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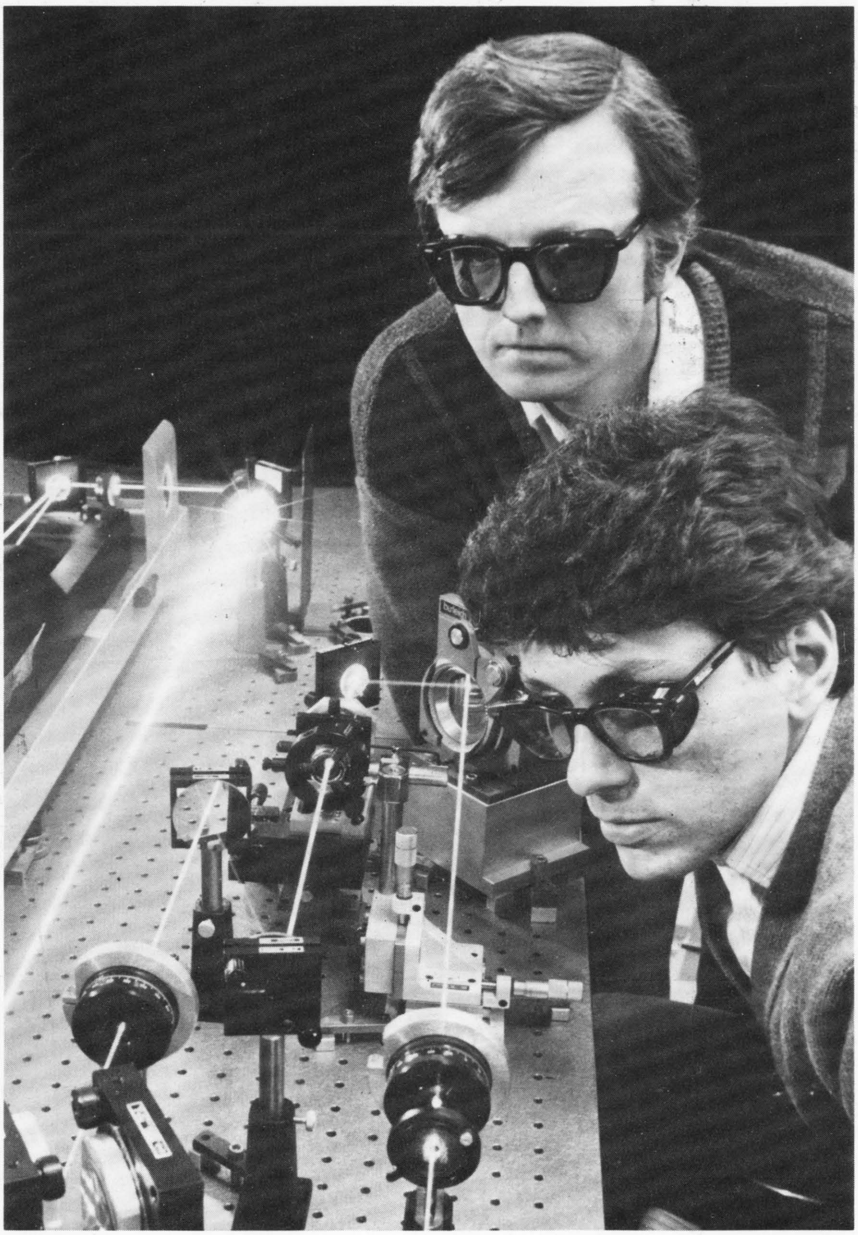

SCIENTISTS GENERATE WORLD'S SHORTEST LIGHT PULSES

The Computer Almanac and Computer Book of Lists — Instalment 40

Neil Macdonald
Assistant Editor

80 TOPICS SCHEDULED FOR COMPUTER SIMULATION CONFERENCE, CHICAGO, JULY 22-26, 1985 (List 850301)

Simulation Methods
- Modeling techniques
- Numerical methods for simulation
- Simulation of continuous systems
- Simulation of discrete systems
- Simulation executives
- Simulation languages
- Stochastic applications
- Simulation environments

Computer Systems
- Supercomputer applications
- Parallel processor applications
- Simulation of computer systems
- Simulation of VLSI circuits
- Simulation with microcomputers
- Graphics

Simulation Credibility and Validations
- Validations methodology
- Credibility of models
- Quality assurance techniques
- Case studies
- Ethics

Physical and Engineering Sciences
- Aeronautical and astronautical systems
- Vibration and mechanics
- Electromagnetic processes
- Controls and optimization

Chemical Sciences
- Chemical reactors and separation processes
- Advanced mathematical techniques
- Dynamic systems in chemical engineering
- Thermophysical properties
- Desktop chemical simulation

Energy
- Power plants
- Simulation of power system transients
- Modeling and simulation of electrical power networks
- Simulation of biomass power generation
- Hydrodynamics and heat transfer
- Reservoirs

Biomedical Simulation
- Pharmacokinetic applications
- Prosthetic applications
- Simulation of biological processes

Environmental Sciences
- Models and simulation of ecological systems
- Simulation of animal populations
- Simulation of chemical transport through the soil
- Aquatic pollution models

Management and the Social Sciences
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- Decision support systems
- War games
- Simulation of production systems
- Transportation

Training and Research Simulators
- Power plant simulators
- Chemical process simulators
- Flight simulators
- Missile simulators
- Simulator technology
- Maritime simulation
- Interactive video simulators

Artificial Intelligence
- Aerospace applications
- Electronic system applications
- Robotics
- Expert and knowledge based systems
- Signal fusing and pattern recognition
- Natural language processing
- Learning systems
- Voice recognition

Data Communications Systems
- The functional evolution and role of data communications
- Design of data communications networks
- Protocols
- Performance analysis
- Multiplexing and concentration
- Design issues
- Integrated systems
- Systems components & their interrelationships
- Satellite communications
- RADAR and SONAR systems
- Avionics
- Signal processing

CAD/CAM & Manufacturing Systems

Flight Simulation Systems
- Visual simulation
- Motion simulation
- Tactical simulation
- Instructional simulation
- Software simulation
- Radar land simulation

(Source: Society for Computer Simulation, P.O. Box 2228, La Jolla, CA 92038)

10 APHORISMS REGARDING THINKING (List 850302)

We find any arguments to justify our beliefs.

We comfort ourselves by repeating slogans.

Nowadays questions are seldom settled for long.

Beliefs cannot change facts into what they are not.

We are surrounded by social agencies which tend to shape our minds to their customary modes of thought.

As long as we neglect the duty of thought, all kinds of beliefs will sprout in our minds.

Thoughts fathered by wishes are apt to be still-born.

We believe unlikely stories on flimsy evidence, because we want them to be true.

Our minds build up an elaborate defense to protect a precious belief.

The way prejudice works is that you do not see what you do not want to see.

(Source: pp 19 to 38 in "Teach Yourself to Think" by R. W. Jepson, published by English Universities Press, London, England, 1938, 164 pp)

THE PERSONALITIES OF THE INTEGERS 1 TO 35 (List 850303)

1 the unit, triangular

2 prime, $1^2 + 1^2$, the binary base

3 prime, triangular

4 2^2

5 prime, $1^2 + 2^2$

6 triangular, 2 x 3, factorial 3

7 prime

8 2^3, $2^2 + 2^2$, the octal base

9 3^2, $1^3 + 2^3$

10 2 x 5, $1^2 + 3^2$, triangular, decimal base

11 prime

12 $2^2 \times 3$

13 prime, $2^2 + 3^2$

14 2 x 7, $1^2 + 2^2 + 3^2$

15 3 x 5, triangular

16 4^2, 2^4, $2^3 + 2^3$, hexadecimal base

17 prime, $1^2 + 4^2$, $1^4 + 2^4$

18 2 x 3^2, $3^2 + 3^2$

19 prime

20 $2^2 \times 5$, $2^2 + 4^2$

21 3 x 7, triangular

22 2 x 11

23 prime

24 $2^3 \times 3$, factorial 4

25 5^2, $3^2 + 4^2$

26 2 x 13, $1^2 + 5^2$

27 3^3

28 $2^2 \times 7$, triangular

29 prime, $2^2 + 5^2$

30 2 x 3 x 5, $1^2 + 2^2 + 3^2 + 4^2$

31 prime

32 2^5, $4^2 + 4^2$, $2^4 + 2^4$

33 3 x 11, $1^5 + 2^5$

34 2 x 17, $3^2 + 5^2$

35 5 x 7, $2^3 + 3^3$

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computers and people formerly *Computers and Automation*
including *Computer Graphics and Art*

The magazine of the design, applications, and implications of information processing systems – and the pursuit of truth in input, output, and processing, for the benefit of people.

Editorial Note

We invite articles on the subject of computers and nuclear weapons. Computers, and computer people who work to make nuclear weapons work, are an essential ingredient of the nuclear evil.

There will be zero computer field and zero people if the nuclear holocaust and the nuclear winter occur. Every city in the United States and in the Soviet Union is a multiply computerized target. Thought, discussion, and action to prevent this holocaust is an ethical imperative.

Front Cover Picture

The front cover shows some apparatus that can generate exceedingly short pulses of light. These pulses endure for 12×10^{-15} seconds, or 12 femtoseconds, or 12 quadrillionths of a second. There are as many femtoseconds in one second as there are seconds in 30 million years. The ultrashort pulses can serve as a "strobelight", slowing or freezing the apparent motion of molecules, atoms and electrons so that their extremely rapid interactions may be studied in detail. Such study could help researchers better understand some fundamental physical processes important to the development of the ultra-fast computer components of the future. The scientists shown here are J.M. Halbout and D. Grischkowsky; the laboratory is at IBM Corp. in Yorktown Heights, NY.

Notice

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Key

[A]	–	**Article**
[C]	–	**Monthly Column**
[E]	–	**Editorial**
[EN]	–	**Editorial Note**
[F]	–	**Forum**
[FC]	–	**Front Cover**
[N]	–	**Newsletter**
[R]	–	**Reference**

Notice

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Editorial

Expert Systems and Machines That Think

Edmund C. Berkeley, Editor

There now exist at least 20 expert systems, incorporations of artificial intelligence, which can perform better than the usual trained human being in dealing with certain types of problem.

For example, there is a system which incorporates the expertise of a very clever and experienced engineer in repairing the mechanical and electrical systems used in a diesel-electric locomotive. There is another expert system which diagnoses bacterial infections of the blood, determining which of many possible organisms might be responsible for a particular infection. Another expert system is called a configurer and applies to assembling, coordinating, and completing orders for VAX computing systems received by Digital Equipment Corp.

An expert system ordinarily engages in conversation with the person using it. It is able to ask questions and take in responses from the person. Such a system produces different results according to different input; if it did not, it would be no expert, but a machine as primitive as an alarm clock. An expert system works because it is based on extensive knowledge gathered by a competent programmer talking to an expert, asking questions, and carefully taking down all that the expert says.

In most expert systems, the knowledge is expressed in more than 500 "if-then" rules. This to some extent resembles the identification of a plant via a table or key of botanical specifications. For example:

48. Pith, spongy or hollowed out ... 49.
    Pith, continuous and persistent ... 53.

49. Leaf-scars raised or else buds superposed ... 50.
    Leaf-scars little raised, buds not superposed ... 52.

This small extract of a plant key is from "Winter Botany" by William Trelease, first published in 1918, republished by Dover Publications, New York, 1967.

What is the significance of these achievements?

In the first place, expert systems can be expanded, updated, copied, and multiplied. In contrast, a human expert can get sick, or die, or leave to go to work for another company, and so become unavailable. The expert system suffers from none of these drawbacks.

Second, the expert system is another step up along the stairs of transferring knowledge into computerized form. For example, the amount of information that a medical student or doctor is responsible for learning and remembering is often so great that it is definitely beyond his unaided capacity to handle. Expert systems to help him can be very useful.

Third, an expert system provides good examples of intelligent, useful conversation between a man and a machine, between a human being and a computer, even though the conversation is restricted to a certain territory of knowledge. And we are all of us accustomed to sizing up other people depending on how intelligent and useful their conversation is.

Expert systems provide more and more proof that machines can think.

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of introducing the computer to a different part of the business world. Each was entrepreneurial. Each was measured. Collectively, they introduced computers in many different fields.

At one time we supplied all the computers in medicine, in newspapers, in machine control. We introduced many applications. We succeeded in doing this by breaking the company into pieces.

We did exciting things and made many contributions. In some ways, we like to think we changed the world. We did it by turning out things quickly and easily and exploiting the components that were available at the time.

Something Unique

In time, it became clear that hundreds of other companies would be technically able to do the things that we were doing. Once the computer was defined in our manuals and with integrated circuits, anybody could make a personal computer or minicomputer, simply by using existing technology and often without having to make any technical contribution. It became clear that if we were to make a contribution to the industry, we had to do something unique.

So we set about to concentrate our efforts and our resources on those things that would be important to customers and those things which other companies would have difficulty doing.

Our goal has never been to just make money or just sell computers, but rather to do something which is unique and make an important contribution to our customers. So we have decided to do big systems, complex software, integrated networks and clustering, complete systems that include everything from personal computers on the desk to large computers in the data center. This requires much discipline, good organization, and intense work.

Superior Service

We set out to develop the best service organization in the world. We now have one of the largest field service operations. In the surveys, some years we come out number one, and some years very close to number one. Our goal, even when we're number one, is to be better. We have the best people, the best logistics for spare parts, the best training, and our goal is to always be best.

We also set out to have an excellent software support group for those customers who want help in working with our computers as systems. So we have a large support group of highly skilled software experts who help our customers develop programs. They are always in greater demand than we can supply; so we think this is a very successful operation.

We also set out to have the best education and training organization. We have about 800 instructors working fulltime teaching our products to our customers.

We also set out to have the best sales force. We do not pay commissions to our sales people. Our goal is to have our sales people be interested in the customers' problems, without having to worry about immediate return in commissions. The result is that we have the highest or close to the highest yield per salesperson in the industry.

We also set out to become expert in the technologies that are most critical to us. We set about to be equal with the best in disk technology. Disks are the most expensive part of the systems we sell. We made major investments in facilities, equipment and people to keep up with the world's best disk manufacturers. We now sell large disks that give more storage per square foot of floor space and per dollar than the competition.

We also set out to be the best in semiconductors -- not those that anybody can build, but those that are proprietary, unique, complex and difficult and can't be bought elsewhere. We now have a VAX-type computer on a chip which we feel is a year ahead of anyone else. We're proud of what we've accomplished in this area -- the speed and complexity of the chip, with floating point and with the memory management features characteristic of the VAX-type computer.

A year ago, to much of the world, it looked like the future of the computer industry was going to be just personal computers with fast, cheap, easy software you buy off a pegboard in a local store. We plan to be the most disciplined, the most organized, the best documented computer company. We plan to produce the highest quality and excellence in the traditional sense of the word. We will worry about every single detail and make sure everything's done the very best we know how.

One Company, One Strategy, One Message

Kenneth Olsen, President
Digital Equipment Corp.
146 Main St.
Maynard, MA 01754

"Our goal has never been to just make money or just sell computers, but rather to do something which is unique and makes an important contribution to our customers."

Based on several talks reported in *Decworld*, published by Digital Equipment Corporation, November, 1984.

38 Product Lines

Early in our history, one of our techniques for success was to break the company into pieces. We called them product lines. At one time, we had as many as 38 of them. They were allowed to run as separate businesses, each with autonomy and freedom. There was little red tape to stifle their originality and creativity. This approach worked well. It produced many products and established Digital in many markets.

Over time, we have evolved a different approach. Today our industry involves large numbers of different products, all of which have to work together, some very large and requiring great discipline to develop and produce. Coordinating these efforts takes cooperation from many people and an enormous amount of interchange -- the kind of cooperation and teamwork that can't come from having many independent groups, each of which is motivated to be independent from everybody else in the company.

Change to One Strategy

When we had 38 separate business entities, we accomplished a lot. You've probably heard me brag about the usefulness of this approach and how it enabled us to enter many different markets. However, over time, this type of organization had to change because a major part of our contribution to the computer market comes from using our resources -- our size, our people, our technology -- to do significant large things. So we've been phasing over from having many separate entities to becoming "one company with one strategy and one message."

Our Most Powerful Computer System, VAX 8600

After years of having separate entities, each taking great pride in its separateness, combining them into one company with one strategy has been difficult. But the results of our strategy were demonstrated with the announcement of our most powerful computer system -- the VAX 8600 -- and with the extensive VMS software offerings that run on it as well as all our other VAX computers, that can be moved from one to the other without change. We're proud of all the cooperation shown in working together on that one program.

We're now well on our way to becoming "one company with one strategy and one message." We're not there yet and won't be for a while. It's not easy for people who have been independent for so long to suddenly realize they depend on one another and must work together.

Technology of the Day

When we started Digital 27 years ago, our goal was to build fast, inexpensive computers using then-current technology. Other computer companies at that time were using technology that was two, three, four years old in their products, and were working in their laboratories on technology that was two, three, four years away. Our contribution was to use the technology of the day to make products for the day. Using available components, we made circuits and computer architecture and solved the problems necessary to make fast, simple, interactive computers. Out of this came what was known as the "minicomputer" and, later on, the personal computer.

We also created a large number of independent business entities, each with the job

Core Product Strategy

At a meeting like this seven years ago, we proposed a core product strategy. We phrase it a little differently today, but it's practically the same, and involves four key points:

- one architecture, one software system,
- linked by Ethernet,
- clustered for performance and data access,
- integrated with personal computers.

One Architecture and One Software System

Seven years ago, we decided to do the majority of our research on one architecture, VAX, and one software system, VMS. Today we have a range of VAX equipment from the desktop to the data center -- from the Micro-VAX to the VAX 8600 -- all of which runs the same software. One computer family with such an enormous range of size and speed with one architecture and one software system has never been done before. We've done it as part of a formal plan ... and we're just starting. We will have larger, more powerful machines, and we will have tinier machines -- all built on the same VAX architecture and with VMS software.

More than 7,000 person years have been spent on the VMS engineering effort, and there are currently a thousand engineers working on VMS software.

When Willie Sutton was asked why he robbed banks, he said, "That's where the money is." When people ask, "Why do the Russians steal our VAXs?" it's because that's where the software is.

VAX has been successful largely because of its software, which ties everything together. We can hook small and large VAX systems together in a complex network and then have that network communicate with other manufacturers' machines and other manufacturers' networks so our customers can freely communicate around the world. The engineering effort that makes that kind of communication possible takes great discipline -- and that is what VMS represents.

Connecting Everything Together

The second point of our strategy is to tie everything together with Ethernet. Most customers use computing in every area of their business. They have to interchange information. They have to work together. We picked what we thought was the best networking strategy and worked with several other manufacturers to try to make it the industry standard. We now have about 1,500 customers using Ethernet networks. Nobody offers more capability in Ethernet networks than Digital, and nobody has more Ethernet systems installed. We also use Ethernet extensively inside our company.

Ethernet can grow very large. It can be a mile and a half long with up to a thousand connections and allow information to flow at very high speeds among all the connections. A key part of our strategy is to use Ethernet to connect everything together.

Clustering

Clustering is a complex, sophisticated way of tying many high-speed computer systems to one set of disks and one data base so the entire cluster functions as a single system. Clustering is a form of parallel processing. Normally, parallel processing means many processors working on one problem. But most business and scientific processing involves solving many small problems using the same data base on the same big computer. For that type of processing, clustering is very efficient. As more processing power is needed, more VAXs can be added to the cluster, and they can all work on the same data base.

For instance, a bank may have many cash-dispensing machines all using the same data base; in other words, a list of accounts for everybody who has a card. So the bank needs a fast machine to handle a large number of transactions, all working on one data base. Clustering is useful in many other situations involving production machinery, subscribers, customers, employees -- wherever access to vast common data bases is required. VAXclusters are Digital's answer to this kind of business problem. We have already sold over 1,400 clusters in the first year of their availability.

Personal Computers

The fourth part of our strategy is to use our personal computers and workstations as terminals to offload our big computers, to give access from the desk to data on our large computers, and to make networks of just personal computers to solve various problems in business, science and industry.

Two years ago we introduced a line of computers built with the quality needed to go with our full line of computers. They were built like we build terminals. We worried about problems that other companies never even heard of. We spent months worrying about the interaction between the disk and the video monitor. We built them for our customers who sit in front of them eight or ten hours a day.

We've done quite well in this area. We have sold significantly more personal computers for the kinds of serious work typically done by our customers than we had in mind when we first designed these machines.

But Digital's personal computers are so beautiful, reliable, safe and easy to use that we tried to sell them in the retail market, as well. We did not do well there. Most people who buy things at retail think in terms of price alone, and are unwilling to pay extra for the quality and features we feel are important.

When analysts ask me, "Is the personal computer market dead?" I answer, "No, certainly not for Digital. We're just starting."

The personal computer is a key part of our systems strategy. Our customers want a significant part of the computer power they need to be in front of the person using it. The overall demand for computing power continues to grow rapidly. Part of that power has to be distributed, by Ethernet or another local area network, among personal computers and workstations linked with larger computers and common data bases. So, we see that the real personal computer market is just starting.

By our definition, a workstation is a sophisticated personal computer with a lot more memory, a lot more speed, and more sophisticated graphics. They're used for such things as designing buildings and machinery or for writing books. Our contribution to this area is workstations built around VAX systems.

So, our one architecture ranges from desktop VAX workstations up to the giant VAX 8600.

Satisfying Our Customers

At the same time, we must not lose sight of our number one goal -- satisfying our customers. Our main thrust in product development is in VAX and VMS, an area where we can make unique contributions. But our customers need our continued and enthusiastic support in other areas as well.

We have committed to our customers to continue to support the PDP-11, the PDP-8 and the DECSYSTEM-10/20 families of products. These important projects go in parallel with our main effort.

We also enthusiastically support other products that our customers want. We sell and support an alternate operating system -- UNIX. And we'll sell and support an alternate local area network called MAP. We love it because General Motors and Ford love it. If they want us to support it, we'll support it with enthusiasm. But that in no way limits our main thrust.

In general, we've done well. It's a great strategy because we're alone there. With VAX and VMS we provide a vast range of compatible, clustered and networked computer systems that meet all kinds of business, scientific, industrial and educational needs. No one can touch us.

Creativity with Discipline

People ask, "When we cut down from many entities to one company with one strategy, do we limit creativity?"

We don't need the kind of creativity where we have 86,000 people going in different directions. Our cables are our biggest problem, because everyone insists on picking their own connector, and all this equipment has to talk together. Then they pick different colors which mean different things, because they don't want to be like anybody else. It's like having a house with every lamp, every appliance with a different connector and different socket. Only in a house that's not as bad, because the toaster doesn't have to talk to the lamp. Let's work together!

In creativity, you want as much done mechanically as possible, so you're free to be creative. When we started Digital, we just took the MIT personnel manual and said it was Digital's. We worked the same hours; we paid at the same time each week; we did everything the same way. Creativity doesn't mean everybody doing something different.

True creativity is available when we have a structure and a goal, and we know where we're heading. We see what the needs are and that opens up opportunity and creativity.

You can't have creativity unless you know the direction the corporation is going. When you're a big corporation and going 38 different ways, you frustrate and stifle creativity rather than generate it. Creativity takes discipline.

By itself, having many separate entities does not generate creativity. Successful entrepreneurs are normally the last people to give freedom to be creative to anybody working for them. So, in time, all those groups, many of which were very successful, were not in a position to encourage creativity. Instead they limited it. We see new creativity in other areas of freedom.

Transactions Per Day

We're now in the midst of a program of introducing new products. With an enthusiastic reception from the press and many of the financial analysts, we announced our new large VAX computer. This is a giant computer. It is a very important part of our product line. We call it our VAX 8600. It is up to 4.2 times faster than the VAX-11/780 which has become the standard in many applications.

It's important to give the background of this machine and the VAX family and the direction the company is going to understand its significance.

This machine is more than just a fast computer. Computer speed is often measured in MIPS -- millions of instructions per second. We don't sell MIPS. We sell solutions. We sell transactions per day. Our customers want to accomplish so many transactions with a computer each day, and that is the most important measure of the power of the system. So in our design, we aim to produce the most transactions in one period of time.

The VAX 8600 was received so well that the question that kept coming up in discussions afterwards was, "Are you out to attack IBM?" Obviously, the answer to that is no. IBM is eight times bigger than we are. It is mathematically impossible for us to take over IBM. IBM has no reason to worry about us. We have a lot of reason to worry about IBM.

In our area of expertise, we are committed to always do something which is better than IBM. And the VAX 8600 and VAXclusters and VMS send a message that, for our area of the market, we have to have products which are clearly better than IBM's.

Having Hard Times Helps

The VAX 8600 illustrates the ways we are changing. That was a massive operation, a beautiful picture of cooperation and size. In the building in Marlboro that used to be the RCA Computer Division, we have manufacturing and engineering and marketing working together as one team, turning out this massive project. The efforts of people at 40 different plants are going into that project and being integrated into one new machine.

Now I feel good about the future and the changes we're making. I'm enthusiastic about the cooperation that we've seen just in the last year. Having hard times helps a lot. A year ago, we were beat up a lot.

Today, most of the world is realizing that what is needed in the world of computing is big computers, inter-connected, disciplined, organized and well done. That's what we have to offer.

We have a system which is complicated, powerful, disciplined, organized, documented. That's a part of the computer industry which is not well populated. Much of the computer industry today is fast-moving, making fast-in, fast-out equipment. We compete in the area where products are carefully done, where excellence, quality and stability are important. Our contribution to the industry is to offer these quality products to the large class of customers who want quality and who will not be satisfied by efforts of the relatively small, relatively fast-moving companies that don't have our discipline. Ω

Newsletter – *Continued from page 27*

search software to enable users to examine the commentaries by author or authors, by line or passage, by words or phrases, by citations of text or any combination of the above.

Central to the project is Dartmouth's Kurzweil Data Entry Machine, capable of reading photocopies or originals of any printed or typed text and recording what it reads on computer-ready magnetic tape complete with underlining, accent marks and some foreign alphabets. Students employed by the project are working up to 70 hours a week on the Kurzweil Machine, and are producing machine-readable versions of Dante commentaries at a rate of about two per month. Depending on the speed and versatility of the Kurzweil Machine, 60 to 80 of the most important commentaries written in English, Latin or Italian will be included in the data base. Ω

Walking Machines—Part 1

Prof. Robert McGhee
Director, Digital Systems Laboratory
Ohio State University
1659 North High St.
Columbus, OH 43210

"The area we are working on most intensively at the present time is terrain adaptive vehicles, ... roughly speaking, an artificial horse."

Hinges

For almost 30 years I have been trying to understand the problem of co-ordination of motion in articulated mechanisms. By an articulated mechanism I mean something that has a lot of hinges.

The first engineering work I did in this area related to the automatic control of aircraft and guided missiles. Let us consider an airplane since most of us are more familiar with those. When it is flying along, it has three sets of hinges. One set has to do with the up and down motion of the airplane. This set is called the elevators. Another set has to do with turning to the right or the left. This control surface is called the rudder. And finally, in order to make a proper turn so that the passengers do not experience discomfort, the pilot must be able to bank his airplane. This involves a set of hinges which is associated with surfaces called ailerons.

There are therefore three degrees of freedom associated with the motion of an airplane in steady flight. Of course there are many other degrees of freedom associated with problems like landing and take-off and change of speed, etc. But we can say that in a certain sense the complexity of the pilot's task is very much related to the fact that he has these three degrees of freedom to control in a co-ordinated way. I claim that this co-ordination goes on at three distinct levels.

Three Levels of Co-ordination

First of all, there is the logical level. When I speak of the logical level, I am talking about a kind of information processing which leads to discrete decisions which can be explained using natural language. In fact, these decisions always involve language, conversations between the pilot and co-pilot, conversations between a pilot and the ground control, messages such as: "Begin your descent"; "clear for take-off", etc. The co-pilot and engineer may give confirming signals to the pilot that the landing gear is up. So we can say that at the logical level one is concerned with discrete events.

There is, however, another level of control which requires rather specialized training. And that I choose to call the geometrical level because it deals with continuous motion. If you happen to be involved in a field called human factors, you might be very much concerned with how the pilot manages his tasks. This is extremely important and a great deal of effort and funds are expanded in designing the cockpit of an airplane so that it is convenient for the pilot and makes a good match to his muscular system. The description of actions that take place at the geometrical level involves curves. We cannot describe it precisely with natural language, but have to use some sort of geometrical or kinematic language. We can make it mathematical, but the most straightforward way is to present the curves of how the pilot's joints move as he controls the airplane. And of course these motions are not independent; they are co-ordinated, depending upon each other so as to achieve the necessary action. It is not fully understood how human beings accomplish this kind of co-ordination.

Finally, even deeper into the nervous system, or robot, or aircraft, is the dynamic level. In order to achieve motion, it is necessary to apply forces. And in order to understand the relationship between forces and motion it is necessary to have the concept of acceleration which really means understanding calculus, going back to the time of Newton and the laws of mechanics.

Task Decomposition and Muscular Impulses

Now, from an information science or biological point of view, one can observe that there are two kinds of processes going on, or two kinds of relationships between these levels. First of all, there is a downward task-decomposition at work. The pilot begins, perhaps, by thinking "I have got to go to work today". He then makes a plan of how to get to work and as he gets to the airplane this plan becomes more detailed and so on. When he is actually flying the airplane, after he has trained, his joint motions are co-ordinated at a subconscious level. And at a still deeper, inaccessible, level is the problem of providing the necessary electrical impulses to the muscles governing the motion of the pilot's limbs. There are some 800 or so individual muscles in the human body and it is finally at this level that the motion is accomplished.

After 15 years of working on guided missiles and aircraft, I became interested in human motion, expecially as related to providing better aids to the handicapped. When you work on weapons long enough, you start wondering about the people who are on the receiving end. I observed that artificial limbs and braces were very primitive and had not changed very much, and that electronics did not seem to be making much of a contribution. So somewhat naively, I thought that it might be possible to use the automatic co-ordination techniques used in guided missiles and aircraft to build a powered artificial limb in which some of the motions would be automatically co-ordinated.

It did not take long to find out that that problem was too hard. With more than 200 "hinges" in the human skeleton controlled by more than 800 actuators, there are too many degrees of freedom. So rather quickly, I and my colleagues at the University of Southern California regressed to a simpler problem: the problem of co-ordinating robot motion. The term "robot" was not accepted, so we said we were working on walking machines. We still say that to distinguish the machines we work on from robots in general.

Fewer Degrees of Freedom

The reason that it is attractive to work on robots is that at the present time they have many fewer degrees of freedom, ranging from about 4 up to 18. You are probably most familiar with industrial robots, but I want to make it clear that I am not talking about industrial robots.

The industrial robot is a machine which is immobile, except when it is brought to its workstation by a forklift truck. It does a repetitive job in a highly structured environment in a factory. That is the reason that it is effective. Today industrial robots are replacing human beings in the dirtiest, most repetitive, most inhuman kinds of job. However, there are needs for robots in other circumstances which require mobility. A very important one is in the nuclear power industry. Recently, in Paris, I saw in operation a prototype of a pipe inspection robot for the Super Phoenix Breeder Reactor. It is necessary to check the integrity of welds in this reactor from time to time in a very high temperature and high radiation environment. The surface of the reactor is at 200 degrees Centigrade, the level of radiation is quite high. And so M. Jean Vertut of the French Atomic Energy Commission has built a very clever device which uses a combination of wheels and legs to move about through the confined spaces of the reactor and inspect the integrity of welds. There is no other way to do that job without shutting down the reactor. The intention is to do this online, during reactor operation.

Another possibility where robot systems might function more effectively than human beings is in space. NASA is talking more and more about constructing large systems in space, large antennas, perhaps solar-powered generating systems, and so on. These structures cannot be constructed on earth because they are too flimsy. If they were not too flimsy they would be too heavy. I am told it costs $50,000 an hour for a man to work on a tether in space. It certainly would make sense to have a mobile robot capable of moving about on a large structure and performing simple assembly operations.

An Artificial Horse

The area I am personally working on most intensively at the present time is in the area of terrain adaptive vehicles. What we are looking for here is, roughly speaking, an artificial horse. We would like something that could cross very rough terrain, without shaking up the rider and without requiring an excessive expenditure of energy.

We are able to consider this range of possibilities in a realistic way only because of microelectronics. I was frustrated for the first 15 years of my research into artificial limbs and robotics by unavailability of sufficient computational power at an acceptable cost. The experimental machines so far are all tethered to a computer via a cable. None of them yet has self-contained computers. We expect that within three years this will be possible because of the availability of the appropriate chips.

Legs vs. Wheels

The question may be asked: "Why walking robots? Why use legs rather than wheels?" After all, the wheel is usually taken as the very symbol of an advanced society and it is often said that the North American Indians, for example, got stuck at a certain level of development because they failed to invent the wheel. That may not be right. It may be they got stuck there because they failed to invent the mechanical leg. Because, after all, they didn't have highways and wheels are not much good without highways. If you look at the development of wheeled transportation in Europe and Asia, it went right along with the development of highway technology.

The most likely possibility for significant support in the near future for the development of walking machines lies in the area of military logistic support. If you look in the hills around you, you will realize that we don't have vehicles that can traverse this terrain. On the other hand, animals live there. They are able to do so because the nature of the interaction of a wheel with terrain is quite different from that of a leg. This is very straightforward. If you put a wheel on soft or rocky soil, the first thing it does is sink into the soil and in so doing it creates a hole which it must continuously climb out of. A leg, on the other hand, a biological leg until now, experiences a contrary effect. If you try to climb a hill or walk through soft soil, the motion of your leg pushes the soil backward, not forward, and it creates a depression which helps you. And that is the fundamental reason that legs are better than wheels in rough terrain. This phenomenon accounts for the fact that roughly 50% of the land surface of the Earth is not accessible to any wheeled or tracked vehicle. Many of these areas are, of course, accessible by helicopter but helicopters are very expensive machines. They only function in good weather and they have a lot of other limitations.

Another reason for using legs rather than wheels is to carry out economically worthwhile activities in fragile or difficult terrain, such as tundra regions, for example. It has been noted that when herds of hundreds of thousands of caribou, which are very large animals, move through an area they damage the terrain. However, that damage heals over within approximately a year. On the other hand, if a caterpillar tractor makes one pass through the same area, it may take up to 100 years for the scar to heal and it may not heal at all. It may induce erosion which will create gulleys up to 20 or 30 feet deep. Again the reason for this is to be found in soil mechanics. Animals create discrete footprints which are small in area. Caterpillar tractors first of all interact more vigorously with the soil in overcoming the before-stated problem and secondly, and more importantly, they produce a continuous track which induces erosion.

I have already referred to space assembly. Not only do wheels require roads to function efficiently, they also require gravity. A wheel is a device which must be biased, it must be drawn down to the surfaces to travel over. The physical force available for this purpose on earth is gravity. Gravity does not exist in space. So you cannot have automobiles in space.

Hazardous Environments

Finally, the example I referred to earlier, of hazardous environments, goes beyond nuclear reactors. It also includes fire-fighting, underground mining and many other possibilities, places we would like to put machines, not men. But the machines are not there for lack of mobility. The fireman goes into the burning building, not because his intelligence is needed there but because his legs are the only things we have at the moment that will pull a hose. He could stay outside and work with television if he only had something to drag the hose into the building.

The Army Mule

Up until about 1943 the United States Army used pack animals to transport supplies through difficult terrain. And a US Army mule, which was an especially heavy breed of animal, was able to carry 400 lb for 15 miles or 250 lb for 30 miles in one day through very rough terrain. Now mules have some

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Weapons In Space

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"It is a dangerous myth that space weapons could be used only for defensive purposes."

Based on the script of a slide presentation given to the members of Computer Professionals for Social Responsibility, Boston chapter, November 1984.

The arms race is moving into a new and frightening phase. Both the United States and the Soviet Union are developing weapons to destroy military satellites and to attack ballistic missiles from orbit. Space looms as the next major battlefield in the dangerous and costly struggle for military superiority.

The impending arms race in space has its origins in the dawn of the Space Age. The launch of Sputnik 1 in October 1957 marked the beginning of the "Space Race," although that race was far different from the one which is threatening us today.

The Space Race of the 1960s

The space race of the 1960s was a race to the moon. It was a peaceful competition for prestige and national honor. It was also a competition to reap the benefits provided by satellites. From their unique vantage points far above the earth, satellites can perform otherwise impossible tasks. Photographs taken from space have led to revolutionary advances in science, industry, agriculture, and commerce. Acting as space-based relay systems, they have radically transformed global communications. Linked with ground-based dish antennas, satellites can instantaneously transmit telephone calls and television programs around the world.

But the real race in satellite technology has occurred on the military front. Today, one satellite is launched from somewhere in the world about every fourth or fifth day to enhance military capabilities.

Intelligence Gathering

Intelligence gathering is one of the most important functions of military satellites. These "spies in the sky" can keep close watch over military activities anywhere in the world. Regional conflicts and troop movements can be carefully monitored, making it easier to prevent local hostilities from erupting into major conflicts.

Early warning satellites maintain a constant surveillance over Soviet missile fields. In the event of a nuclear attack, these satellites would provide an immediate warning to our military decision makers in Washington, D.C.

Successful arms control depends on the use of military satellites as well. An underground nuclear test is the only kind of nuclear bomb test allowed under current US-Soviet agreements. Many arms agreements depend on the probability that treaty violations will be observable from space.

Communications

Communications between military forces and their commanders are highly dependent on satellites. Today, the soldier in the field, the pilot in flight, and the ship captain at sea can establish instantaneous communications via satellite with their military commanders on the other side of the world. This highly sophisticated communications system allows for rapid decisions during a military crisis. Over 70% of the US military's long-distance communications currently travel via satellite. By the year 1990, this number may reach 90%.

Essentially all US military vessels depend on satellites for navigation services. At any time of day and during all weather conditions, ships at sea can determine their precise locations by locking in on signals from navigation satellites. By the end of the century, the newest generation of navigation satellites, called NAVSTAR, will provide incredibly accurate navigation information to US military around the world.

Spacecraft

The US and the Soviet Union have developed essentially the same types of military spacecraft. But there are important differences between the satellite networks of the two nations. The Soviets launch about 5 times as many satellites each year as does the US. However, the lifetime of an average Soviet satellite is about 5 times shorter than that of its American counterpart. US satellites last for years, whereas many Soviet satellites remain operational for only a few weeks or months. Soviet satellites are also considerably less sophisticated than US spacecraft. In some areas of satellite technology, the Soviet Union is merely ten years behind the US.

Because satellites are used so extensively for military purposes, both superpowers regard each other's space activities as significant national security threats. For this reason, each nation has sought to develop weapons which destroy satellites. The US was the first to develop an anti-satellite weapon, called an ASAT, when -- in the early 1960s -- the US tested its Nike-Zeus antiballistic missile against targets in space.

From 1964 to 1970, the US also conducted 16 tests of the nuclear-armed Thor rocket for possible use as an anti-satellite weapon. A deployed force of these large rockets was stationed on Johnston Island in the Pacific until 1975, when they were decommissioned. It was realized that the nuclear explosions of the Thor ASAT would generate electromagnetic pulses, or EMP, that would have destroyed not only the Soviet Union's military satellites, but those of the US as well.

The Soviets began testing an anti-satellite system in 1968. They have since conducted a total of 20 tests. The Soviet ASAT circles the earth, maneuvers to within a few miles of its target, then explodes, sending out a cloud of pellets to destroy the satellite. This weapon, however, has many significant limitations. The Soviet ASAT is launched into orbit atop a massive rocket. Since this booster requires extensive preparation, and because the weapon must achieve earth orbit before it can intercept its target, the US would have substantial warning time before any of its satellites could be attacked.

When testing their ASAT, the Soviets first launch a target satellite into orbit. Later, the ASAT itself is launched, and it circles the earth one to two times to attain an orbit similar to that of the target. The Soviets have tested two different sensor systems to guide the ASAT to the target. One, a rather primitive radar sensor, has had a 65 percent success rate. The other, a more sophisticated heat-seeking sensor, has failed completely.

However, the most significant limitation of the Soviet ASAT is its range. Because it is very heavy, the Soviet ASAT can only be launched to within range of a handful of US targets -- those in low earth orbit and those in so-called Molniya orbits. The weapon cannot threaten the most important US satellites which travel in [other] orbits.

The New US Anti-Satellite Weapon

Despite the many weaknesses of the Soviet ASAT, the Pentagon considers it an operational system, and is now racing to develop a highly advanced anti-satellite weapon of its own. The new US ASAT is a small cylinder, housing sophisticated electronics, an internal computer, eight tiny telescopes, and 56 steering rockets. This weapon will be mounted on a two-stage missile which will be launched into space from specially equipped F-15 aircraft. The F-15 will carry the weapon to an altitude of about 18 miles, then release the missile, which will carry the ASAT to the vicinity of the target. The device will then home in on the targetted satellite, and destroy it by direct collision.

Once deployed, this weapon will be a serious threat to strategic stability. Since these aircraft could speed from the earth to the upper reaches of the atmosphere in a matter of minutes, the Soviet Union would have little or no warning of an attack. This would add markedly to US-Soviet tension by increasing Soviet fears for the safety of their satellites.

And since the US ASAT is so small, the Soviet Union will face tremendous difficulties in trying to verify the numbers and locations of these weapons. Because of the verification problems that would accompany the US ASAT, deployment of this weapon would make ASAT arms control difficult, if not impossible to achieve. A full-scale ASAT race would begin in earnest, with the Soviets likely responding with an advanced ASAT of their own.

One Soviet response could be a weapon which uses ground-based lasers to destroy targets in space. The Soviets could also develop mines or a system similar to the new US ASAT. Any lead which the US gained by deploying the F-15 ASAT would be quickly lost when the Soviet Union responded with advanced ASATs of its own.

Aware of the many dangers of an ASAT race, the Carter Administration conducted three rounds of ASAT talks with the Soviets in 1978 and 1979. These discussions were the result of a two-track decision by the US: one track being the development of the F-15 ASAT, the other track being the pursuit of a treaty that would make deployment of the weapon unnecessary. With the invasion of Afghanistan, however, these talks fell by the wayside, and the two-track approach has since been abandoned.

President Reagan marked the final test flight of the US space shuttle on July 4th, 1982, by announcing a new national space policy. In that statement, it was made clear that the US will press ahead with efforts to develop an ASAT system. Plans now call for continued ASAT development with operational deployment scheduled for 1987. Resumption of ASAT arms control talks has been deferred indefinitely.

The "Star Wars" Speech

The US Air Force, anticipating an increase in the militarization of space, formed a new command center, called "Space Command," in late 1982. Space Command will control the US ASAT missions, as well as other military space operations that might arise in the future. The scope of those potential activities became apparent in March 1983, when President Reagan, in a nationally televised address, delivered his now-famous "Star-Wars" speech. In that speech, the President called for the development of exotic new anti-ballistic missile weapons to provide a "technical fix" to the nuclear arms race. He called on the American scientific community to develop defensive weapons which would, in his words, render nuclear weapons "impotent and obsolete."

The laser beam was one of the principal technologies that President Reagan had in mind. There exist a variety of lasers, many of which could potentially inflict damage to a distant target at the speed of light. In theory, this makes the laser an ideal candidate for use as a weapon. Present-day lasers can shoot down certain targets, such as slow-moving drone aircraft. But miraculous scientific breakthroughs would be required to develop weapons capable of defending the US against a nuclear attack. Nevertheless, the Pentagon is planning to spend tens of billions of dollars on the research and development of space weaponry.

One ongoing US space weapons program, called TRIAD, is aimed at developing a space-based laser weapon powered by highly reactive chemicals. The three separate research projects of the TRIAD are working to develop the laser, tracking system, and mirrors that would be required for a space laser. If the three parts of the TRIAD are perfected, they could perhaps be integrated into a laser battle station and placed into orbit via the space shuttle. Dozens -- perhaps hundreds -- of these orbiting battle stations would be needed to assure adequate coverage of Soviet missile fields. Proponents claim that if the Soviets initiated a nuclear attack, these weapons could detect the missiles and start shooting them down.

Orbiting Mirrors

Another space weapons plan that has surfaced since the "Star Wars" speech involves enormous orbiting mirrors to target and focus laser beams generated on the ground. Under this plan, up to 100 laser stations would be dispersed across the continental US. During an attack, the laser beams would be transmitted into space, bounced off the mirrors, and focused on the enemy ICBMs, thousands of miles away.

Yet another plan calls for the development of X-ray laser battle stations. These weapons would theoretically be powered by the energy released by nuclear explosions. The long spoke-like arms of the weapon would be aimed at ascending ICBMs. When the command was given -- the nuclear devices within each system would be detonated -- sending pulses of X-rays toward the missiles. According to proponents, the targets would be destroyed by the shock waves created by the laser beams.

Whether the development of these futuristic space weapons is possible, nobody knows. None of these systems have yet been built and the technological hurdles facing their development may never be overcome. There are many questions and few answers. But the answers that we do have all suggest one thing: We must stop the development of these weapons now, while we still have the chance.

The effect of a space weapons race on future arms control would be disastrous. The

Outer Space Treaty, the Limited Test Ban Treaty, and the Anti-Ballistic Missile Treaty could all be shot full of holes if the US proceeds with these "star wars" systems. Of greatest concern would be loss of the ABM Treaty, the most important arms control agreement to date.

If the US presses forward with space weapons, a strong Soviet response is likely. They could develop countermeasures such as warheads that fly evasively, missiles that rotate, or weapons with polished surfaces to blunt the effects of laser beams. They could build up an offensive force of terrain-hugging cruise missiles and low-flying bombers, none of which could be destroyed by space-based ABMs. And finally, they would likely deploy space weapons of their own, any of which could be used in a pre-emptive strike against the US space weapons.

Misreading, Misinterpreting

It is a dangerous myth that space weapons could be used only for defensive purposes. All these weapons would have inherent, highly destabilizing offensive capabilities. They could be used to shoot down anything the other side put into orbit. The offensive capabilities of these weapons would create an unprecedented threat to the command, control, and intelligence of both superpowers. If a military satellite or orbiting battle station suddenly stopped functioning, it could be misinterpreted as the beginning of an attack. A computer failure, a collision with a piece of space junk, or a faulty instrument reading on earth could all be misread as enemy acts of war.

If conventional hostilities were to break out between the two superpowers, with both sides possessing sophisticated space weapons, military satellites would be among the first targets destroyed. The loss of these systems at an early stage of a crisis would dangerously increase the odds that the conflict would escalate to nuclear war. Without the reliable communications and early warning services provided by military satellites, the emerging crisis would rapidly slip out of control. Our military commanders would be forced to act on incomplete information, and our nuclear forces could be severed from the national command authorities. Split-second decisions about the use of nuclear weapons would have to be made, probably without adequate information about our adversary's intentions. And if the initial attack on military satellites severed the communications links between the superpowers, the crisis would run its full course without any possibility of bringing it under control through diplomatic efforts.

Mutual Test Ban

A nuclear war would likely be the most disastrous event in human history, causing unimaginable death and destruction. This is a devastating thought, and we all wish it could be wiped away, but the development of space weapons as a promised shield against nuclear destruction is clearly not the answer. A space arms race would only increase the danger. To reduce the threat of nuclear war we must bring the arms race under control; we must prevent it from escalating off the planet and into space.

The space weapons most immediately coming down the line are ASATs. The development of ASATs should be stopped through a test moratorium with the Soviet Union. A mutual test ban on ASATs would slow down the evolution of these weapons. It would set the stage for an ASAT limitation treaty, and would be a significant achievement toward preventing the deployment of future generations of space weapons. Verification of an ASAT test moratorium could be achieved using the worldwide network of sophisticated telescopic cameras, radar, and infrared sensors which the US has in place or is now constructing. The Soviet Union has similar detection capabilities to monitor US compliance.

The Soviet leadership has indicated their interest in preventing a space arms race on a number of occasions. In August 1983, for example, former Premier Yuri Andropov told a group of visiting US senators that they would stop testing their ASAT if the US did likewise. The Soviets also presented to the United Nations a draft treaty that would ban space weapons. The extent of the Soviet leadership's interest in an ASAT treaty is uncertain. The only way to find out is to sid down with them at the negotiating table.

If the emerging race to build space weaponry is not stopped soon, the billions of dollars now being devoted to these weapons will turn into tens of billions, then hundreds of billions. And the history of the arms race has clearly demonstrated that once deployed, weapons are very difficult, if not impossible, to negotiate away.

Our planet is caught in the grip of a dangerous and costly arms race, and has been for over three decades. But the arms race on earth will dwarf in comparison to an arms race in space. If we act now, however, we can prevent space weapons from being built.

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Problems, Solutions, and Methods of Solving —Part 3

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"Problems play an essential role in the progress and teaching of science."

This series of articles has three main propositions:

- The problems that computers can solve are far fewer than all the problems that human beings are faced with;
- The types of solutions that can issue from a computer are far fewer than the types of solutions that possibly can issue from a human being;
- It is desirable to notice and consider all the problem solving methods that human beings use.

In the first article (Sept.-Oct., 1984) we talked about:

1. The Principle of No Action
2. The Principle of Feedback Control

In the second article (Nov.-Dec., 1984) we talked about:

3. The Principle of Action
4. The Principles of Authority

Here we shall talk about:

5. The Principles of Analysis and Synthesis
6. The Principle of the Scientific Method
7. The Principle of the Model

5. The Principles of Analysis and Synthesis

The Principles of Analysis and Synthesis constitute a large and important area of problem solving. This area consists of thousands of procedures for making or doing something.

What do we mean by analysis? Taking apart some problem or procedure and considering each element of it.

What do we mean by synthesis? Putting together the various elements in original or modified form, while we say to ourselves, "maybe if we organize the procedure in this way, the solution will be improved, and the problem will be solved."

For example, suppose on the dining table there is a new jar of grape jelly from the store. To eat the jelly the jar has to be opened. We try to unscrew the lid, but it does not budge. Our hand just slips on the lid. So we run hot water for a minute or two on the lid, and then the jar opens with only normal effort. Why? We make use of the fact that a metal lid should expand when heated.

How do we accomplish this solution? We substitute in imagination a looser lid for the tight lid, and imagine a way in which the additional looseness can be achieved.

We can list in a table 20 common ordinary activities or operations where analysis and synthesis in problem solving apply, yet computers are hardly usable.

Table 1

20 COMMON ORDINARY ACTIVITIES OR OPERATIONS IN WHICH COMPUTERS HARDLY APPLY

1. Cooking a meal
2. Darning a sock
3. Doing a load of laundry
4. Shopping for food in a store
5. Selecting a doctor

6. Getting a book from a library
7. Driving a car
8. Setting a thermostat for a house
9. Insulating a house
10. Shoveling snow
11. Taking a bus
12. Cleaning a room
13. Mowing a lawn
14. Repairing a leaking faucet
15. Sewing on a button
16. Setting a table for a meal
17. Reading a book
18. Getting up in the morning
19. Wrapping a present
20. Hanging a picture

For instance, suppose we take a very simple operation, darning a sock. The materials are a bag full of socks with holes and a box which contains:

- several spools of darning cotton
- a small packet of darning needles
- a needle threader, and
- a wooden egg which can go inside a sock and can be held so as to present conveniently the sock area (or hole) that needs darning

The method of darning is like the method of weaving. First, the space of the hole is covered with parallel threads of the darning cotton sewn into two margins of the hole, and then again covered with transverse threads of the darning cotton going in and out. Other methods of repairing, such as just sewing the sides of the hole and pulling it together, are much less satisfactory.

Or suppose we take as an example a more complicated operation, driving a car. Most people in the United States have reached the degree of proficiency where they "think nothing of" driving a mile or 10 miles or 100 miles, because they have become very much accustomed to their car, the roads, the traffic, and the technique, and have had at least several years of experience.

In teaching someone to drive a car, a natural way of proceeding is to divide the task into various stages. The first stage is stopping: the car is moving and the trainee is to stop it. The second stage is slow forward motion and steering, making sure that surrounding traffic is almost nonexistent. And so on, through stage after stage, until finally the trainee appears ready to go to the state examiner accompanied by the instructor to be tested for his or her driver's license.

The 20 operations listed in Table 1 are just a small sample of common everyday problems. What are the sources of knowledge which enable us to deal with the multiple facets of our ordinary everyday problems?

Here is a list of them:

- Instruction / people or directions tell us what is reasonable to do
- Experience / with experience we find out what to do and what not to do
- Practice / we become expert by practicing
- Common sense / we save unnecessary steps in a procedure when they don't make sense
- Comparison / if someone else does much better, we study how he does it
- Experiment / we make trials and find out knowledge for improving the procedure

6. The Principle of the Scientific Method

The Principles of Analysis and Synthesis develop naturally into the Principle of the Scientific Method. This, according to the dictionary, consists of principles and procedures for the systematic pursuit of knowledge involving the recognition and formulation of a problem, the collection of data through observation and experiment, and the formulation and testing of hypotheses. But actually we are using the scientific method when we derive any conclusion by means of testing and experience. For example, we find that a friend is 15 minutes late six times out of six, and accordingly we simply plan on his being regularly late.

In the scientific method there are about a dozen chief ideas. They are listed with some clarification or comments in Table 2. Some of these ideas are also to some extent discussed further on.

Table 2

THE CHIEF IDEAS IN THE SCIENTIFIC METHOD

1. Curiosity / interest in some thing, event, or phenomenon, leading to in-

quiring about it, studying it, and seeking to understand it

2. Observing / noting (paying close attention to) things, events, phenomena, using our senses and their extensions including instruments
3. Recording / making records of what we observe and learn so that we can compare current observations with what was actually observed yesterday, or last year, or long ago
4. Collecting Specimens / so that we can confirm records against actual samples (as in museums) and investigate further what may not have been observed and recorded at the time of collection
5. Sample Operating Environments / so that we can study collections and series of phenomena (as in flower pots, aquariums, botanic gardens, laboratories) and make records of the interaction of phenomena, including behavior
6. Experimenting / arranging new behavior of phenomena so as to contrast one possible explanation with another, and determine which one is more satisfactory
7. Measuring / counting the number of some phenomenon or the number of certain units of that phenomenon plus a fraction of the last unit
8. Variation (called more precisely "concomitant variation") / if one phenomenon repeatedly varies in a certain way when a second phenomenon repeatedly varies in a certain other way, then one is a cause or an effect or causally related to the other
9. Explanation / a description of the behavior of some phenomenon as causally resulting from certain other phenomena, confirmed by evidence
10. Hypothesis / a tentative supposition or assumption made in order to examine and test its reasonable consequences
11. Theory / a hypothesis confirmed by many experiments with almost no contradictory experiments
12. Law (of nature) / a statement of the behavior of a cause and an effect that has been found to be invariable under the same conditions

Curiosity

Curiosity, the first topic in Table 2, has not always been welcomed and encouraged in the long centuries of humankind on the earth. Young monkeys and young children always start out being intensely curious. But parents often suffer from children's questions like "Why is the grass green?" and "How do you know there is a God?". And sometimes the answer is "Because it is" and "Because there must be, " and such answers do not satisfy the inquisitive young mind.

In the Bible (Ecclesiasticus) occurs: "Be not curious in unnecessary matters." In St. Augustine's writings occurs: "God fashioned Hell for the inquisitive." And the dictionary gives as an archaic meaning of "curiosity": a blamable or reprehensible desire to seek knowledge, as of sacred matters.

In the 1500s and 1600s in Europe it became proper and fashionable for studious educated men to investigate the natural world. As one of the results, Galileo, the great Italian scholar (1564-1642) observed through a telescope (one of the first to reach Italy) that the satellites of Jupiter orbited that planet, and that this confirmed the Copernican theory that the planet Earth orbited the Sun. Later he recanted at the command of the Catholic Inquisition.

In current years, curiosity is welcome almost everywhere. Curiosity, the passion to know and understand and so perhaps to be able to predict, is the mainspring of scientific research and development. It is well regarded and considered right and sensible by the great majority of people.

Observing

To observe is to see or detect, especially through directed careful attention. Observing in the scientific sense is not easy and often requires discipline. It is particularly necessary to separate between facts and interpretations, for regularly we see interpretations and not facts.

A good example of the difficulty in observing is found in the appearance on the horizon of the sun just setting or the full moon just rising. Each of these images seems unexpectedly large; and the reason is the eye automatically compares the image with scenery on the horizon near to the image.

Sample Operating Environments

A good example of an operating environment is a small aquarium. There is an inviting account of such an environment in the fine book "King Solomon's Ring" by the naturalist Konrad Lorenz:

"The whole charm of childhood still lingers for me in a fishing net: the rim, an ordinary bent wire; the net, a stocking or piece of curtain. With such an instrument, I caught at the age of nine, the first Daphnia for my fishes, thereby discovering the wonder-world of the freshwater pond which immediately drew me under its spell; and my fate was sealed, for he who has once seen the intimate beauty of nature cannot tear himself away again."

Variation

An interesting example of concomitant variations is reported in a book by the English logician and teacher, W. Stanley Jevons, written in 1870.

"A most extraordinary case of variations consists in the connection which has of late years been shown to exist between the Aurora Borealis, magnetic storms, and the spots on the sun. It has only in the last 30 or 40 years become known that the magnetic compass needle is subject at intervals to very slight but curious movements; and that at the same time there are usually natural currents of electricity produced in telegraph-wires so as to interfere with the transmission of messages. These disturbances are known as magnetic storms, and are often observed to occur when a fine display of the Northern or Southern Lights is taking place in some part of the earth. Observations during many years have shown that these storms come to their worst at the end of every eleven years, the maximum taking place about the present year 1870, and then diminish in intensity until the next period of eleven years has passed. Close observations of the sun during 30 or 40 years have shown that the size and number of dark spots, which are gigantic storms going on upon the sun's surface, increase and decrease exactly at the same periods of time as the magnetic storms upon the earth's surface. No one can doubt, then, that these strange phenomena are connected together, though the mode of connection is quite unknown. ..."

In other words, astronomers had noticed that the phenomenon sunspots and the phenomenon magnetic disturbances on the earth were linked, varying together with the same period of 11 years. But the cause (streams of electrically charged particles from the sun) had not yet been determined.

7. The Principle of the Model

Another important method of problem solving is the Principle of the Model. This is the principle of representing the significant features of a problem by a convenient analogy or model of the problem. For example, if we are interested in representing a "gibbous" moon or planet, it is a simple matter to draw a model diagram showing the moon or planet "with more than half but not all of the apparent disk illuminated."

The word "model" has several definitions in the dictionary:

- a structural design of something
- a miniature representation of something
- a pattern of something
- a description or analogy used to help visualize something that cannot be directly observed

A model is often smaller than the thing which is modeled, but sometimes larger. Other terms often used for model are image, map, representation, analogy, etc.

Some simple ideas are very powerful models, apply widely, give answers to many problems, and provide insights for understanding many situations. These ideas give pictures, ways of thinking, that we can carry around in our mind, and that help to explain events and processes in the real world.

Many problems are solved by the use of models, images, maps, representations. They may be on paper or mental, and show or report or reveal the structure of a problem. For example, some migrating birds have star maps in their minds which enable them to fly in a selected direction for thousands of miles. A rat trained in a maze to find food develops a mental plan which solves the maze faster and faster. An adult person crossing a well-traveled street makes a momentary model in his mind which enables him to see gaps in traffic streams and avoid oncoming cars.

How do we know? Partially, we know because it is not possible without assuming these models in the minds of animals and human beings, to explain what they do. Additionally, an aviary with representations of stars can show in what directions birds seek to fly. There is more evidence besides.

The word "model" has received an increment of meaning from its use in engineering in the last century. A proposed engineering struc-

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Annual Index

for "Computers and People" 1984, Volume 33

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Computing and Data Processing Newsletter

INDUSTRIAL ROBOTS IN THE UNITED STATES

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The industrial robot was invented in the United States about 25 years ago. In the decades since then, worldwide confusion developed over the definition of industrial robot. The problem arose because the term was used to refer to automated equipment that did not possess the special abilities of robots. Robotic Industries Association (RIA) attempted to solve the problem by creating the following definition that is now recognized by most nations:

> Industrial Robot - a reprogrammable, multifunctional manipulator designed to move material, parts, tools or specialized devices through variable programmed motions for the performance of a variety of tasks.

The key words are "reprogrammable, multifunctional manipulator". Unlike other forms of automation, robots can be programmed to do a variety of tasks, making them the most versatile of manufacturing tools. Many advantages result from the robot's reprogrammability. Since robots can switch tasks with a minimum of start-up and debugging costs, a company is able to maximize its use of a proven design and reduce overall manufacturing costs.

Currently, RIA estimates that some 13,000 industrial robots are installed in the United States (as compared with 50,000 in Japan). About 35% of the installations are in the auto industry. Other major industries using robots include home appliances, aerospace, consumer goods, electronics, and off-road vehicles. Recent developments that give robots added intelligence such as machine vision, tactile sensing, and mobility make robots suitable for a wider range of industries. The near future will find robots used increasingly in industries such as textiles, food processing, pharmaceuticals, furniture, construction, and health care.

Robots offer substantial gains in manufacturing productivity, particularly when integrated into an automated system. The history of U.S. robot installations indicates that robots increase productivity by 20-30%. Since the majority of robots are applied to existing machinery, companies using robots can accelerate payback on current equipment while reducing the need for new capital investment.

RIA believes that the future strength of our nation depends upon American companies becoming more productive and staying competitive in world markets. Other nations have recognized the need to automate and are moving ahead at full speed with government, industry and labor support. They have also recognized the importance of robot technology in achieving their goals. America will have to develop this same cooperative commitment to automation, and robots will play a key role.

Despite the fact that the technology was invented in America, the Japanese have become the leaders at putting robots to use. Estimates indicate that Japan has about 50,000 industrial robots installed. In the mid-60s Japanese industries and government agencies recognized that the vast productivity potential of robots offered Japan a chance to become a far more powerful manufacturing nation. Nearly a decade ago (1975) Japan's Ministry of International Trade (MITI) targeted robotics as an industry to dominate. Incentive programs were created to aid their domestic robot suppliers and encourage the use of robots. These incentives included government sponsored research and development projects, tax benefits to manufacturers and users as well as depreciation allowances for robot users. National robot leasing programs, and more recently, direct funding of robotic sensor development reflect Japan's continuing commitment.

These programs have been extremely helpful to the approximately 200 Japanese robot manufacturers and to the Japanese economy. RIA seeks the same type of incentives from the U.S. government to help insure that the U.S. robot industry can be as strong and as beneficial for America's economy as Japan's robot industry is for their nation. Robot use is likely to top the 90,000 level in America by 1990. It is important that the domestic suppliers retain a large share of the market so that jobs created in manufacturing robots are retained in the U.S.

The fear of robots by American workers should be lessened by a greater awareness of the following facts: 1) most current robot installations involve the selection of a robot over another form of equipment, not to replace a person; 2) robots in factories generally perform the hazardous, boring, demoralizing and repetitive tasks that allow workers to be removed from dangerous environments; 3) the increased productivity offered by robots can pave the way to a shorter work week, higher pay, and better working conditions; 4) higher productivity means fewer jobs lost to overseas manufacturers in competitive industries.

The substantial threat to the American worker is failure of U.S. industry to make full use of robots and automation. In declining industries, the failure to automate can mean a massive loss of jobs when competitive pressures put companies out of business. In thriving industries, the failure to automate can lead to a major decline if overseas companies use automation to become more competitive. For example, the highly successful Japanese auto and electronics industries made extensive use of robots to become formidable competitors for their counterparts in America. These American industries have responded to the challenge, but not before suffering major losses.

THE SCOTTISH POISONS INFORMATION BUREAU

A.T. Proudfoot and W.S.M. Davidson
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(Based on a report in the "Computer Bulletin" for March 1984)

Dealing with acute poisoning poses a serious burden on our National Health Service. Each year it accounts for about 150,000 hospital admissions and even this number is probably an underestimate of the real size of the problem in the community. Poisoning in toddlers is usually accidental and, in addition to drugs, involves toiletries, cosmetics and the countless domestic cleaning and decorating products which we seem unable to prevent ourselves from storing in cupboards underneath kitchen sinks. In contrast, adult poisoning is most commonly self-inflicted, either in the form of a drug overdose in a moment of distress or the use of 'magic' mushrooms, 'glue' or illicit drugs in search of a 'buzz'. Fortunately most episodes cause relatively little harm although this is not always predictable in the early stages. Others result in serious illness and death.

Obviously it would be quite unreasonable to expect doctors to know the ingredients or effects of all the substances that might be swallowed, inhaled or spilt on the skin or how the resulting problems should be managed. Appreciation of these difficulties and awareness that the incidence of poisoning was rising rapidly led a Health Services committee in 1962 to recommend the establishment of national poisons information centres. The English and Scottish services started operating in September 1963 and were soon followed by others in Wales and Northern Ireland. They are basically telephone answering services to give doctors concise information on the features and treatment of poisoning. Over the years information has been collected on some ten thousand products and stored in a paper file system. The ingredients, possible fatal dose and features and treatment of poisoning are typed on one side of a standard sheet of paper and filed alphabetically according to product name in large ledgers.

Not surprisingly the system has become unwieldy. There is considerable duplication of information to minimise cross referencing and comprehensive updating has become extremely difficult because there is no index of products according to toxic ingredient or effect. Moreover the personnel answering calls in the first instance includes information officers, secretaries, nurses and doctors none of whom is necessarily expert in poisoning, and it is difficult using a paper system to indicate the urgent or important points which they should stress when reading the information.

Initially we intended to store our data in a microcomputer for in-house use but at the last moment, early in 1980, we were introduced to viewdata. This technology was new to medicine but its potential was immediately apparent -- it was simple to use, attractive, could cross-reference with ease, and colour and flashing words could be used to convey urgency. About 84 per cent of enquiries were already being satisfied by reading from the paper files without reference to doctors and installation of relatively inexpensive, easy-to-use terminals, especially in busy hospital emergency departments, would allow doctors to access the data directly and reduce the need for Bureau staff to answer the telephone.

Before setting up the viewdata data base we had to identify groups of products containing the same toxic substance or having the same toxic effect (e.g. all the painkillers containing aspirin, weedkillers containing paraquat, etc.) and generate a unique (page) number for each product since we were changing from a system which was indexed alphabetically to one which was numeric. This was done using a microcomputer but was bedevilled by inconsistencies in the use of spaces, hyphens and commas in the spelling of chemical names over the years. Considerable experimentation with different colours and screen lay-outs was also undertaken to obtain maximum clarity of presentation. Data transfer then began. The first frame on each product in a group contains its name, ingredients (provided they are not confidential) and potentially fatal amount but all link to one viewdata page which gives the features and treatment of poisoning. In fact it transpired that more than half the products in the data base could be linked to about 200 pages on features and treatment. Updating is thereby facilitated and more likely to be complete. The project was completed within the period of funding (two years) and within its budget (£82,500).

Viewdata has come up to our expectations. We believe it is a much better way of conveying basic information than having it read over the telephone from an archaic paper system by a non-expert. Language and communication problems are eliminated and doctors can take as much time as they require to assimilate the data. Already all but one of Britain's poisons information centres, 17 hospitals (including accident and emergency departments, intensive care units and clinical pharmacology departments) and 18 general practices have terminals. Moreover seven foreign countries have expressed interest in buying the data base. Computerisation has also made it much easier to keep information up-to-date.

DARTMOUTH COLLEGE REVOLUTIONIZING HUMANITIES RESEARCH WITH COMPUTER PROJECT ON DANTE

Robert P. Graham, Jr.
Dartmouth College News
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Hanover, NH 03755

Six hundred and fifty years' accumulation of commentary on the great literary classic the "Divine Comedy" written by Dante Alighieri (1265-1321) -- much of it scattered across two continents in libraries and private collections -- will find new accessibility and exposure in the 20th century thanks to projects at Dartmouth College.

No other secular work in any culture has attracted such an unbroken tradition of line-by-line commentary as has Dante's 14th century poem. And only a few libraries in the world contain all of even the most significant commentaries.

In an endeavor entitled The Dartmouth Dante Project, the National Endowment for the Humanities (NEH) has awarded Dartmouth $120,000 plus $60,000 in matching funds to produce a computerized data base equivalent to 100,000 typed pages of the most significant commentaries. The project is expected to produce an important research tool for humanistic study and would not have been possible without the computer.

In a second complementary project, NEH has awarded Dartmouth $237,867 for two years to offer six-week summer institutes for undergraduate teachers featuring intensive study of Dante and his "Divine Comedy." The "Divine Comedy" increasingly is being taught in undergraduate humanities courses across the country, but most of the teachers leading these courses are not Dante specialists and are not familiar with important recent research which has radically revised traditional views of Dante's work.

Dante's remarkable work, "Divine Comedy," recounting in three stages the tale of his journey through hell ("Inferno"), purgatory ("Purgatorio") and heaven ("Paradiso"), was written as if it were an extension of the Bible. It is considered a magnificent synthesis of human knowledge in the 14th century. Dante also broke new ground by writing his masterpiece of 14,000 lines in vernacular Italian instead of the more scholarly Latin, thereby helping to establish Italian as the literary language of his country.

Almost immediately after his death in 1321, scholars were drawn to conduct a line-by-line examination of his voluminous text, beginning with his sons Iacopo and Pietro, as well as Giovanni Boccaccio, a 14th century poet and storyteller who held the first chair of Dante studies in Florence. Other commentators have included 19th century King John of Saxony and American poet Henry Wadsworth Longfellow.

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Newsletter – *Continued from page 26*

The commentary tradition has continued to the present so that currently there are about 125 completed works of commentary in existence. But therein lies the chief problem. To do a thorough review of commentaries on a single point may well require travel to distant libraries or weeks of waiting for interlibrary loans. For example, it would take two full days of work to review Cornell University's renowned holdings of commentary on a single verse of Dante's poem. With access to Dartmouth's data base -- a collection of information organized especially for rapid search and retrieval -- such consultation would only take minutes. More importantly, many a closed door to understanding certain passages may be re-opened when thorough review of all significant commentaries is possible, an exciting research possibility.

For example, it would take two full days of work to review Cornell University's renowned holdings of commentary on a single verse of Dante's poem. With access to Dartmouth's data base -- a collection of information organized especially for rapid search and retrieval -- such consultation would only take minutes. More importantly, many a closed door to understanding certain passages may be re-opened when thorough review of all significant commentaries is possible, an exciting research possibility.

The project will provide easy on-screen instructions and sophisticated index and

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McGhee – *Continued from page 14*

serious problems. First of all, they are stubborn, so it is difficult to get them to do what you want. Secondly, the fuel they run on is not very dense. Hay is harder to carry around than gasoline. Thirdly, 250 lb is not always enough, especially for a modern army. If you want to put a radar system on the top of a mountain, for example, it may be very difficult to break it down into 250 lb modules and the mule may throw a critical piece off his back. So the U.S. Army launched a project through the Defense Advanced Research Projects Agency (DARPA) in the second half of the 1960s to try to realize a new kind of vehicle. They did not get what they wanted but they did get some scientifically significant results.

I shall now talk about something that is a reality. This is a Swiss-manufactured machine called the Menzi Muck (possibly the name sounds better in Swiss). It has five legs, or maybe four legs and one arm, and like insects it exhibits limb specialization. You might think of it as a kind of mechanical praying mantis which happens to be interested in excavation. The rear portion of the machine is a very powerful arm capable of excavation or of cutting trees with a special tool. The back two legs are for mobility, so they have wheels associated with them. There is no power in those wheels, the power comes from the scoop. And in the middle, there is a pair of legs whose function is stabilization.

(continued in next issue)

Berkeley – *Continued from page 22*

ture may often be usefully imagined, studied, and tested by means of a model that is a convenient, small-scale reproduction of the proposed structure, provided the model reproduces approximately all the important features. A model may be static, or still; it may be dynamic, or moving, like a toy electric train. All models are incomplete; and all deductions from the behavior of working models are subject to the source of errors that the analogy may be deficient or incomplete.

Common everyday examples of models include:

- maps / such as a map of a town showing the location of all streets
- timetables / which show the sequence of stations along a railroad, and the times of scheduled trains
- tree-like networks / such as one which shows how water supply pipes come into a house, branch here and there, and have shut-off valves at certain points

Models are a good field for the application of computers, and simulation is a subject with extensive program languages, a host of professionals, and much packaged software. But most people do well with non-computer models that use maps, indexes, pencil and paper, and their minds. Ω

Union of Concerned Scientists – *Cont'd. from p 18*

We can prevent the world from becoming even less secure than it is today. The momentum behind the development of space weaponry may be strong and getting stronger, but it can be stopped. We can stop it. To do so, howver, we must speak up now. Ω

Games and Puzzles for Nimble Minds — and Computers

Neil Macdonald
Assistant Editor

It is fun to use one's mind, and it is fun to use the artificial mind of a computer. We publish here a variety of puzzles and problems, related in one way or another to computer game playing and computer puzzle solving, or to programming a computer to understand and use free and unconstrained natural language.

We hope these puzzles will entertain and challenge the readers of *Computers and People.*

NAYMANDIDGE

In this kind of puzzle an array of random or pseudo-random digits ("produced by Nature") has been subjected to a "definite systematic operation" ("chosen by Nature"). The problem ("which Man is faced with") is to figure out what was Nature's operation.

A "definite systematic operation" meets the following requirements: the operation must be performed on all the digits of a definite class which can be designated; the result must display some kind of evident, systematic, rational order and completely remove some kind of randomness; the operation must be expressible in not more than four English words. (But Man can use more words to express the solution and still win.)

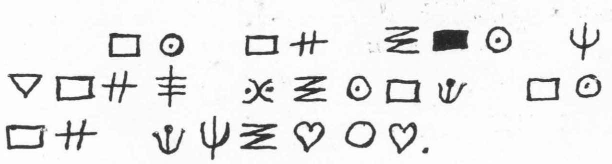
NAYMANDIDGE 8503

8	8	9	7	4	8	6	9	3	2	2	1	3	2	6	6	3	5	6	7
4	2	3	4	7	4	9	1	8	1	9	4	5	0	7	2	6	5	5	5
6	9	3	3	5	7	8	6	6	6	7	5	7	8	5	3	8	3	2	5
0	5	0	2	3	6	3	3	7	7	9	3	1	5	2	9	4	0	6	7
6	4	4	0	9	4	5	0	8	8	9	6	1	4	4	1	7	7	1	8
1	2	4	8	0	4	0	5	4	5	7	2	6	8	6	1	3	7	3	7
3	1	1	0	1	1	6	8	6	0	4	6	5	8	3	7	6	2	4	3
8	8	2	2	3	6	0	4	7	8	4	4	2	0	8	5	7	9	2	3
8	6	8	0	1	2	0	1	2	5	3	6	0	3	0	8	8	7	3	3
5	3	0	7	1	0	5	0	9	0	0	2	0	0	4	0	0	8	0	4

MAXIMDIDGE

In this kind of puzzle, a maxim (common saying, proverb, some good advice, etc.) using 14 or fewer different letters is enciphered (using a simple substitution cipher) into the 10 decimal digits or equivalent signs, plus a few more signs. To compress any extra letters into the set of signs, the encipherer may use puns, minor misspellings, equivalents (like CS or KS for X), etc. But the spaces between words are kept.

MAXIMDIDGE 8503



NUMBLES

A "numble" is an arithmetical problem in which: digits have been replaced by capital letters; and there are two messages, one which can be read right away, and a second one in the digit cipher. The problem is to solve for the digits. Each capital letter in the arithmetical problem stands for just one digit 0 to 9. A digit may be represented by more than one letter. The second message, expressed in numerical digits, is to be translated (using the same key) into letters so that it may be read; but the spelling may use puns or deliberate (but evident) misspellings, or may be otherwise irregular, to discourage cryptanalytic methods of deciphering.

NUMBLE 8503

```
              T H E Y
            * K N O W
            ---------
            T T A S H
          A W Y H O
        A N A W T
        N K Y O
      ---------------
      = W K S E N O H
```

1095X X948Y 8782103

Our thanks to the following persons for sending us solutions: T.P. Finn, Indianapolis, IN – Numble 8501, Maximdidge 8501; Steven Shulman, Maximdidge 8501, Naymandidge 8501, Numble 8501.

SOLUTIONS

MAXIMDIDGE 8501: It is better to be sure than sorry.
NUMBLE 8501: Your son is as you are.
NAYMANDIDGE 8501: Make diagonal of 4's.

NAYMANDIDGE 8501

9	6	8	0	0	1	2	4	6	7	6	3	6	5	0	7	2	6	4	3
8	3	8	4	1	1	2	5	5	2	2	2	2	3	8	4	4	9	4	7
0	3	7	9	8	2	7	5	2	8	5	6	3	4	4	3	6	4	9	3
6	0	5	5	0	8	5	9	4	4	2	3	4	0	2	4	1	3	9	5
5	0	3	6	8	2	6	9	3	7	4	6	5	4	0	5	9	1	2	8
2	7	1	1	1	8	1	4	4	5	5	2	0	4	0	6	0	7	2	5
8	4	8	4	5	6	4	0	3	3	3	6	3	8	3	5	6	9	4	2
2	0	5	8	4	5	6	8	5	3	4	4	8	5	9	6	4	2	2	7
2	7	4	6	7	3	5	9	0	1	9	9	8	1	6	5	8	1	7	8
4	2	0	7	2	8	8	6	4	8	3	0	2	2	1	6	1	2	7	2