinary differential equations.
Invert and multiply matrices.
Solve simultaneous algebraic equations.
Integrate a function between arbitrary limits.
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Learn Mode. Teach the SR-52 your personal approach to problem solving. Simply key-in your problem left-to-right as you would in calculate mode, using the following options for precise control:

- Preprogrammed "if" Statements (8). Makes a decision based on the condition of the display.
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Run Mode. Load a magnetic card. This puts the card's contents in memory. Insert the card above the 5 user-defined keys representing 10 functions.

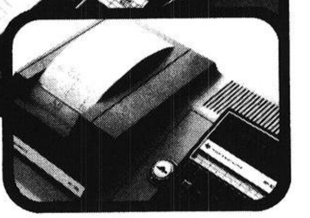
Enter numbers directly into the program. Or into one or more of the 20 addressable memory registers. Or both.

Execution is completely automatic. A program runs until it encounters a halt, which may be part of a program or a keyed-in interruption.

Repeat a program as often as needed. Change values of your variables. Solve for different unknowns. The stored program is unaffected.

With the SR-52 comes a Basic Library Program Manual and preprogrammed cards: Factors of an integer. Complex arithmetic. Reconcile checking account. Ordinary annuity. Permutations and combinations. Means and moments. Random number generator. Hi-pass active filter. Low-pass active filter. Dead reckoning. Hyperbolic functions. Trend line analysis. Solution of quadratic equations. Conversions. Game.

Additional Libraries may be purchased separately: Statistics. Math. Electrical Engineering. Finance. And more are on the way.



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Accompanying an SR-52: Operating guide. Comprehensive owners manual. Basic library of prerecorded programs, diagnostic cards and head cleaner in carrying case. Basic library manual. User instruction & coding forms. Blank magnetic cards. Fast-charge battery pack. AC adapter/charger. Sturdy vinyl carrying case.

SR-52 lock-in printer.
(available early 1976)

- Print out an entire program.
- Print calculate mode results.
- Print instructions or results without halting program execution.
- Trace program execution step by step for error detection.

Calculate Mode. Operated manually, the SR-52 is one of the most powerful calculators available today.

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Quakes that Shake and Break Engineers

by Rudi Beck

"... the earth's frail crust cracked, sending waves of tremendous force traveling through the rock in all directions."

The place was a mountain, one of the highest in America, its serene beauty topped with the whitest of snows. At the foot of the mountain a small lake reflected the spectacle of the Andes in its emerald waters, at about 14,000 feet above sea level. The time was about five years ago. Two expeditions of mountain climbers, Japanese and German, worked their way to the top of this gigantic mole, to conquer it.

About two hundred miles to the west, deep in the Pacific Ocean, the earth's frail crust cracked, sending waves of tremendous force traveling through the rock in all directions. The giant trembled and some of its snow loosened, starting its way down. The Japanese watched as the German expedition was swallowed by the white mass, only a few hundred feet away. The snow, falling into the lake, letting forth a huge avalanche that lifted rocks weighing tons, trees, and houses, and after leaping over a small hill, razed a village in which five thousand terrorized humans where recovering of the shock of the earth tremor that had taken place a few minutes before.

Our planet is a layered sphere. Of all the layers that form the earth, the lithosphere, the outermost, is the coolest and therefore the most rigid. But this layer is not all in one piece, but in plates which move with respect to one another. It is in the boundaries between these plates that most earthquakes take place.

How do they happen? Take for example two such plates that are coming close to one another. The speed at which this takes place is, of course, relatively very small. The plates push against each other, compressing the rock at the boundary until it reaches its breaking point, releasing the energy accumulated in it and letting forth the quake. If the pressure along the plate boundaries was constant, there would periodically be quakes all over, about every few hundred years. Instead, pressure is not constant, and the phenomena becomes isolated at different points in the boundary at different times.

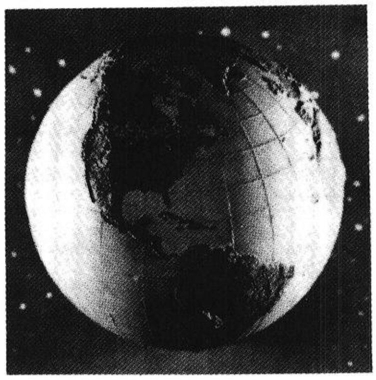
The boundaries may collide, forming mountains as the crust is pushed up, or one may move under the other, as happens west of this continent.

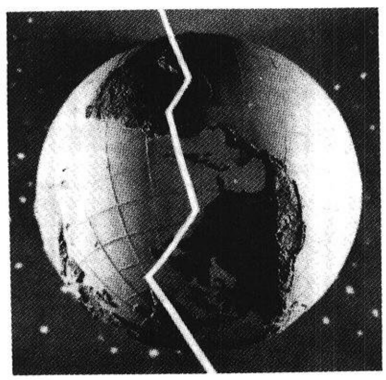
This theory of lithospheric plate movement is called plate tectonics. The movement of the plates is brought about by the movement of the next layer in the planet, the mantle. The mantle is a shell of red hot rock about 1600 miles thick.

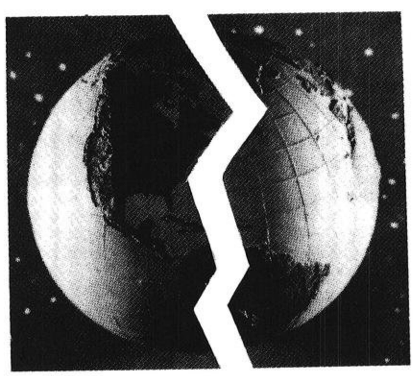
When the energy built by the compression of the rock at the focus of the earthquake is released by breakage, it produces mainly two types of forces, which travel in all directions through the crust and across the earth. These forces travel in waves and they act in two directions with respect to the direction of travel: The primary waves (P waves) transmit longitudinal compression forces, and the secondary waves (S waves) transmit perpendicular shear forces. To best visualize this, Figure 1* shows an element of crust being subjected to the two types of forces. The primary waves are also referred to as push - pull waves and the secondary waves as shake waves. Also, the primary waves travel faster through the crust than the secondary waves.

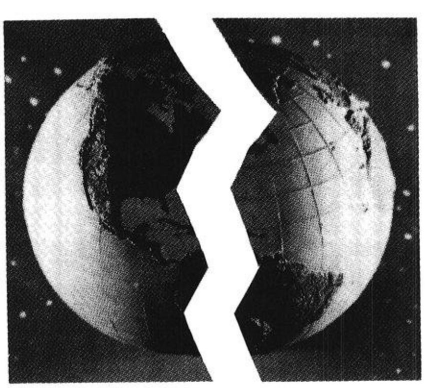
These earthquake waves can be measured by means of seismographs, which typically consist of a large mass (weighing a ton or more), suspended by a spring. When a seismic wave passes, it transmits a force to the mass through the spring, but since the mass is large, the acceleration the wave brings about is negligible, so we can assume the mass to be static. If a pen is attached to the mass and a piece of graph paper is fixed to the ground, a plot of the passing wave can be obtained. (Figure 2)

Given the rigid structure of our buildings and bridges, earthquakes pose a great many problems to civil engineers in certain areas of the world. Structural analyses are therefore more elaborate than those done for static conditions. There are strict safety codes for building in areas where quakes are likely to occur; for example, staircases should not be built inside a building since they constitute very rigid elements. The same is true for elevator pits.









Dilatancy is a phenomena that permits the accurate prediction of an earthquake weeks before it actually takes place. It is also a very simple concept to grasp. As the stresses in the rock build up, approaching its breaking point, tiny cracks develop in its structure and consequently, the compression P waves slow down, since the transmission of force is not as immediate as in the more rigid, solid rock. This slowing phenomena only occurs with the P waves, apparently because the cracks are perpendicular to the direction of travel. Some time after the cracks have developed, water from the ground fills them, restoring a continuous medium. The velocity of the P waves at this point returns to normal. The water in the cracks also accelerates the final failure of the rock and the consequent tremor, because it causes a uniform distribution of pressure inside the crack and therefore a great deal of force in the edges of the crack, precipitating failure. (Figure 3)

Measuring the difference in velocity between the P waves and the S waves constitutes an accurate method of predicting earthquakes. When the difference between the velocities decreases, it indicates that a quake will eventually take place where the waves originate. When velocity conditions are returned to normal, the earthquake is imminent (within a few months).

The next breakthrough in seismology is expected to be the control of earthquakes. The problem is that the prevention of a major quake would cost in the order of $1 to $2 billion. For now, there is enough time to run.

***See p. 16 for figures.**

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Fig. 1

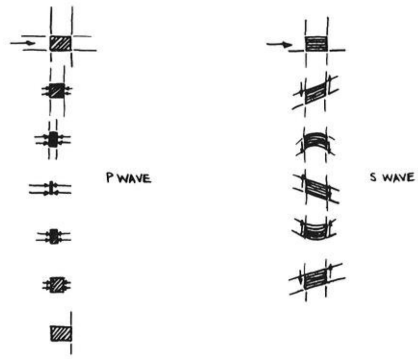

Fig. 2

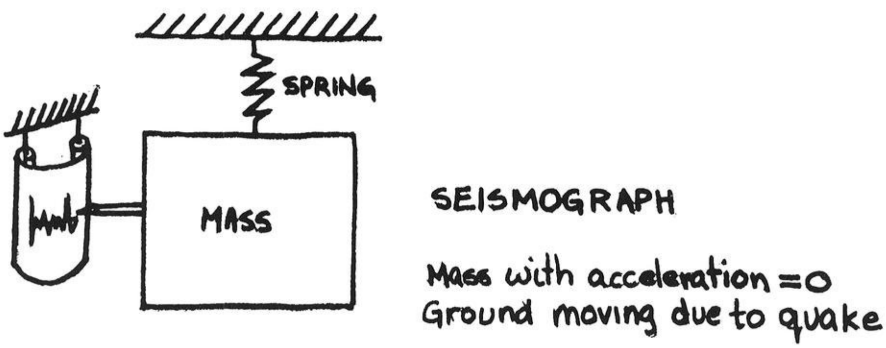

Fig. 3