NEW APPLICATION OF LASER TECHNOLOGY

S. Korepanov, TASS correspondent specially for Sovietskaya Rossia

This time I saw the national television programme on a 12 square metre screen in a laboratory of the Physical Institute of the USSR Academy of Sciences (Russian abbreviation FIAN). When light was switched on, I saw the familiar kinescope tube instead of a cine-projector. But unlike in a TV set a laser beam operated here. In the butt-end of the installation the thick glass of three symmetrical screens glistened.

"The brightness of the glow of the laser-based kinescope is 100,000 times higher than that of a conventional television kinescope," said Alexander Nasibov, D. Sc. (Techn.), head of a sector at the Physical Institute. "Each of the three screens gives its own colour -- blue, red and green. If one unites them, one can obtain a colour image. Nevertheless, we have decided to go further: to create an installation in which a colour image would be obtained with the aid of a single kinescope.

"Our device reconciles two types of art -- cinema and television the differences between which are associated with different recording methods. In cine-art an image is recorded on a silver photographic film, while in television an electronic record is made. The use of videoprojectors of high light power will enable one to make traditional cinema electronic."

"What are its advantages over conventional movies?"

"It is possible to substitute expensive motion-picture film by video. The switch-over to electronic recording of films requires the setting up of the centre of the storage of videofilms and the organizing of systems of their transfer to users. Such a scheme of obtaining information from the main computing centre to display screens has been established in many leading research institutions of this country. But we use not display units but screens of laser-based television sets or, as we have called them, quantoscopes."

The invention made by scientists of FIAN has enabled our country to take advanced positions in the world in the field of laser-based television. The quantoscope has been patented in the United States, Britain, Austria, Italy, France, West Germany and other countries. But it is not enough to invent quantoscopes. It is necessary to make them. The first pilot-commercial samples have been manufactured. The next stage is to launch them into serial production. The quantoscope has opened vast prospects for the theatre.

"The conventionalities of the theatre are associated primarily with the limited possibilities of the stage," said Gennady Yudenich, Chief Art Director of the Moscow Experimental Drama Theatre. "Dresses, scenery and even the curtain are attributes which serve the single aim -- to produce the illusion of the reality of the action taking place on the stage. The future of the theatre lies in three-dimensional television by means of which we shall be able to create a multi-faceted living nature which is seen in films and on television."

In a hall of Yusupov's former residence in Bolshoi Kharitonyevsky Lane in Moscow I found myself in a fantastic theatre of the 21st century. A performance about the Baikal-Amur Mainline (BAM) was given. A helicopter was chattering over my head. It seemed that if I stretched my hand I would touch a majestic cedar. The taiga unfolded -- machines were humming and high crane booms were moving. The main character of the performance was among construction workers. The screen was switched off, and the "movie" hero descended on to the stage. It was hard to understand straight away where the movie ended and where the theatre began.

So far this is only an experiment. Although many of the technological units of the future polyphonic drama theatre are still on the drawing boards in scientists' laboratories, the theatre is already preparing for mastering them. The theatre's staff now includes such new specialists as photo, television and cine-engineers, programmers, etc.

In the polyphonic theatre, as I was told by FIAN scientists, tests will be conducted and experience in handling electronic movies will be acquired.

"It is necessary to elaborate a comprehensive research and technological programme for the development of laser-based television," Alexander Nasibov said. "Quantoscopes turned out by industry can be used even now for showing films in cinemas with screens of up to 100 square metres. But even this is not the limit: laboratory installations will make it possible to obtain still larger screen images."

The scientist believes that the USSR State Committee for Cinematography and the USSR State Committee for Science and Technology should take part in the implementation of the comprehensive laser television programme.

(Sovetskaya Rossia, August 5. In full)

AN ICEBERG IN TOW

UN experts regard the Soviet project for supplying the Arabian Peninsula with water as the most acceptable and safe

For several decades researchers have been attacking the problem of supplying the Arabian Peninsula and the Horn of Africa countries with water. A great variety of projects has been suggested - one more fantastic than another. Finally the most realistic of them has proved to be the variant of... transporting icebergs from Antarctica. Several countries, the USSR is among them, have offered their methods of delivering ice mountains. UN expert Yuri Bogomolov, Cand.Sc. (Geology and Mineralogy), has been charged with the preparation of the Soviet project. Recently he returned from the Yemen Arab Republic where together with specialists of that country he studied the problem of water supply to the region.

"So far they have been trying to solve the water problem by traditional methods here," he says. "But, as experience shows, these methods do not give the necessary effect. On the Arabian Peninsula water that would lie directly on the surface is not available for a large part of the year. Extracting it from great depths is cost prohibitive; installations for desalination of sea water are also very costly - even for the rich oil-producing countries. In Kuwait, for example, such an installation provides the population mainly with drinking water, it is not used for irrigation. Meanwhile, the climate is becoming ever more arid..."

Question: And Antarctic icebergs have proved the only way out?

Answer: The lowest-cost, at least.

Question: What makes the Soviet project distinct from others?

Answer: It offers the cheapest way of carrying out all operations. This has been mainly achieved thanks to an original method of melting an iceberg and some technical innovations in transporting it. You understand that taking an iceberg across the sea is a unique experiment. Before handling this task, a comprehensive study of the situation has to be made, doing calculations and finding ways to guarantee safety. "Quick-fix" attempts have already been made, but they have failed - the iceberg simply overturned and its transportation had to be abandoned.

Question: Really, an iceberg is something huge, dangerous, isn't it?

Answer: Well, we won't touch very big icebergs. Such as, for example, larger than Belgium or Holland in area. Though such proposals have been made. They proved economically unfeasible. Suffice it to say that transferring such an iceberg (the French project) would cost over half a billion dollars.

The Soviet project will handle medium-sized icebergs. Five hundred meters long, three hundred wide, thirty high. The submerged part of such a "baby" goes down for 200 metres. It, of course, will thaw partly while en route, only a third will reach Arabia. Nevertheless the stocks of fresh water in this remaining part are still huge: about one tenth of a cubic kilometre, or 100 billion litres.

Question: Please say a few words on how the delivery of an iceberg to Arabia itself will proceed.

Answer: Satellites will help find a suitably-sized iceberg off the shores of Antarctica. Then several remote-controlled automatic ships will take them across the Indian Ocean to the shores of Arabia... The "roaring" 40th parallel, warm underwater currents will have to be passed. The most important thing is to keep during transportation the layer of cold water forming beneath the iceberg and protecting it from thawing and overturning. By the way, it was fairly hard to figure out the optimal speed at which to keep this layer intact. We had to do a lot of thinking on the models...

And so the iceberg finally arrives at its destination - the Bay of Aden. With convenient approaches to the shore, this is the most suitable place for its"processing." The iceberg will be "anchored" and begin to thaw under the rays of the hot tropical sun. Thawing will last for about a month, and during this time new ice mountains will be driven from Antarctica. Via special water supply lines the precious liquid will go to the entire peninsula.

In other words, a new undrying river, representing about one-twentieth of the Volga in volume, can be created by man for the agricultural and industrial needs of the countries of the Arabian Peninsula.

Transcript by V.Harlamov.

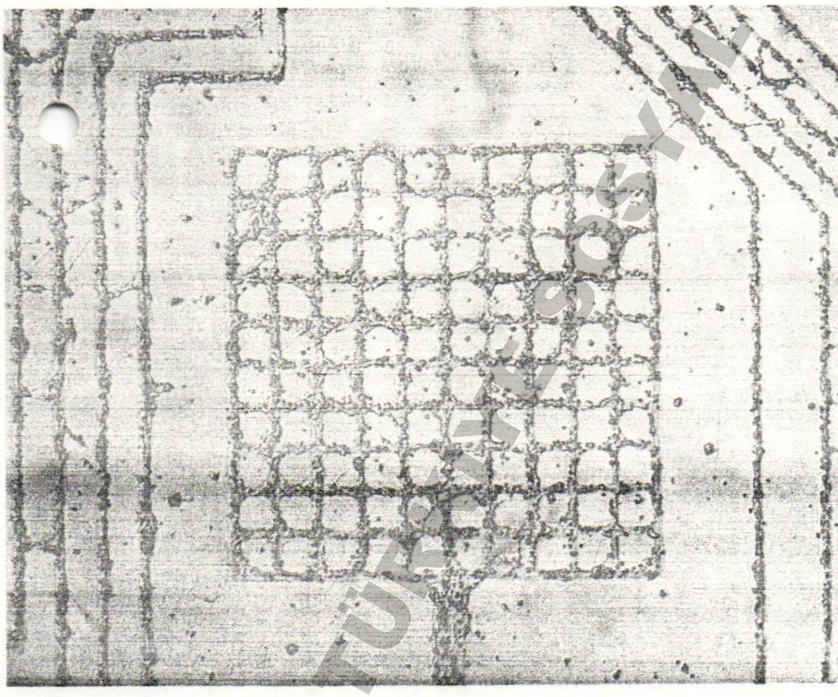
(*Trud*, June 4.In full.)

HOW TO REVIVE U.S. HIGH TECH

Can anything be done about America's slipping technological lead? You bet, says Simon Ramo, the scientist-turned-entrepreneur who founded two FORTUNE 500 companies.

Simon Ramo—the Ramo in Bunker-Ramo, a computer venture, and the "R" in TRW, the giant defense electronics company—has advised Presidents and served on the boards of corporations and universities. Throughout a long and productive career that began in 1936 at General Electric, Ramo, who will be 75 in May, has followed closely the development of American technology and of the industries that depend on it. From that perspective, he concludes that the U.S. is losing the clear technological lead it enjoyed two decades ago and therefore faces an uncertain future.

In the second of two excerpts from his book The Business of Science: Winning and Losing in the High-Tech Age, *to be published in June, Ramo considers why the U.S. position in technology has weakened and suggests how a new emphasis on entrepreneurship—a quality that the Japanese, for example, value less than Americans do—could help strengthen it.*



AT&T Bell Labs researchers are studying interactions of mouse neurons arranged on a silicon grid. Eventually, such work may lead to the biocomputer Ramo foresees.

IN THE DECADES JUST AHEAD, we will probably win more medals in the world technology Olympics than any other country. That is because we have the fortunate combination of a strong economy, a broadly developed infrastructure, and considerable natural resources. The competition to consider, however, is not from any single nation but from the totality of them. It seems safe to predict that America will have a decreasing fraction of the world's engineers and that other nations on average will back up their engineers with resources comparable with those we can make available. By the year 2000 four out of five technological breakthroughs are likely to originate outside the U.S. The challenge may be not how to keep our leading technology from other countries, but how to acquire theirs.

How could this have happened? How could the U.S. have changed so quickly from being preeminent in technology to being a country with diminished future prospects? Is our system, from goal setting to implementation, which has never been perfect, no longer suited to the nature of an ever more technological society? Does free enterprise lack strength or applicability? Could the government do more to improve the competitive position of the U.S.? Are Americans so poorly informed that they fail to demand changes they should realize are needed?

There is plenty of blame to go around. Parents? The parents of American schoolchildren have spent billions on computer games (useful, aside from entertainment, only for developing quick eye-hand coordination, not for learning either mathematics or computer science), but they have steadily voted down taxes to provide more funds to pay math and science teachers. The federal government? In 1981 the Reagan Administration suggested that the Department of Education should be abolished. Industry? In the 1980s, the largest American technological corporations conspicuously lowered their interest in striving for major breakthroughs through high-risk research and development projects. Instead, they spent to acquire nontechnological operations such as financial services companies.

The free market should automatically correct some of

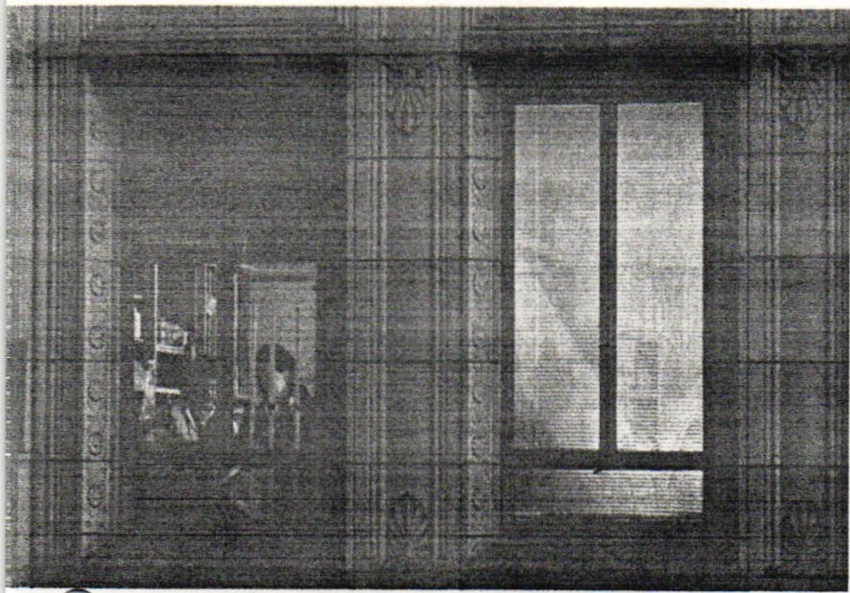
DAVID STRICK—ONYX

If he were starting out again, Ramo says, he would find irresistible opportunities in the possible merger of biology and computer science.

our shortcomings, given time, and nothing could be easier than to let that happen. If America has too few math teachers or too few computer scientists, then salaries will rise in those fields. The news of these opportunities will get around, and young people and their parents will sacrifice to prepare to fill the openings. Technological corporations, finding they are losing out to foreign competitors, will eventually cut dividends and increase R&D budgets in order to improve their products and manufacturing technology and win back the markets they have lost. If there are too few college graduates in the most important fields, industry will ultimately find ways to help the universities produce more of them.

By themselves, however, these forces will be utterly inadequate. The free market may produce more computer scientists in a decade, but five decades may pass before the market persuades us to pay high school math teachers enough to ensure an adequate supply. In our country the citizens have to perceive the seriousness of an important problem before the government will take action. For strong public pressure to form, the situation must become so bad that it is widely seen as intolerable. Hence, the pragmatic American formula for progress is that things have to get much worse before they can get better. Facetious as it may sound, we can be optimistic about our eventual success leading to a superior technological society, because things are now deteriorating so rapidly. Take education in math as one example.

Our inferiority in the teaching of math to our youngsters has finally started to hit the front pages. The problem has become that bad. Parents are learning for the first time from newspaper headlines that, in standard (identical) ex-



…eeti… national …eed in science …ducation: With …overnment …nding, …ndergraduates at …arnegie Mellon do …asic research in …iology.

ams given to children in most non-Communist nations, U.S. elementary and high school students scored among the lowest of the industrialized nations. These astounding results are not merely news reports. They are the subject of serious editorial commentary.

While the media were parading these results, I found occasion, as a member of the governing board of the National Science Foundation, to bring up the subject frequently with Senators and Representatives in Washington. They, too, were becoming aware of our outrageously low math scores and were amazed that this could have happened without our noticing and taking action. They pledged to look favorably on appropriate federal government activity designed to change the situation. This new congressional attitude, and the growing public appreciation of the problem on which that attitude is based, has enabled the National Science Foundation to get Administration approval for innovative programs in primary and secondary education. Congressional funding has begun to follow. New programs costing tens of millions of dollars per year are now slated to rise to the $100 million level. Things have become so unacceptable that we are finally moving.

> Soichiro Honda built his automobile company even as the establishment, he told me several times, put severe pressure on him to stick to motorcycles.

Industry is awakening as well. For example, David Packard, chairman of Hewlett-Packard, has led White House–sponsored studies of shortcomings in our university education. Those studies have influenced the projects and budgets of the National Science Foundation, leading to joint government-industry programs to substantially improve facilities and equipment used in undergraduate education.

How can the United States prosper as future success becomes ever more dependent on technological superiority? How can we win in a world in which so many nations are competing on a highly sophisticated level? Assuming that we preserve our national security, how do we also preserve, and preferably enhance, our standard of living? As a nation, we can't raise our average personal income by shifting a constant total of assets around among our own people. Nor can we count on discovering huge deposits of gold, oil, or diamonds on our land. The sure way for the U.S. to raise its living standards is to excel in technology. Technology can be applied to increase the resources of a nation, to generate wealth that would not exist if the technology were not employed.

TECHNOLOGY IS A TOOL that can multiply the effectiveness and hence the worth of time and work. Technology makes it possible to manufacture for our needs with less effort and less dissipation of valuable natural resources. (A pound of glass fiber-optic cable, made mainly of sand, can carry as much information as a ton of copper. A $10 computer chip, its raw materials constituting about 1% of its cost, can make calculations in a few minutes that would require thousands of hours of effort by a human calculator.) Technological breakthroughs can lead to substitutes for resources that are in diminishing supply and to novel products that merit the investment required to develop them.

Is there a natural strategy for the United States to achieve technological superiority? I am certain there is. It is to foster technological entrepreneurship. We produce business entrepreneurs at an enormous rate, but only a small fraction are involved with technology. Yet technological entrepreneuring has been the main force behind our industrial development from the beginning. It is not today at its full potential. We can and should magnify it.

In Japan, it is rare for an entrepreneurial team to set out to raise venture capital backing to establish a fresh technological corporation. Americans, on the other hand, often leave established organizations to form new companies. Anyone in Japan who quits to start a new company is considered an eccentric, not a hero. The American culture, in contrast, admires such an achievement. "Japan Inc.," a term used by Americans to sum up the Japanese nation's highly integrated planning and the Japanese people's deep feeling for their national interest, does not include the concept of entrepreneurship. The occasional Japanese entrepreneur succeeds not because of encouragement from the system, but despite opposition. Soichiro Honda, for example, built his automobile company even as the government-business establishment, so he told me several times, put severe pressure on him not to; he was virtually directed to stick to motorcycles.

Our answer to aggressive competition from Japan or other nations should be to foster entrepreneurship. But what about our existing large technological corporations, which employ most of the engineers in America and produce most of the goods that the nation needs and that can be sold overseas? What is their role in our economic growth and in competitive international trade? Simply put, they will continue to be the core of our technological strength, and we must do nothing to impair their health. Those companies are the result of the entrepreneurship that launched them decades ago. Today's successful new companies will become mature major industrial units in the future. But even if present large companies contribute as much as we can possibly expect them to, that will not guarantee U.S. technological superiority, because certain inherent characteristics of big companies that account for their success also cause them to leave gaps, miss breakthroughs, and move too slowly. A steady, high birthrate of new technological entities is mandatory if the U.S. is to enjoy a competitive edge.

America's large technological companies have the capacity to carry on enough R&D to improve and replace their products, diversify to add scope and to maximize return on investment, handle giant projects, and employ enough experts to manufacture and market globally. But these strengths are not enough to guarantee our nation first place in international technology, because they are not unique to America. They are matched by the mammoth technological companies of Japan and Western Europe that are consistently aided by their governments, while the U.S. government helps only occasionally and sometimes hinders. Furthermore, for every strength of a large company, there is a weakness. The negatives of big organizations, I am convinced, are natural, hence extremely difficult to counter.

It is harder to spur and exploit high creativity in an old and large organization than in a new, small one. A long-established unit almost certainly will have developed a substantial bureaucracy, and bureaucracy is the natural enemy of creativity. Sometimes a big company, seeking to relieve its best innovators of the burdens of the company's own red tape, will set up a team outside its regular bureaucracy and allow it to innovate in isolation. But this does not make the activity entrepreneurial. It also does not always make it successful. An entrepreneur is one who takes full responsibility for an effort, standing to gain greatly if it succeeds or be penalized severely, financially and otherwise, if it fails. A recent study showed that in the last two decades almost every large technological corporation has tried setting up small startups outside its organizational control system—and almost all failed.

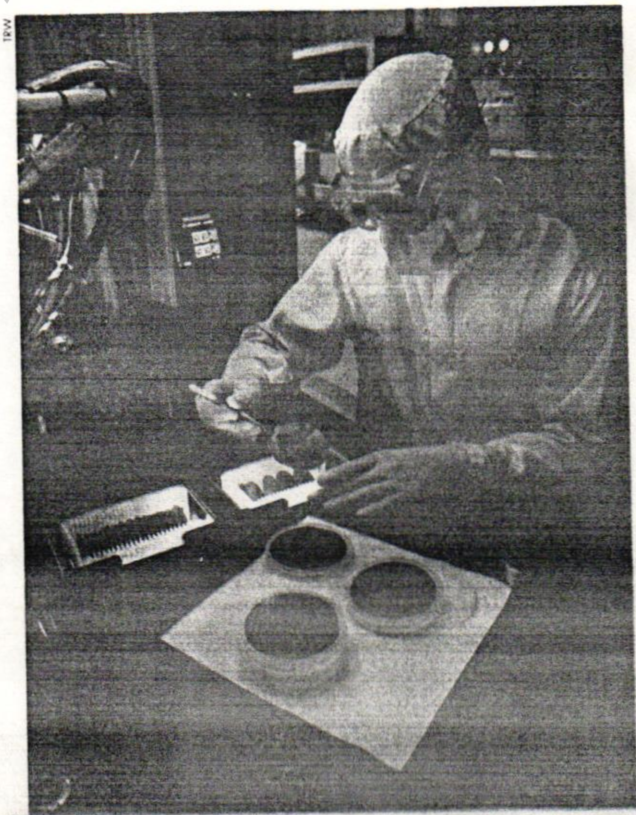
AS LARGE CORPORATIONS become giants, their managements often miss critical trends and technological breakthroughs. General Electric did not notice the beginning of the computer revolution, the most significant electrical-equipment development in the second half of our century. Its efforts to catch up were misguided, and they collapsed. IBM, today the world's foremost computer company, was not even in the electrical business when evidence first began to surface that electronic computers had become practical. Especially astonishing is that every one of IBM's present U.S. competitors in computers was nonexistent or would not have been categorized as an electrical company in the first half of the century.

Almost the same story applies to semiconductors, the basic building blocks for the computer revolution. Semiconductor products (such as the transistor and, more recently, the extremely large-scale integrated circuit on a chip) now are being produced by many companies. With the exception of AT&T, in whose Bell Laboratories the transistor was invented, all of today's major U.S. semiconductor producers were not yet in business or were not players in the electrical arena when the semiconductor era began. Regulatory restriction made it necessary for AT&T to offer its semiconductor technology to everyone for a modest license fee. This helped many new companies spring up, some of them headed by leading researchers who left Bell Laboratories to become entrepreneurs.

There are occasional exceptions, large technological corporations that have not missed opportunities in their fields, that have steadily shunned unrelated diversifications and acquisitions. Such companies—Hewlett-Packard, Boeing, Digital Equipment Corp., and TRW are examples—have consistently maintained high research and development budgets and applied their positive cash flow to develop new products and extend their activities within their fields of expertise. (If my including TRW appears self-serving, let it be noted that it is only in the past decade that TRW reached the size when its leadership might have been expected to follow the usual pattern of becoming an investment manager while simultaneously losing technological superiority. This was after the retirement of those of us who had originally assembled TRW and set its initial objectives and mode of operation. Credit accordingly belongs to TRW's present leadership.)

Granted that entrepreneurship and the


HEWLETT-PACKARD


TRW

While many big companies miss the boat in R&D, some are consistently strong. Two Ramo cites are Hewlett-Packard, where computer drives use new thin-film techniques (above), and TRW, which applies an innovative technology to high-frequency communications.

advance of technology are natural partners, what are the mechanisms for success? It is not enough to foster R&D and sit back, expecting technological breakthroughs and new companies to exploit them. We must help entrepreneurs find sources of capital. However, the anticipated returns on the investments must be competitive with other ways in which the capital might be employed.

In technological entrepreneuring, there are an infinite number of ways to lose. Fortunately, it is also possible to win. Most often, failure is due not to one shortcoming but to a combination. For instance, the product on which the fledgling company is based may have a fatal flaw. It may work but fail to fill any real market demand. Building a better mousetrap will not cause the world to beat a path to your door if there are no mice in the area, or the existing mousetrap is satisfactory and much cheaper, or your sensational trap requires bait which is unavailable. A new product may be excellent in all respects, but a competitor may come up with an even better one.

The product may have a fatal flaw. Building a better mousetrap will not cause the world to beat a path to your door if there are no mice in the area.

Some new companies fail because their founders assume, incorrectly, that a sure way to arrive at success is to ride this train of connected events: First, unearth a new scientific phenomenon; second, develop novel technology incorporating the new science; third, design a product based on the new technology that will meet a market need that will become apparent. This scenario is often referred to as science or technology push. While building a technologically oriented business sometimes works this way, market pull is a much better bet in laying plans for a new company. There the starting impetus is a need, a market that awaits the entrepreneur who, ahead of others, sees both the market opening and how new technology can meet it.

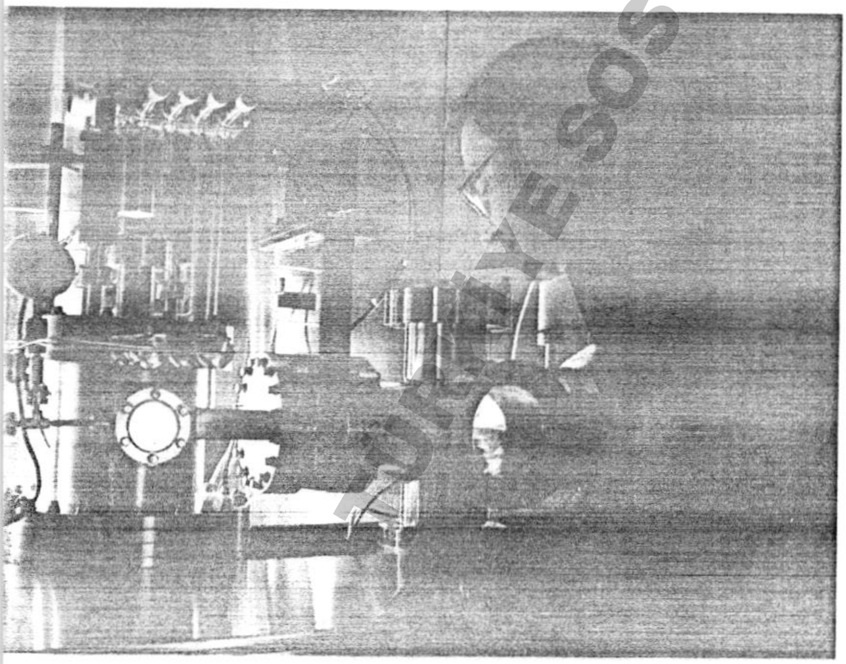
The true essentials for success in launching and operating a new high-technology company are common sense and imagination. Common sense will tell you that you had better do something different from the competition and do it well. The product or the technique for manufacturing or marketing it—one or two or all three of these—must entail novel elements. That requires imagination.

Every year, numerous textbooks and articles are published that offer formulas for success in technological entrepreneuring. Most I find to be one-third obvious, one-third motherhood, and one-third unproven theories concocted by people who write well but have never started or managed a successful company. They are largely unnecessary for a team that joins originality with practical realism.

In the course of several decades spent in forming and operating high-technology ventures, I have been involved personally with many startups. I have observed overly optimistic, inexperienced enthusiasts and wise, skeptical owls, the first group proposing and the second rejecting new business plans. I have seen many successes and as many failures and have participated in both bonanzas and busts. Unfortunately, many proposals are extremely difficult to classify as good or bad. The newer the technology, the more exciting may be the possibilities, yet the harder it may be to obtain useful market information.

IF I WERE TO AWAKEN tomorrow morning and discover myself to be far younger than when I went to bed, I would find numerous frontiers of high technology irresistible for another entrepreneurial adventure. Two fields, information technology (computer communications) and biotechnology (microbiology and genetic engineering), probably will lead the list of technology advances likely to stimulate great industrial expansion in the coming decades. What if a significant mating of these two frontier technologies were to occur—biocomputers? Why should we expect biocomputers to be enormously important? Note first that we have learned how to pack millions of semiconductor devices (similar in function to the neurons of the human brain) on a single silicon chip of fingernail size. These solid, metallic chips have made possible very cheap, reliable, small computers that can multiply two numbers in a billionth of a second, put thousands of names in alphabetical order with ease, switch connections a million times a second, and perform innumerable information processing tasks beyond the capability of *Homo sapiens*.

The human brain, the compact information handling machine—so uncompetitive with semiconductor chips for some information processing jobs—is superior to any computer so far built or presently designable for intellectual functions like creative thought, visual pattern recognition, and associative memory. One probable explanation for the difference is this: Each neuronlike device on a semiconductor chip has at most a few connections to adjacent devices. In contrast, the ten billion neurons of the brain are generously interconnected; hundreds and often thousands of



Bell Labs umnus, ntrepreneur orman Schumaker Emcore Corp. akes machines at coat miconductors th thin exotic ms.

connections run from a typical neuron to distant as well as nearby neurons. The interconnections among the brain's neurons doubtless provide the basis for the remarkable thought processes of the brain, which the man-made chips, despite their enormous switching and computing speed, cannot equal.

Meanwhile, frontier research in biology and chemistry is giving us the capability to produce complex molecules, both animate and inanimate, that are different from any that appear in nature. It is becoming possible to engineer matter to order at a molecular level. This will create a degree of microminiaturization in design that reaches far smaller dimensions than the elements of even the densest, very large-scale integrated circuits on a semiconductor chip.

> We will not maintain our economic strength if our citizenry are occupied mainly with suing each other or repairing each other's foreign autos.

The existence of the human brain proves that if the right biochemical molecules are formed with the right connections among them, the combination can provide the memory, logic, sorting, inferring, recognition, association, invention, learning, and other intellectual capabilities that our brains possess. Hence, some future computers will quite possibly be biochemical. When we attain the ability to create complex biochemical molecules interlinked in a pattern of our choosing, we will have opened up the potential of engineering a synthetic brain that might combine the best properties of the human brain with those of the largest, fastest semiconductor digital computer. The field is not properly labeled artificial intelligence, but rather ***superintelligence.***

LET US SHIFT AND EXAMINE a factor in world technology competition critical to the U.S.: manufacturing productivity. Against Japan quite generally, and in specific manufacturing fields in Germany and elsewhere, the U.S. is firmly entrenched in second or third place in manufacturing technology. This applies, for example, in two frontier fields, robotics and computer-controlled production. Our standard of living will go down if other countries win all the manufacturing technology races. We will not maintain our economic strength, even if we lead in scientific discoveries, if our business and citizenry are occupied mainly with selling each other insurance or shares of stock, taking in each other's laundry, suing each other, or repairing each other's foreign-made autos and appliances. We must bring advances in technology onto the factory floor.

The manufacturing technology field, I believe, can be particularly responsive to American entrepreneurship. Automation, whether handling production-scheduling information or the processing and movement of materials, requires a detailed understanding of the product, the process of manufacture, and the human components—the workers—involved. Quality control in manufacturing is attained both by designing for quality in the first place and by providing economical yet meticulous factory testing and inspection, much of it performed automatically by devices rather than people. To design and combine skillfully all the elements of a truly modern production activity is a challenging engineering task. Much analysis and invention is needed. The engineers employed by manufacturers to develop superior production technology will hold the keys to victory in our nation's bid to close the gap and excel again over other nations in manufacturing.

If controls, measurement devices, computers, fabrication machinery, and other hardware and software are worked out for one factory, they are generally useful elsewhere. Companies that improve their manufacturing skills are essentially uninterested, however, in providing their systems to others. If some of the engineers responsible for the advances possess the entrepreneurial spirit and put together a proper team, they will be able to obtain financial backing to start new corporations whose mission will be to offer production technology to a wide range of customers.

If we do alter America's pattern of decision-making, improve the way we determine priorities and goals, build the stature of our technology, probe the scientific frontiers aggressively, put the results to work quickly and efficiently, and even achieve world preeminence again in science and technology, will that solve all our problems? Unfortunately, the answer is no.

The business of science and technology is to discover the secrets of the universe and apply scientific and engineering skill to yield us security, prosperity, and health. Yet science and technology can never be more than tools. Poverty, disease, starvation, crime, overpopulation, ignorance, wars, and impairment of the environment cannot be cured by science and technology alone. That requires parallel social advance. The world's most serious unresolved issues are not science-technology ones; they are social, economic, and political. But those issues intersect, and science and technology are right plunk in the middle of every intersection—sometimes causing or exacerbating the problems, often offering possibilities for solution, and frequently providing opportunities that, if grasped, would enable civilization to rise to new, higher levels of achievement, satisfaction, and tranquillity. Whatever we ultimately are able to do to elevate the society will occur earlier and with greater success if our scientific and technological tools are many, sharp, versatile, and effective. Wise application of those tools should offer us a life that is steadily better as we progress, more slowly than we would like, toward one that is best. F

> If we do achieve world preeminence again in science and technology, will that solve all our problems? Unfortunately, the answer is no.

May 9, 1988

Nürnberger Nachrichten

Klimaforscher: Deichbau forcieren

Küsten in Gefahr

11.1.89 NN

Wärme läßt die Meere ansteigen

BONN (rtr) — Das Bundesforschungsministerium hat die norddeutschen Küstenländer aufgefordert, sich angesichts des drohenden Anstiegs der Weltmeere verstärkt Gedanken über den Küstenschutz zu machen.

Zum Auftakt einer Konferenz von Klimaforschern, sagte ein Sprecher des Riesenhuber-Ressorts, in den Niederlanden gebe es bereits Untersuchungen, die eine erhebliche Verbesserung bei den Deichanlagen nach sich gezogen hätten. Da eine Erwärmung der Atmosphäre durch den sogenannten Treibhauseffekt unvermeidbar erscheine, andererseits aber schon ein Temperaturanstieg um ein Grad Celsius die Meere um 65 Zentimeter steigen lasse, wäre eine Untersuchung der Konsequenzen auch für den bundesdeutschen Deichbau „sicher sinnvoll".

2.2.89

1988 war im Mittel das bisher wärmste Jahr auf dem blauen Planeten

Treibhaus „Erde" gibt Alarmzeichen

Umweltverschmutzung durch den Menschen die wahrscheinlichste Ursache

LONDON (dpa) — 1988 war das im Mittel wärmste Jahr auf der Erde, seit die Meteorologen vor rund 100 Jahren ihre statistischen Aufzeichnungen begannen. Wissenschaftler geben zu bedenken, daß die Entwicklung die Befürchtungen über den Treibhauseffekt, ausgelöst durch Luftverschmutzung, zu bestätigen scheint.

Die Meteorologen errechneten, daß die Temperatur im vergangenen Jahr weltweit um 0,34 Grad Celsius höher lagen als der Durchschnitt der Jahre 1949 bis 1979. Dabei sei seit 1900 ein deutlicher Trend nach oben zu beobachten. So lagen die sechs wärmsten Jahre des Jahrhunderts alle in den achtziger Jahren.

Es gebe jedoch noch keine wissenschaftlichen Beweise dafür, daß die Menschheit tatsächlich das Klima auf dem Planeten verändere. „Aber es ist die wahrscheinlichste Ursache", sagte Dr. Phil Jones vom Klimaforschungsinstitut der Universität von Ost-Anglia.

FORTUNE
MANAGING/COVER STORY

THE INNOVATORS

America's most imaginative companies are turning new ideas into big dollars. As restructuring threatens to slow growth, more managers need to learn how they do it. ■ *by Kenneth Labich*

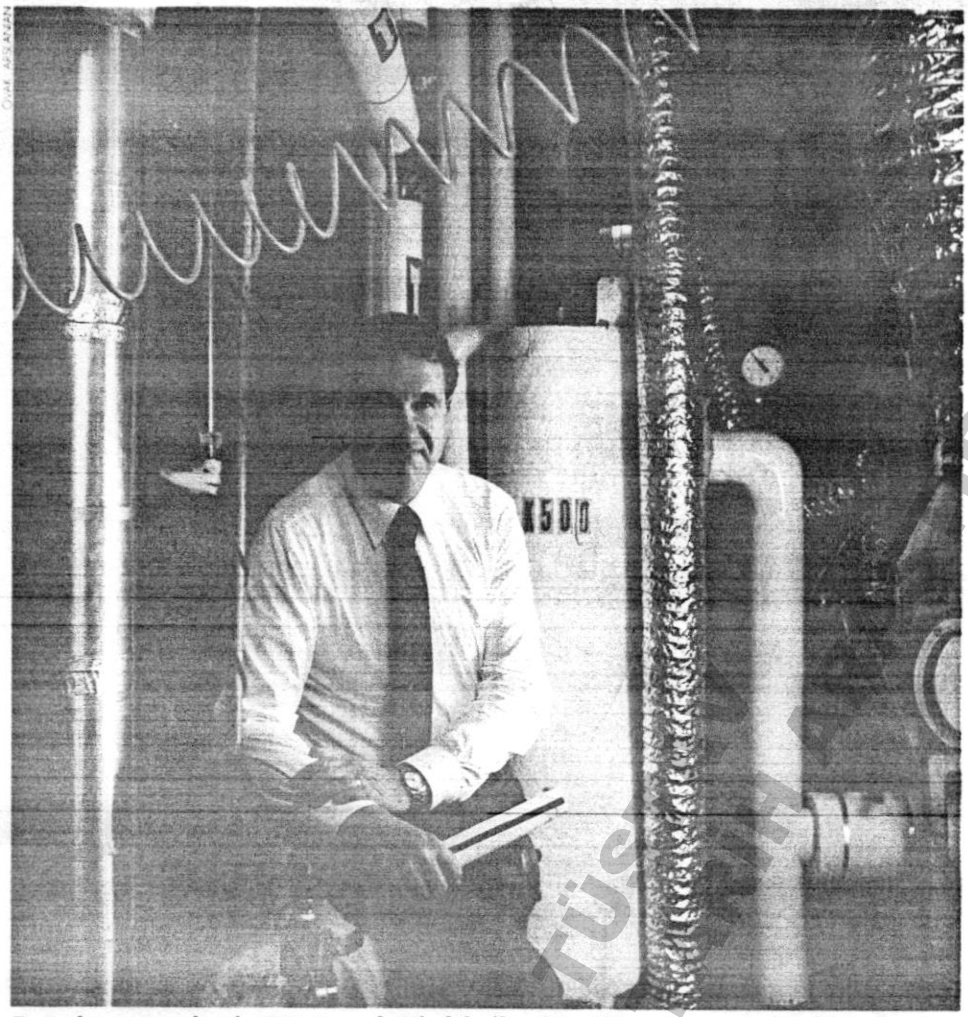
MY OLDER SON, now almost 7, was an exceedingly good-natured baby except at bedtime. He required two bulky diapers plus rubber pants to get through the night. He looked and, I suspect, felt quite silly, and even with all that swaddling sometimes suffered from fierce rashes. Poor Paul was simply born a bit too soon; Procter & Gamble and Kimberly-Clark, leaders in the $5-billion-a-year disposable-diaper market, have been advancing the art and turning out new products at a sizzling pace. My younger son, soon to be 2, tumbles cheerfully into his crib each night wearing a thin, superabsorbent little number able to soak up lakes of whatever. His bottom is rashless, a thing of beauty. Lucky David.

One way or another, thousands of product lines in every type of industry are being transformed. Innovating—creating new products, new services, new ways of turning out goods more cheaply—has become the most urgent concern of corporations everywhere. That is partly because restructuring has left many companies with a few core businesses that are solid but slow growing. Innovation is their best bet for revving things up. In addition, technology has forced the pace of change and sharply cut the effective lifetimes of all kinds of products. Long-playing records sold briskly for decades before cassette tapes posed a serious threat; now compact discs are shaking the market, and a new technology, digital audio tape, is on the way. Consumers respond more quickly than ever to the latest rage, so fat market shares can shrink dramatically in almost no time. Little wonder that innovation is this year's hot word among management consultants and the subject of several new management advice books.

U.S. innovation has long been the envy of world competitors, especially the Japanese. A list of important products introduced by American companies in just the past five years is breathtaking, ranging from Lotus 1-2-3 software to Chrysler minivans, from Abbott Laboratories' AIDS antibody test to Apple's Macintosh, from Kodak's lithium batteries to Merck's cholesterol-lowering drug, Mevacor. Last year more than 25% of 3M's worldwide sales were generated by products new to the market in the past five years. Johnson & Johnson produced a similar percentage of U.S. sales with freshly minted products. James Burke, J&J's innovation-minded chief credits his company's success at product development to close contact with customers and a corporate culture that encourages risk. "We want change here," says Burke. "I try to give people the feeling that it's okay to fail, that it's important to fail." That philosophy goes back a long way at J&J, as Burke well remembers (see box).

Innovation is often elusive, a process Gordon F. Brunner, a P&G senior vice president, calls "the marriage between what is needed and what is possible." Some top executives feel the urge to keep their hands on. Monsanto Chief Executive Richard Mahoney

Inventions that will bring in billions: Procter & Gamble's popular Ultra Pampers Plus (left) and Corning Glass Works' gossamer optical fiber (right)



To make a new plastic, GE's Joseph Wirth built a $1 million plant—then told the boss.

spent several days working in his company's biotechnology labs to understand some of the problems in developing products in that field. He not only increased his knowledge, but also showed the troops that he is serious about new products. Mahoney still keeps within arm's reach of his desk a folder that outlines the step-by-step progress of each research project under way.

Other innovative companies seem to thrive in part because top managers have proclaimed the hoary ideal of entrepreneurialism—and then proved that they mean it. Researchers at General Electric's plastics division labored on Ultem, a durable, heat-resistant plastic used in everything from circuit boards to auto parts, for over a decade without getting or seeking approval from corporate headquarters. They even built a $1 million pilot plant to turn out samples of the stuff before getting the nod from the top. Ultem sales are expected to reach $100 million annually by 1990.

REPORTER ASSOCIATE *H. John Steinbreder*

Any company hoping to get into the innovation race has to pay some stiff entry fees. New products, whether variations on old designs or entirely original, often require enormous capital expenditures for plant and equipment. Procter & Gamble has spent more than $500 million on new manufacturing equipment for its avant-garde diapers.

RESEARCH and development money also flows freely at innovative companies. Corning Glass Works, long known as a hotbed of innovation, spends about 5% of sales on R&D, above the average for U.S. industrial companies. "Scientists are a commodity—you buy ideas," says David Morse, a particularly inventive research manager at Corning. Spend enough in the labs, he says, and "even with average management, you are going to get some commercially viable notions." At GE, research expenses have risen 54% since 1982 to $1.2 billion. J&J spent $617 million on research last year, about 8% of sales and five times the amount spent ten years ago.

Smart managers seek innovation outside their companies as well. When Mahoney wanted to shift Monsanto's resources from bulk commodity chemical businesses into more *haut* science fields such as biotechnology a decade ago, he invested heavily in joint ventures with small startups like Genentech. He also planted seed money with research scientists at leading universities all over the world. Monsanto expects to see the first fruits of these expenditures in the 1990s, when such products as proteins to stimulate milk production in cows and reduce fat in pigs hit the world market.

To get the biggest bang for their research bucks, innovative companies go to great lengths to guide their development teams into areas with the greatest commercial potential. The pitfall to avoid is spending too much time and money on what are known at Monsanto as "trombone oil projects": You may turn out the best product available anywhere, but the entire world needs only about a pint of the stuff each year. "Focus, focus, focus," chants Mahoney. "Let them know you're in the research business not for the pursuit of knowledge but for the pursuit of product."

A key to focusing research projects is developing the commercial instincts of company scientists. It is not always easy to get a biophysicist, say, to start thinking in terms of market share or return on equity. Cash can get his attention. Monsanto hands out an annual $50,000 prize to the scientist or team of scientists who have come up with big commercial hits. Lester Krogh, 3M's vice president for R&D, says his company's efforts to get scientists attuned to commerce have been so successful that much of the hot talent gravitates to projects with the most obvious market appeal. "People in corporate research, who do the more theoretical work, are almost scorned around here at times because they aren't seen as knowing anything about business," says Krogh.

Most innovative companies provide their scientists with two possible ladders of advancement. They can stay in the lab and move up on the basis of scientific achievements, almost as they would in a university. Or they can move into management and head product development teams. When the system is working right, enough researchers choose each path so that good ideas and the people to channel them into specific products bubble to the surface with regularity.

The ideal employee, of course, is a highly inventive scientist with a firm grasp of the

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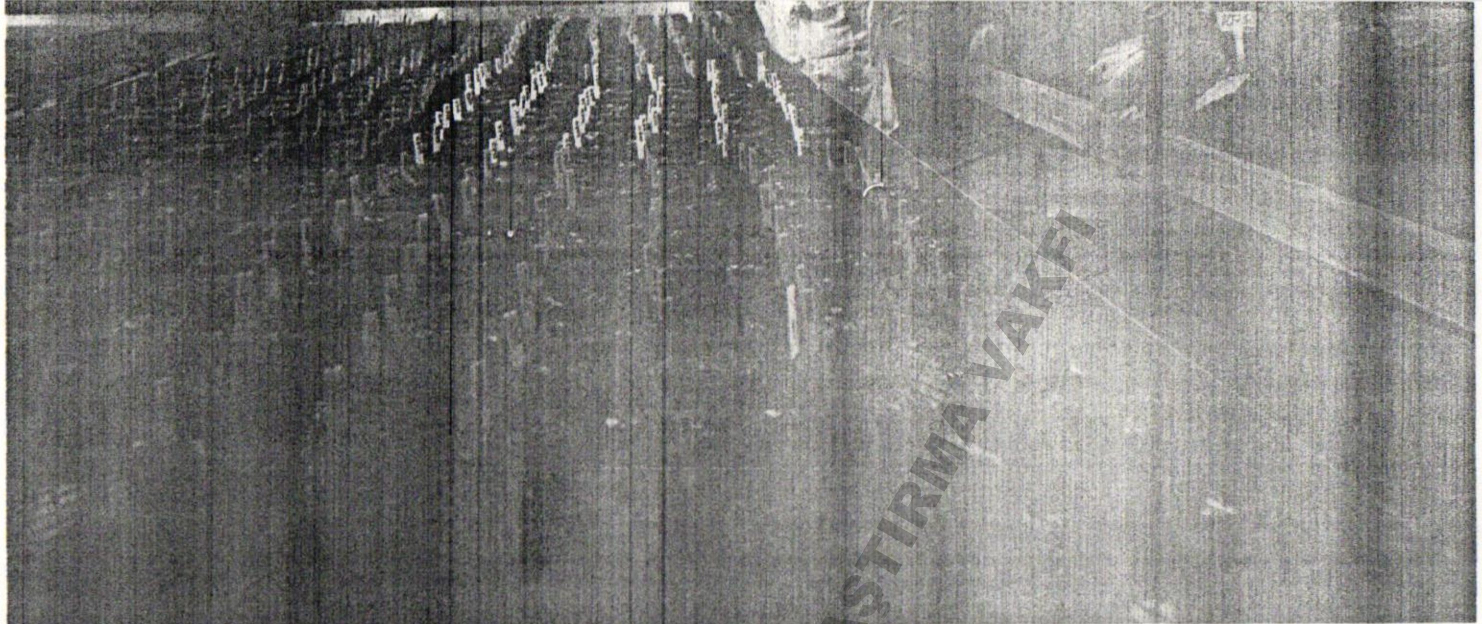


A Monsanto technician checks disease-resistant tobacco plants. The company's biotech finds include proteins to reduce fat in pigs.

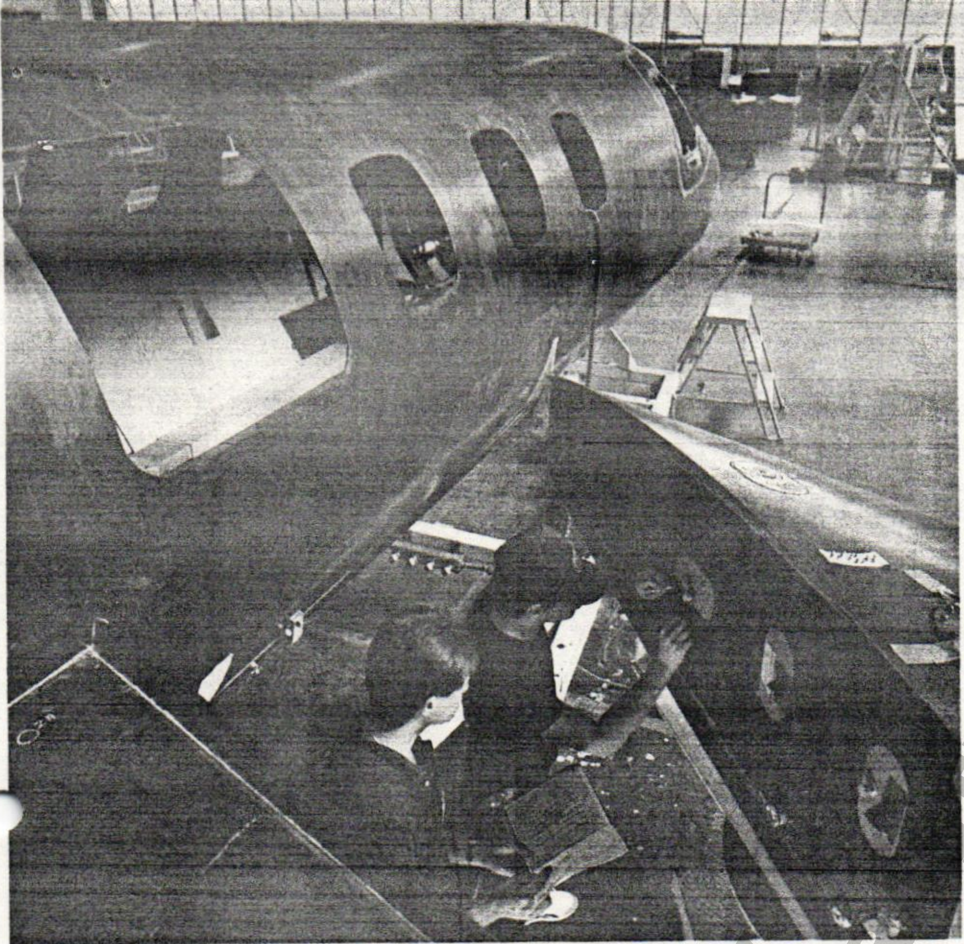
marketplace. Example: Corning's David Morse, 35. He is involved in fairly mundane administrative tasks, such as hiring new employees and hammering out budgets, but he also holds a doctorate in chemistry from MIT and still ponders arcane theories about the physical properties of glass and ceramics. A few years back his flights of fancy led him to a formula for glass with an especially porous surface. "I had just been thinking about surfaces, and this came up," he says. Morse's commercial instincts were honed well enough so that he soon realized this new glass might provide a physical anchor for various coatings, such as a layer of Teflon on the company's popular Visions line of cookware.

Morse, a shy, bespectacled man who looks very much the research scientist, knew the company had long hoped to introduce nonstick versions of the product, and he was convinced he had found the solution. He began tirelessly promoting his discovery—"I became obsessed with the product," he recalls—and eventually got top management of the consumer products division to take a look. Next came years of test-marketing and fiddling with the concept in the lab. The finished product should be rolling out shortly, and its potential for boosting sales of the Visions line is big. About 65% of the skillets sold in the U.S. are nonstick.

FEW THINGS HAMPER corporate innovation more than lack of communication and coordination between divisions. SmithKline Beckman, the Philadelphia pharmaceutical giant, is a champ at introducing new products, but the company's experience in developing a vaccine for hepatitis taught management some painful lessons. The vaccine, a breakthrough in treating certain forms of hepatitis, was discovered by company researchers in the early 1980s. But SmithKline marketers turned the idea down because the company did not normally sell vaccines in the U.S.

The scientists persisted, siphoning money from various projects to conduct clinical trials. Even after these tests succeeded, the marketers said no primarily because vaccines present serious risks of product-liability lawsuits. The researchers finally persuaded the company's international division, which already marketed vaccines, to give the product a try, and success was swift. SmithKline will sell about $50 million of the drug overseas this year and is finally seeking FDA approval—a two-year process. "Too bad they didn't listen to us a couple of years ago," says Martin Rosenberg, a SmithKline research vice president. "They would have a $100 million drug by now."

Innovative companies continually bring together the various divisions involved in product development. These contacts might be informal in the early stages of a project. Starting about five years ago, Xerox held a series of roundtable discussions and customer focus groups to find out what product planners, systems engineers, marketing people, manufacturing types, and others thought the next generation of duplicating machines



A cloth airplane: Imaginative designers at Beechcraft, a division of Raytheon, constructed a lightweight plane from graphite fabric impregnated with epoxy resins.

should be like. The company even brought in potential suppliers. "We want those vendors to see the insides of the machine, to really understand what it is we want them to make," says a chief engineer, William Drawe.

Lines of communication get busier when a project is far enough along to warrant a development team. In choosing members, it's usually smart to cast the net wide, beyond scientists, marketers, and manufacturing experts. Procter & Gamble, heavily reliant on products that must appear seductive on supermarket shelves, usually assigns a packaging engineer to a development group in the earliest stage. Most smart companies also make sure their patent lawyers are in the flow early. A successful patent strategy can make all the difference in a new product, and the complexities of patent law have increased nearly as fast as technical advances in many fields. A company's patent lawyers can protect the company's proprietary position without giving away too much in the application process. For instance, when GE's lawyers on the Ultem team determined that they could secure a "composition of matter" patent, which protects the material itself, the entire project made more sense. The lesser protection provided by a "process" patent, for example, often all but invites competitors to find alternative ways to produce a similar or identical product.

When all hands are really pulling together, the process of discovering a product and getting it out can seem almost effortless. Procter & Gamble's recent introduction of calcium-enriched Citrus Hill orange juice showed unusually close coordination between seemingly diverse divisions. Researchers in the health care unit, in the course of developing drugs to treat bone disease, had become aware of rapidly worsening calcium deficiencies among U.S. adults. One obvious remedy was to put calcium into the orange juice marketed by P&G's food and beverage division. The problem was how to make the mixture palatable. The answer came from a third division, laundry and detergents, which had long before learned how to "sequester," or suspend, calcium particles in liquid soap products.

EVERYONE BUT the janitors seems to have joined in Corning's effort to produce an antipollution device for automobiles. The process started in the early 1970s, when marketers from Corning were trying to sell General Motors on a new line of safety windshields. No sale there, but GM did express an urgent need for some kind of antipollution device because Congress seemed intent on applying the new Clean Air Act to automobiles. Corning's lawyers and lobbyists talked to everyone they could find—oil companies, auto manufacturers, chemical companies, even the legislation's champion, Senator Edmund Muskie—to determine whether a market was indeed looming. The answer came up yes.

Corning's scientists next began to look at the technical problems. At least four companies were working on diverse methods of trapping pollutants inside a catalytic converter. Corning's researchers favored a ceramic device honeycombed with hundreds of tiny chambers. They had discovered a material porous enough to do the job years before, but they had no clue how to produce the complex, relatively delicate converters in quantity. The answer came from a Corning engineer who developed a radical new extrusion process to turn out the devices to precise specifications. Says David Duke, Corning's vice chairman: "Up to the moment we decided to go with the project, there were people who said we were crazy, that the Clean Air Act was going to go away."

Corning's top executives are now very pleased they took that risk. Last year they sold about $150 million of the ceramic devices.

While the catalytic converter was a case of planned parenthood, happy accidents can take place when you have a lot of bright research scientists on the premises. The trick is recognizing the commercial possibilities of those accidents—and exploiting them. "You have to be alert to serendipity," says S. Allen Heininger, a Monsanto corporate vice president.

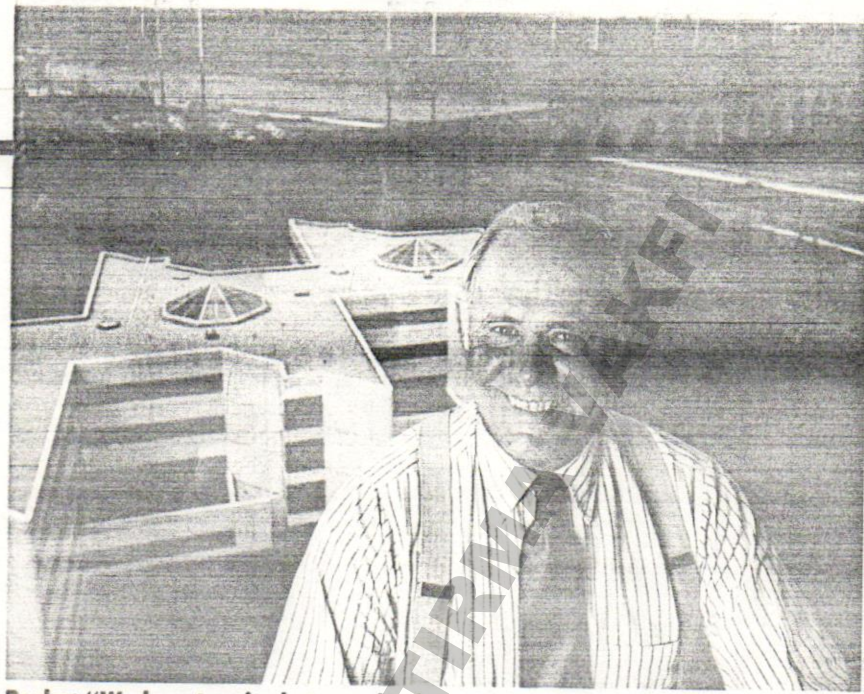
At companies where research employees think always of product, stories abound of scientists stumbling on big discoveries. An engineer at Raytheon was working on experimental radar equipment in a lab one day when he noticed that a chocolate bar in his shirt pocket had melted. Intrigued, he went out, bought some popcorn, and cooked that too. Raytheon eventually transformed that discovery into the first commercial microwave oven. A chemist at G.D. Searle spilled some experimental fluid one day and cleaned it up rather haphazardly. Later he licked his finger to turn the page of a book and was surprised by a sweet taste. The result was aspartame. A researcher at 3M dropped a beaker of industrial compound and noticed after several days that her sneaker had stayed clean where the drops had landed on it. Out of that spill came the highly successful ScotchGard fabric protector.

One of the toughest decisions a manager faces is whether to pull the plug on an expensive research project or faltering product line. Some rat holes should be abandoned. Monsanto spent millions trying to develop chemicals that regulate plant growth—imagine rows of corn ready for harvest at precisely the same time—but the researchers were never able to produce consistent results. Corning, which got into the light bulb business at the behest of Thomas Edison in 1880, pulled out in 1983 because of overwhelming competition. After years of market dominance, Raytheon has sharply scaled back microwave oven production because cheaper imports have stolen more than 90% of its market share. "They killed us," says Raytheon Chairman Thomas Phillips. "But don't feel sorry for us—we made a lot of money on this invention."

Some of the most valuable innovations don't create new markets for a company; they rescue old ones. Procter & Gamble's innovative skills have been continually tested in its diaper wars with Kimberly-Clark. P&G founded the disposable-diaper business in the early 1960s, starting with the Pampers brand, and later added a premium product called Luvs. As the market exploded through the 1970s, P&G's share in most years hovered near 70%.

KIMBERLY-CLARK mounted a challenge in the early 1980s with its Huggies brand. By concentrating its marketing effort on a single premium brand and introducing design changes such as elasticized waistbands, Kimberly-Clark seriously reduced P&G's dominance. The Pampers brand, perceived by consumers as a no-frills product, was hit especially hard. As the bloodletting continued into the mid-1980s the company urgently sought ways to improve the product and regain momentum. The stakes were sobering: Disposable diapers accounted for about $2 billion, or 15%, of P&G's revenues in 1985.

The break came when research scientists, looking for ways to cut down on diaper rashes, began working with polymers able to hold at least 1,000 times their weight in water. After much experimenting, researchers turned out test diapers that were not only far more absorbent but also much thinner than previous models. The scientists considered the latter quality largely coincidental; the polymers happened to work better when the core of the diaper was compressed. But mothers who came in to use the new diapers in P&G's test labs were immediately taken with their babies' streamlined look. "We discovered that thinness had a special appeal



Burke: "We love to win, but we also have to lose in order to grow."

TAKING CHANCES AT J&J

Jim Burke's first stay at Johnson & Johnson didn't last long. He had come to the company in 1953, but he left after just one year. "The company was centralized and stifling," Burke recalls, "and I was bored." In addition, he says, "we did not have a new-products division, and when I left I suggested we should have one."

It wasn't three weeks before Burke was back at J&J. His former bosses took him up on his suggestion and created a new-products division—and asked him to head it. Burke began developing a number of new ideas, but one morning he was summoned to the office of the chairman, General Robert Wood Johnson. The problem: One of Burke's first stabs at innovation, a children's chest rub, had failed dismally. Burke worried that his second stint at J&J might be as short as his first.

When Burke walked in, General Johnson asked, "Are you the one who just cost us all that money?" Burke nodded. The General said, "Well, I just want to congratulate you. If you are making mistakes, that means you are making decisions and taking risks. And we won't grow unless you take risks."

Some 30 years later, Burke, 63, is still spreading that word. "Any successful growth company is riddled with failures, and there's just not any other way to do it," he says. "We love to win, but we also have to lose in order to grow."

Burke believes that innovation can be nurtured through creative conflict. "I have tried to encourage that sort of conflict without fear of retribution," he says. "You end up with a lot more ideas." That philosophy, like his entrepreneurial urge, appears to have been born during Burke's childhood in the hamlet of Slingerlands, New York, when he and his three siblings sat down for dinner with their parents. "We were encouraged to argue," Burke recalls. "The dinner table was always a very stimulating place to be."

Suppertime isn't much different around the Burke household these days. There is always a lot of discussion when bread is broken, and the discussion is often led by Burke. He has tried to fashion that same sort of dinner-table atmosphere in his office. Long ago he forsook a conventional desk for a more expansive conference table, made of wood from the floor of a room at the Palace of Versailles. Says Burke: "I do most of my work with people, so I needed something they could all sit around."

Burke is careful not to dominate. To do so would contradict his fervent belief in decentralization. "Those of us in top management often say to each other that we had more fun running a J&J company than anything since," he says. "If you are having as much fun running a big corporation as you did running a piece of it, then you are probably interfering too much with the people who really make it happen." —**H. John Steinbreder** right away," says J. Richard Andre, a P&G vice president in charge of paper and diaper technology.

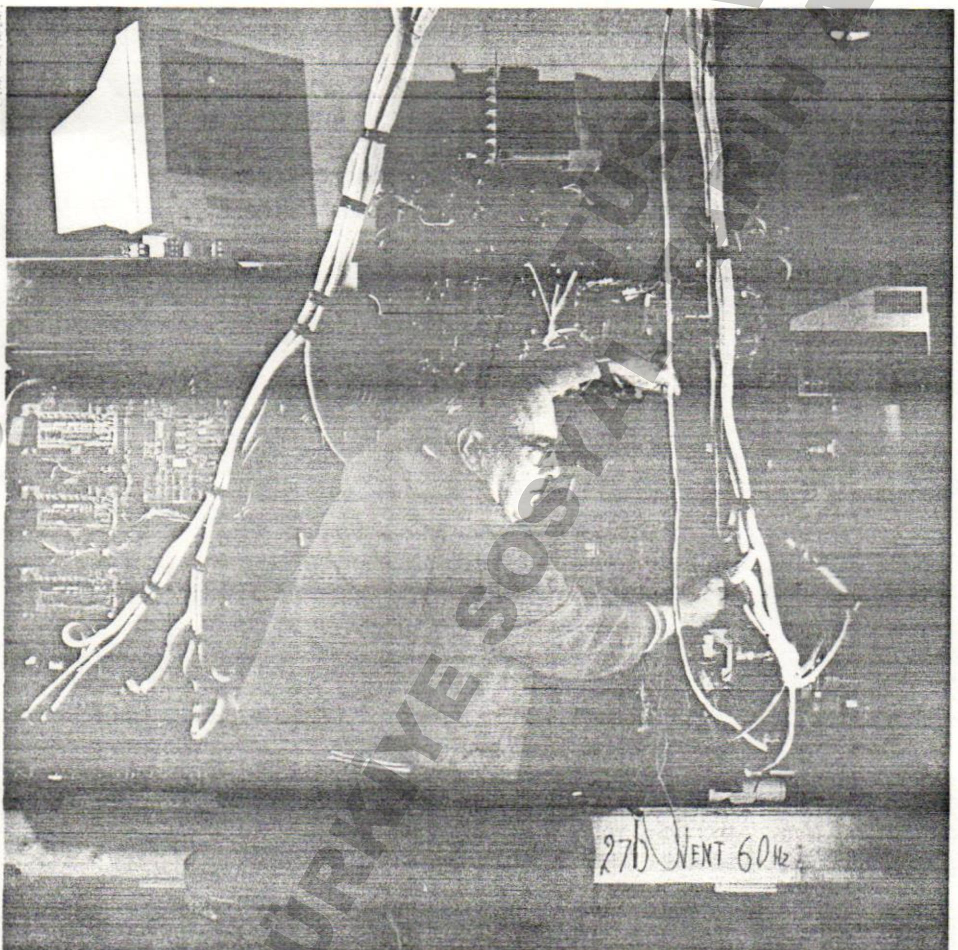
The company deployed the new technology as quickly as possible, rolling out Ultra Pampers nationally in 1986 and Ultra Pampers Plus, 30% more absorbent and 30% thinner, in the summer of 1987. P&G guards market-share figures ferociously, but industry analysts estimate the company's current total at 50%. Says Andre: "The deterioration has just stopped."

Heroic efforts to save a big product line make for dramatic chapters in a corporate history. But savvy managers know that over the long run squeezing every last bit of profit from every bit of business is at least as crucial—and requires at least as much innovative skill. Johnson & Johnson has introduced more than 200 new products in the U.S. over the past five years, but only two were legitimate home runs, with annual sales in excess of $100 million. (The products: extra-strength Tylenol caplets and Ortho-Novum 777 birth control pills.) Says Burke: "Blockbusters help, to be sure, but they are not the most important element here."

Smart companies invest plenty in the vital if less glamorous work of batting out singles. At 3M, about 10% to 15% of the R&D budget is spent on relatively rudimentary backup work for the company's four major product sectors. Another 10% to 15% goes for joint projects with the manufacturing side in pursuit of better, cheaper production methods. Somewhere around 50% to 60% is specifically aimed at finding new products, both related and unrelated to the company's current lines of business. And about 15% is spent on long-term projects out at the technological edge. Monsanto tries to divide its research expenditures evenly according to when commercial results can be expected. Class I projects should bear fruit in a year or two; Class II work should pay off in three to five years; Class III efforts, the groundbreakers, are supposed to provide viable products in eight to ten years. Says Monsanto's Heininger: "The name of the game is to keep putting things through the pipeline."

Often the most reliable source of new revenue is a line extension. Johnson & Johnson has produced 17 versions of the Band-Aid since introducing the product in 1920. Corning has continually found a market for variations of that ceramic device first designed to clean up auto exhausts. The company makes a larger, modified version for diesel trucks, a smaller type used by steelmakers to filter molten metals, another that captures pollutants emitted by wood stoves, and an extra large variation to fit into factory smokestacks.

GE is especially aggressive in seeking new targets for its product arsenal. For Ultem, that heat-resistant plastic, the company has discovered close to 200 applications, ranging from airplane interiors to packaging for microwaveable food. The key was focusing the development team's energies on this product to the exclusion of all others. Says Jeffrey Immelt, a GE new-business manager: "These people live, sleep, breathe, and eat Ultem."



In developing new copiers, Xerox brought together customers, product planners, engineers, marketers, manufacturing experts—even potential suppliers.

SAD BUT TRUE, many large U.S. companies have yet to perceive the importance of sharpening their innovative skills. At least some of those companies may require a complete cultural overhaul to open themselves to fresh concepts. "Too many big organizations have created a risk-averse environment," says John R. Rockwell, an innovation expert with the management consulting firm Booz Allen & Hamilton. "They have become market-share manipulators with no entrepreneurial flair."

It doesn't have to be that way, as some of the more innovative American organizations have shown by continually taking intelligent chances. "There's one thing you've got to keep telling yourself," says P&G's Gordon Brunner. "Virtually every success was a failure somewhere along the line."

At Corning, senior vice president James Riesbeck maintains one of those offices that all types of people from all parts of the company seem to pass through now and again. When research scientists have a particularly far-out idea, they like to make a model and put it on a long shelf in Riesbeck's office just in case someone from another part of the company might have a notion how to use it. These days the shelf contains a motley collection of glass pans, plates made from strange new alloys, an experimental photo lens. It doesn't look like much, but it represents a great deal: the dreams and energies of people committed to helping their enterprise prosper. ■

Fortune June 6th, 1988

TECHNOLOGY IN THE YEAR 2000

Only a dozen years ago there were no PCs, no CDs, no VCRs, no genetically engineered vaccines. The next 12 years could bring ten times as much progress. ■ *by Gene Bylinsky*

ALL IS VANITY, said the Preacher, and there is nothing new under the sun. Well, maybe there wasn't in the time of King Solomon, and anyway the author of Ecclesiastes was pondering the human condition, not man's evolution as toolmaker and healer. In these high-tech last days of the second millennium A.D., something new whizzes by practically every minute. In just the past dozen years the personal computer has transformed offices; videocassette recorders and compact discs have revolutionized home entertainment; and biotechnology has conferred genetically engineered vaccines and a host of other benefits on mankind. The next dozen years will bring the world to the year 2000. What further wonders are lurking in the labs today that will be commonplace when the next century begins?

"We'll see a minimum of ten times as much progress in the next 12 years as we've seen in the past 12," exults John Peers, president of Novix Inc., a Silicon Valley company that recently put a computer language on a chip to give new zip to communications-signal processing. He adds, "I wouldn't want to be a science fiction writer today because reality is leaping ahead of fantasy." Quite soberly Peers and his peers on the high-tech frontiers say that by the year 2000:

■ Computers that don't look and act like computers will surround you—shirt-pocket and notebooklike devices that respond to handwritten and spoken queries and commands, maybe even gestures.

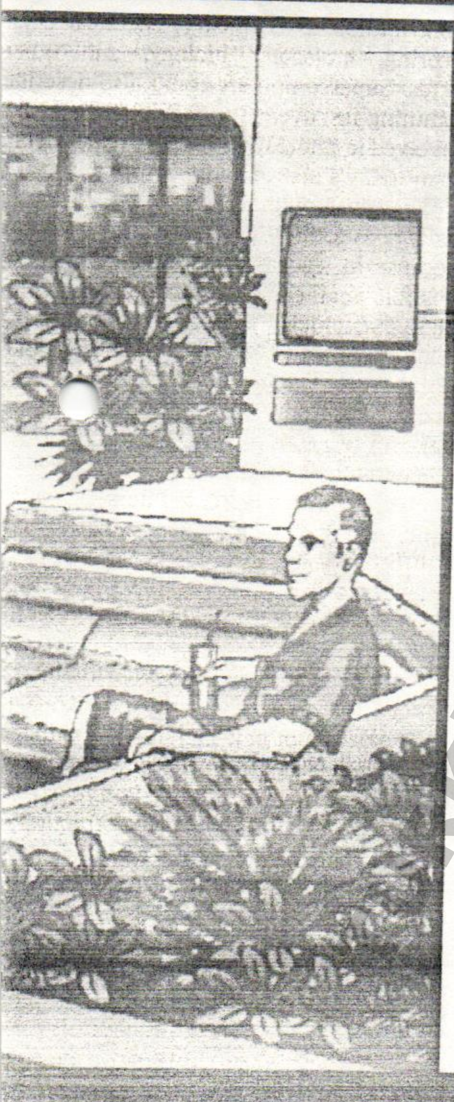
■ In corporate research centers, supercomputers 1,000 times more powerful than today's will calculate electron interactions in molecules in order to create materials that never existed before.

■ When you travel, you may carry along an electronic book that opens up to display text on two facing screens. The book's memory will contain as many as 200 novels or nonfiction volumes; you just write the name of the one you want to read—and up it pops.

■ Your doctor will check your heart by having you walk through a diagnostic machine rivaling Dr. McCoy's on *Star Trek.*

That's just a glimpse of the year 2000, when "we'll have capabilities no humans ever had," says Ralph E. Gomory, senior vice president for science and technology at IBM. Gomory, 59, adds, "When my father was young, he used to take a horse-drawn carriage to the railroad station. There were no automobiles, no telephones, no movies. No airplane had ever flown. There was no television, no atomic bomb, no man on the

REPORTER ASSOCIATE *Julianne Slovak*



The illustrations for this article were prepared on a personal computer using a version of Pixel Paint software that is not yet commercially available. The year 2000 could bring flat-screen TV with insets, book-size computers, electronic chefs that cook on command, and tiny picture phones.

moon. But by the time he died, he had flown in a jet and had seen all those other things happen. No generation had ever been through a transformation like that."

With all that has happened already, why are today's high-technologists so superconfident that the next 12 years will lead to a technological as well as a chronological millennium? What could possibly top all that has gone before?

The answer is that now, in contrast with earlier decades of invention, man stands at the dawn of the Age of Insight—a new era of understanding how things work and how to make them work better. In both electronics and biotechnology, the two principal fountainheads of new products, the immediate future holds not just the compilation of more and more data but also some startling new visions. In the view of many scientists, the computer is being transformed from a number cruncher into a machine for insight and discovery. It will become an instrument even more revolutionary than the microscope or the telescope. Unlike those fabulous and still evolving tools, the computer can look into the future. Supercomputers do it already by forecasting weather a few days ahead. As they leap forward in power, by the year 2000 they will be forecasting the structures of new materials and simulating such cosmic phenomena as the evolution of stars and galaxies.

The new Age of Insight will also offer views of the workings of the human body never before attainable. Deciphering the interactions of the body's own healing substances and the underlying causes of disease will allow researchers to develop novel drugs and methods of treatment. They will increasingly tap the body itself as a new pharmacopeia, an almost inexhaustible trove of medications that genetic engineers can copy and improve on.

CONVERGING with these new insights and new computing power is the rapid emergence of telecommunications networks. It is as if—for a change—high-powered cars and sleek highways to accommodate them were arriving at the same time. Telecommunications experts see nothing less than a world linked by great computerized networks that process voice, data, and video with equal ease. The first ISDNs—integrated services digital networks—are just going into service in the U.S., Japan, and Western Europe. In a few years they are expected to yield billion-dollar annual savings to corporations in increased productivity and lowered communications costs.

The certainty of these advances makes the experts drool. "I've never been as excited about the future and about the speed with which we're making progress," says Gordon Bell, vice president for research and development at Ardent Computer of Sunnyvale, California, a maker of supercomputers. Bell is one of the world's top computer designers and visionaries: He led the development of Digital Equipment's landmark VAX computer systems. Now he is pioneering the new insight and discovery machines.

Most of the underlying technologies for products that will be on the market by the year 2000 are already in the labs or just entering them. Walter Utz, Hewlett-Packard's manager of advanced engineering, notes that it takes about 12 years to translate a new technology into useful products. Since the turn of the century is only 12 years

ILLUSTRATIONS BY PEPE MORENO, PHOTOGRAPHS BY WILLIAM LOMBARDO away, many of the directions have already been set.

This article is based on an assessment of the future as a framework of the possible—as helicopter pioneer Igor Sikorsky once described it—by some 100 experts in industry, universities, federal agencies, and venture capital firms in the U.S., Western Europe, and Japan. Forty of these experts make up FORTUNE's Probability Panels, offering their predictions about the likelihood of specific innovations as shown in the accompanying tables. Surprises are bound to emerge along the way that may throw some of the predictions off track: Witness the recent surge in high-temperature superconducting materials. But, says IBM's Gomory, "forget the unexpected—the unexpected will just accelerate the progress. Believe me, we're having a revolution *without* superconductivity or anything like that."

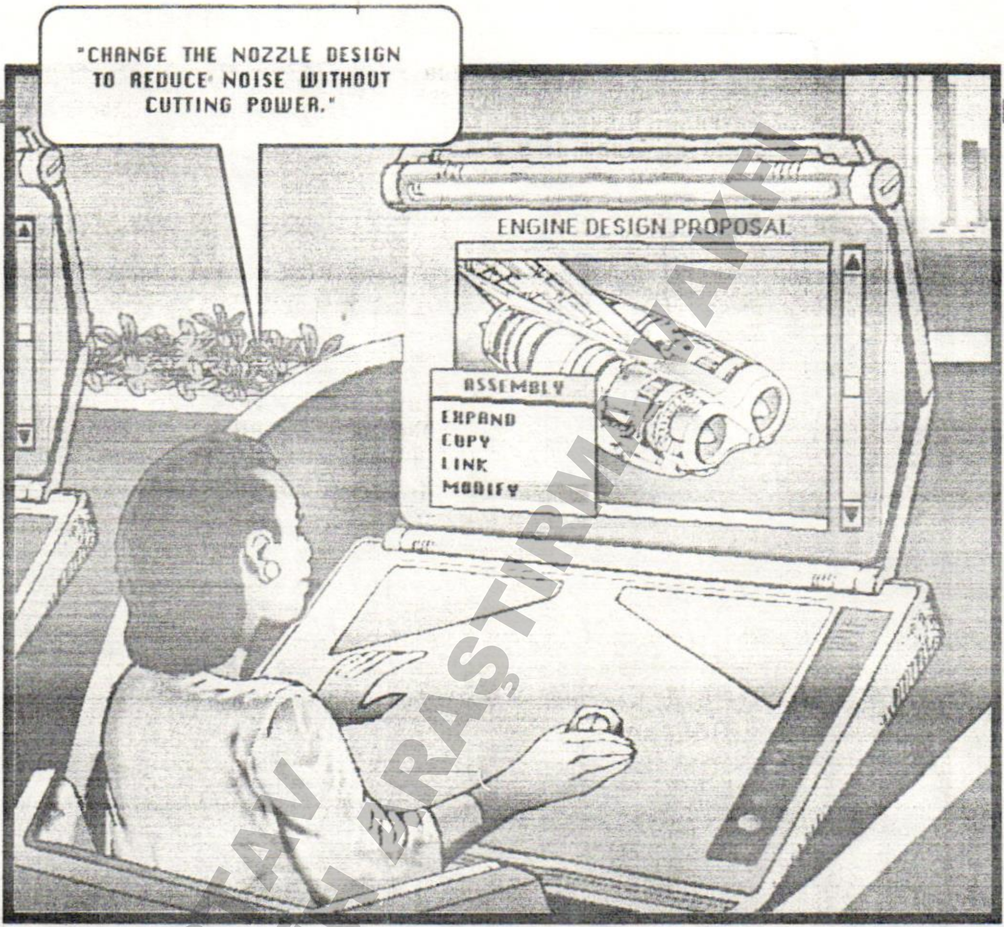
A tour of what's coming by 2000:

THE EXPERTS AGREE that progress in both consumer electronics and computers will continue to be led by advances in semiconductor chips. These advances have been nothing short of spectacular, and they will continue to be so. Just 18 years ago Intel Corp. pioneered a 1,024-bit, or one-kilobit, DRAM (dynamic random access memory) chip, which held about 4,000 transistors and related components. Today, four-*megabit*—four-million-bit—DRAMs with about 16 million components are already in use.

"A one-billion-transistor chip by the year 2000 is not inconceivable," says Robert N. Noyce, vice chairman of Intel and co-inventor of the silicon chip. He thinks that a hundredfold, perhaps even a thousandfold, improvement is still possible with conventional technology, including so-called wafer-scale integration—building hundreds of different chips into a single system. Greater chip density makes chips cheaper and computers smaller and more reliable.

Along the way a new kind of information storage and processing technology may possibly emerge. One intriguing candidate: an optical liquid-crystal medium that would allow information to be stored in three dimensions, instead of the two dimensions of today's chips. This would permit the equivalent of thousands of memory chips to be jammed into a device the size of a coffee cup, says Caltech chip designer John Hopfield.

It's already clear that the galloping extension of today's technology will give



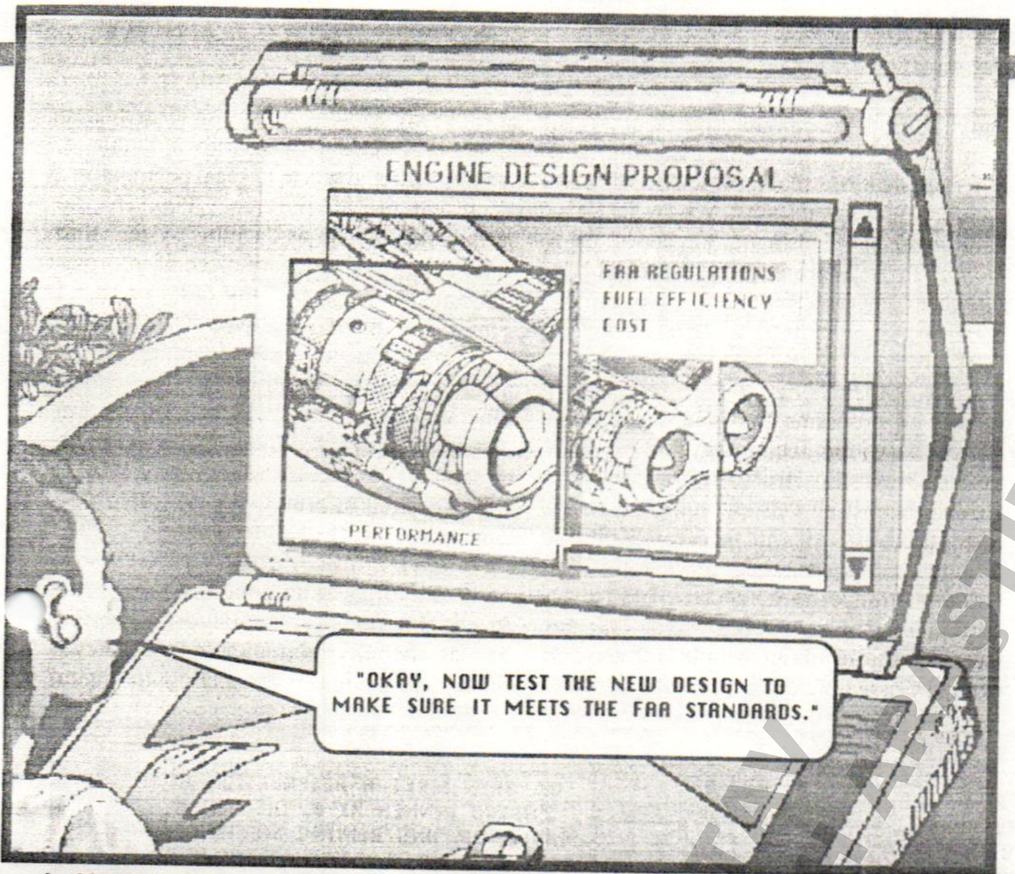
To spoken commands, a computer reconfigures a jet-engine housing and submits it to tests.

computers of the year 2000 an electronic punch that will startle today's users. Desktop workstations will pack the power of what we now know as supercomputers. Supercomputers themselves will soar into the numerical stratosphere—as will their cost. Supercomputers of the future are expected to do at least four trillion complex calculations a second—1,000 times more than today. The biggest may cost as much as $1 billion, but that will represent a vast improvement in computing bang for the buck. A whole corporation might be built around a single supercomputing system.

One big challenge: devising appropriate software to run these supercomputers, which will likely consist of hundreds or even thousands of individual computers running in parallel. If that type of programming can be mastered, and most experts believe it will be, supercomputers will emerge as great vision- and intellect-extending engines by the year 2000. Kenneth G. Wilson, a Cornell University Nobel Prize winner in physics and an expert on supercomputing, predicts that the machines "will open vast new domains of scientific research—domains that are inaccessible to traditional experimental or theoretical modes of investigation." Supercomputers, he explains, will enable scientists to "see" objects on a smaller scale than microscopes can—a vital contribution to chemistry, chemical engineering, molecular biology, and other fields. Supercomputers could also describe lightning-fast events, such as the chemistry involved in photosynthesis, in greater detail than today's instruments permit.

The supercomputer of the year 2000 will emerge as an indispensable industrial tool, because its enormous capacity will make possible mathematical modeling of complex phenomena that are influenced by huge numbers of variables. Among other things, it is likely to serve by then as a full-fledged electronic wind tunnel. Where today only portions of airplanes can be tested in computers, complete airframes will be "flown" inside supercomputers at supersonic and hypersonic speeds. Better cars will be designed in computers because an engineer will be able to "feel" how a car handles before it is built. On the screen the designer could repeatedly crash his computer-model car into barriers or other cars to see how well it withstands the damage.

The design of new materials should benefit spectacularly from the new supercomputer power. "Scientists have so far explored only an infinitesimal fraction of possible forms of matter," says Wilson. Since the properties and structure of molecules are ultimately determined by the interactions of the electrons within them,



In this Apple Computer concept, a design could be proved out without building a prototype.

Wilson says, sufficiently powerful super-computers should theoretically be able to "predict everything about a material with no experimental information whatsoever" by calculating those interactions. He adds, "The potential importance for both basic research and industry applications is beyond anything one can imagine today, if reliability could be achieved."

The discovery capabilities of computers of all sizes will be enhanced by the great leap in computing power by the year 2000. The reason: the advent of what scientists have begun to call "visual computing," which in effect reproduces reality mathematically within a computer so that objects can be both seen and manipulated in all sorts of ways. The nature and behavior of an object or phenomenon can be described in equations and presented visually; the objects simulated can include anything from the steering mechanism of a car to the interior of a star. This kind of computing will open up new areas to scientific inquiry and bring products to market at unheard-of speeds by allowing the rapid testing of almost infinite product variations.

Visual computing makes seeing become believing. It gives engineers and scientists a new window into complex realities. As Donald P. Greenberg, director of the computer graphics program at Cornell, explains it: "I don't care whether we're traveling down the bloodstream and inside the heart, or looking at a building shaking in a simulated earthquake, or at an interior design of a house, or at a demographic projection with six variables. I just want to see what's happening so that if my model does not yield the results I anticipated, or if the interrelationships between the variables are incorrect, I can go back and change the simulation."

Another great benefit of soaring computing power will be the arrival of the truly "user friendly" computer. A great gap still separates man and machine. Despite their computational brilliance, which dwarfs man's, machines have horrendous difficulty with speech recognition because people speak in unstructured and inconsistent ways. Computers have comparable problems identifying visual patterns and recognizing objects from varying angles.

To the rescue, by the year 2000, may come neural circuits, simplified analogs of much more complex human auditory and visual nerves and related structures. One of those unpredictable twists in the high-tech road to the future may be a $2,000 board for PCs that will allow them to understand several hundred words of continuous speech. The board, which Digitech Inc., a small Missouri company, says it will deliver by the end of this year, uses chips that try to imitate some of the ear's sound-processing functions. Similar work is in progress in vision. Caltech's noted microchip designer Carver Mead, for instance, has already built a chip that imitates some of the eye's information processing.

By putting some of these ideas into practice, says Jean-Louis Gassée, Apple Computer's senior vice president for research and development, "by the year 2000 computers will seem magic to my wife, who really doesn't like computers." The day may well have come when machines respond readily to spoken commands—and even answer back, just as the strong-willed HAL-9000 computer did in the 20-year-old film *2001: A Space Odyssey*.

BY THE YEAR 2000 most computers will have lost their familiar boxy shapes. The idea is to make them more compatible with people by making them look less like machines. Says Gomory: "One way to make computers easy to use is to pretend there is no computer. Instead, you reproduce on the screen whatever you're used to. If you want to write a letter, you reproduce a piece of paper on the screen and you write on it. The computer translates your handwriting into type. If you want to file the letter, a

A FORTUNE PROBABILITY PANEL

COMPUTERS

Ten experts in industry, universities, and government agencies rate on a scale of 1 to 10 the likelihood that each item listed will be available by the year 2000.

	TEN EXPERTS										CONSENSUS
Computers that recognize handwriting	7	9	9	8	8	9	9	4	9	7	7.9
Instant access to all available information on a subject	9	9	7	8	10	8	3	9	4	4	7.1
Voice-controlled computers	5	3	1	3	10	9	9	10	8	9	6.7
Gesture-controlled computers	3	8	8	6	10	1	9	10	7	3	6.5
Flat desktop computers	8	6	2	5	10	5	9	7	5	5	6.2

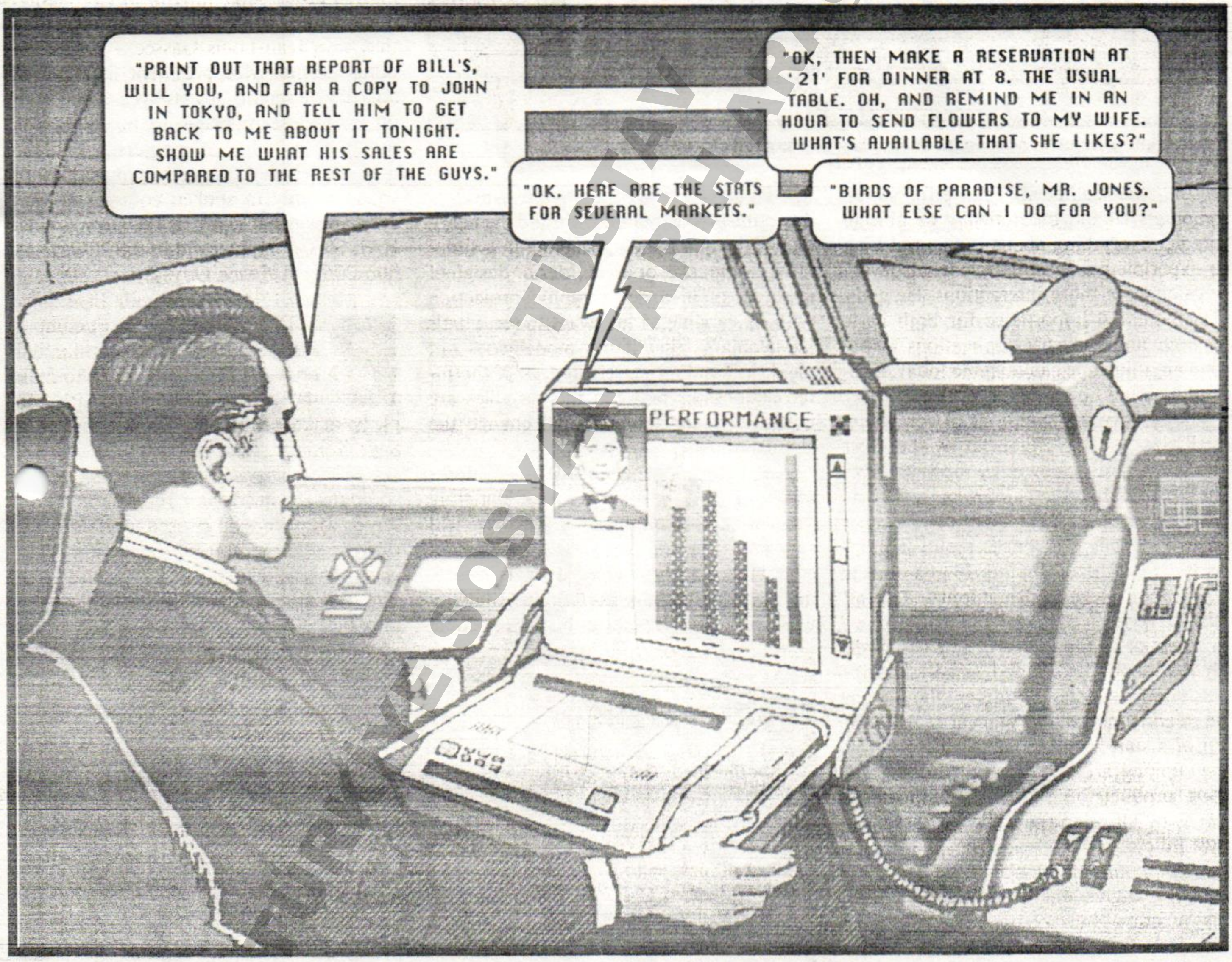
picture of a filing cabinet appears and you stick the letter in."

Handwriting as a means of entering data into computers, in fact, tops the list of many experts' predictions. They feel it is a more natural way to interact with computers than using keyboards, even though some people can type faster than they write and others have messy handwriting. The writing would be done on thin flat screens placed on desks, much like blotters.

Companies are hard at work on putting these concepts into practice. IBM, for one, is developing components of an electronic book that would contain the text and illustrations from hundreds of volumes on a small diskette, with an easy-to-read liquid-crystal screen instead of pages. "We could even give it to you in a leather binding, if you prefer," says Gomory. In addition, it could be used as a computerized workbook, a small machine for word processing and other applications that a traveler could carry along and communicate with in long-hand instead of using a keyboard or a mouse. Texas Instruments is also exploring the idea.

MITCHELL KAPOR designed the Lotus 1-2-3 spreadsheet programs and is now chairman of On Technology Inc., a Cambridge, Massachusetts, software company. He sees almost all PCs assuming the shape of hard-cover books in the year 2000. He predicts the appearance of a computer-based reference book, a cross between a dictionary and an encyclopedia, that answers questions about people, places, and events. Gassée of Apple envisions computers of many sizes—from a 3-by-5-inch card to a blackboard tapped into a database. Noyce of Intel expects to see a personalized electronic file by the year 2000. He describes this device as "a filing system that will read and recall every piece of information that comes across my desk, or that I deal with in my daily activity." The device, furthermore, would have "instant communication with every other computer." The function of computers will also change dramatically. They will, in essence, become instruments of access to a network over which desired information flows rapidly on demand.

Telecommunications are converging with computers at an opportune time. Just as computational capabilities are beginning to soar, the telecommunications industry is rapidly switching from analog to digital



An executive uses Apple's projected Knowledge Navigator, combining an interactive talking computer with advanced telecommunications.

A FORTUNE PROBABILITY PANEL

TELECOMMUNICATIONS

The experts give all these possible products a good chance to be on the market in 12 years except the instantaneous-translation telephone, a Japanese dream machine.

	TEN EXPERTS										CONSENSUS
Voice-controlled telephones	5	8	8	10	7	8	9	10	5	8	7.8
Color fax	8	8	4	10	7	6	6	10	10	8	7.7
Combined telephone/computer/TV	9	5	8	4	8	7	8	8	2	9	6.8
Picture phones	3	4	6	7	5	6	9	10	8	8	6.6
Instantaneous-translation telephones	4	4	5	3	3	3	3	5	1	6	3.7

transmission of signals—the "bit" language of computers. Furthermore, the industry is greatly enhancing the transmission capacity of existing telephone lines to allow simultaneous transmission of voice, data, and video. A few years further in the future is wide use of capacious fiber-optic cables in business and at home. Gassée calls such a [illegible]le "a data hydrant."

The telephone of the year 2000 will evolve into what Bell Labs' vice president for research, Arno A. Penzias, refers to as "an integrated information appliance." This would be a sleek device with a large flat screen that would allow picture-phone conferences in full color as well as offer all the other accouterments of the information age: the ability to send and receive documents and messages, act as a full-size computer, and provide access to many information sources.

ROLAND C. MORENO, president of Paris-based Innovatron and inventor of a "smart" credit-and-charge card equipped with a chip, sees counterparts of the French Minitel system in wide use in other countries by the [illegible] of the century. (West Germany's Bundespost, the federal postal service, is now expanding its version of the system.) Minitel replaces telephone books with a small computer terminal. Besides finding addresses, it can buy theater, plane, and train tickets, send bouquets of flowers with notes translated if need be—albeit clumsily—and find girlfriends or boyfriends, the machine's most popular service. Minitel is now in use in nearly four million French households and offices as a government-subsidized experiment.

Japan's entry in the future-telephone derby is likely to be an instantaneous translation telephone that will work at least in English and Japanese, for openers. NEC, the Japanese electronics giant, began research on the project in 1983. Akihiro Kitamura, a NEC vice president, says it will take at minimum another five to ten years to complete the device—assuming the problem of recognizing continuous speech will have been mastered by then.

The Age of Insight is also revolutionizing both medical diagnosis and treatment by making them far quicker and more specific. An imposing array of new tests and instrumentation—from antibodies that seek out harmful viruses and bacteria to vastly improved body-scanning technologies—are opening the interior of the body to a new view. All this should allow doctors to diagnose infections in minutes instead of days and heart attacks in seconds instead of hours. They should also be able to detect tumors before symptoms appear, permitting treatment to begin earlier and drastically improving the chance of success.

New insights into human diseases would spur the creation of elegant new treatments. For instance, Leroy Hood, a brilliant Caltech immunologist, says that by the year 2000 it should be essentially possible to prevent such autoimmune diseases as rheumatoid arthritis, multiple sclerosis, and insulin-dependent diabetes, in which the body mistakenly attacks its own tissue. Clones of immune system cells gone haywire do the damage. Hood and his associates are already designing ways to remove such undesirable cell families in mice.

One of the experts' most startling predictions is that by the year 2000 it should be possible to regrow whole organs, or parts of them, in the body instead of replacing them with transplants. This could come about in at least two ways. First, scientists could decipher the remarkable biological program that leads to the growth of a new heart in an embryo, for example. Second, they could repair sections of a heart that had been damaged by a heart attack, say, by administering such tissue-restoring substances as the fibroblast growth factor that the body makes to regenerate blood vessels. California Biotechnology Inc., of Mountain View, the first company to clone the factor, has shown that it significantly accelerates the healing of wounds in animals; tests on people start next year. The growth factor also appears to repair nerve cells such as those destroyed in the brains of Alzheimer's victims.

BY EXTRACTING such healing substances from the human body and duplicating them through genetic engineering, scientists are cashing in on—and enhancing—the body's remarkable ability to heal itself. Genetic engineers have hit a potential bonanza: The body makes about 100,000 proteins. Says David Botstein, vice president for science at Genentech, the biggest U.S. biotech company: "Suppose 1% of them have the potential of being turned into pharmaceuticals. That's 1,000 new drugs." Other drugs of the year 2000 should include inexpensive and highly specific molecules tailored to fit receptors for hormones, peptides, and other substances that regulate physiological events in the body from hunger to the sex drive. These precisely targeted drugs will replace chemicals discovered by the historical trial-and-error method. Genetically engineered vaccines, such as the recently introduced hepatitis killer, could eradicate many infectious diseases, including malaria.

This century's crowning achievement in biology could well turn out to be the deciphering of the human genome—the deter-

A FORTUNE PROBABILITY PANEL

BIOTECHNOLOGY & MEDICINE

The medical experts give an AIDS vaccine by the year 2000 less than an even chance, but quicker diagnosis and better treatment should limit damage from heart attacks.

	TEN EXPERTS										CONSENSUS
Defeat of heart disease	7	10	6	7	8	0	4	3	6	2	5.3
Defeat of AIDS virus	5	2	3	5	8	10	1	5	7	2	4.8
Defeat of rheumatoid arthritis and multiple sclerosis	8	5	5	5	2	6	5	0	6	3	4.5
Defeat of leukemia and lung cancer	6	5	5	5	4	2	3	0	2	1	3.3
Defeat of Alzheimer's and Parkinson's	3	2	4	1	1	2	0	2	0	0	1.5

mination of the order, content, and location of the genes on the human chromosomes that control the body's growth and well-being. Broken down to the most basic chemical level, says Hood of Caltech, those instructions would fill 500 volumes, each 1,000 pages long, each page containing 1,000 words, each word consisting of six letters of the DNA language. The mapping of the genome would open broad new avenues of medical diagnosis and treatment. In basic biology, comparative analysis of the genomes of mice, fruit flies, and people would allow scientists to break the other two still undeciphered DNA codes—one that dictates steps in cell differentiation and development, another that governs the structure of chromosomes.

CRACKING the remaining codes, Hood suggests, would raise the spectacular possibility of creating entirely new types of biostructures for medical and industrial uses. A molecule might be designed, for instance, that would connect with cancerous cells and make them revert to normal. Deciphering the genome would also allow doctors to prepare a genetic printout of a baby at birth to spot susceptibility to various diseases and to start early treatment.

A FORTUNE PROBABILITY PANEL

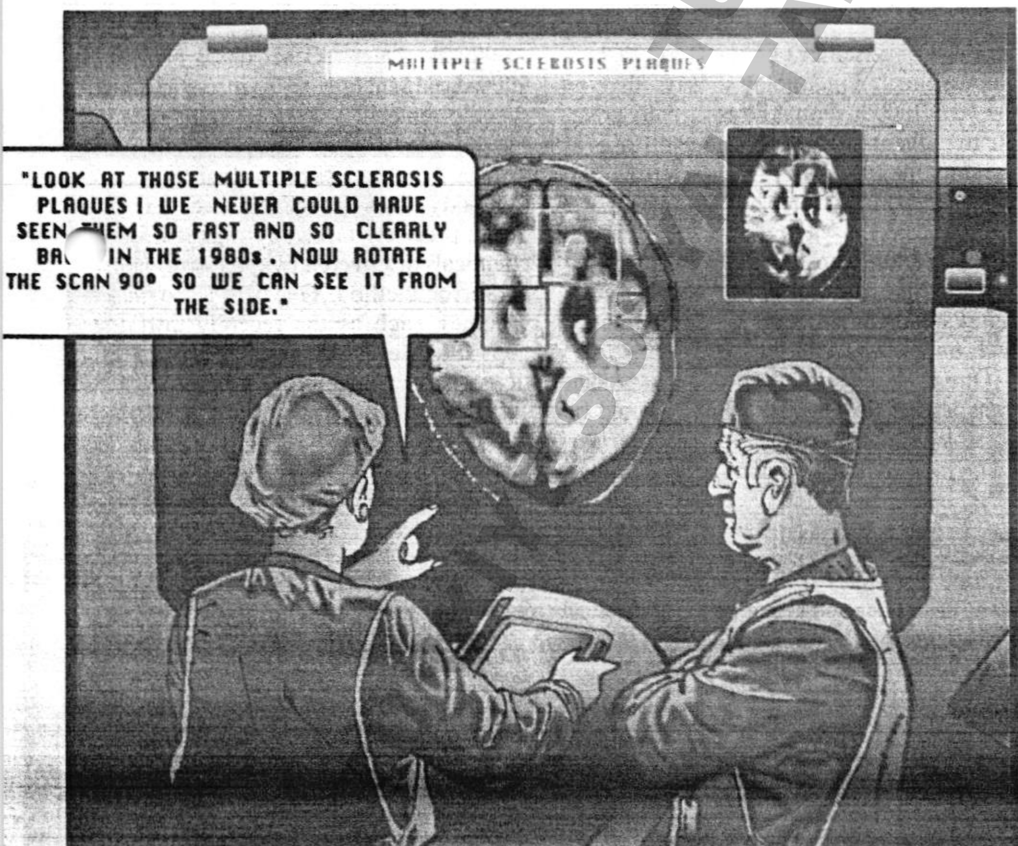
SUPERCONDUCTIVITY

These experts think the technology is likely to improve magnets and motors, but doubt that such things as magnetically levitating trains will soon be a commercial reality.

	TEN EXPERTS										CONSENSUS
Magnets	5	7	8	4	7	7	7	6	1	7	5.9
Motors and generators	5	7	7	6	7	7	8	5	0	5	5.7
Energy storage	4	7	4	4	8	4	4	5	0	5	4.5
Power transmission	4	2	4	5	2	4	5	4	0	5	3.5
Levitating transportation	4	2	6	2	1	2	2	2	0	2	2.3

Surprisingly, FORTUNE's Probability Panel doubts that the most talked-about recent scientific breakthrough—superconductivity—will contribute much by the year 2000. The phenomenon greatly speeds the flow of electrons by cooling the conductors they pass through—to the point where they lose resistance. But Ian Ross, president of Bell Labs, says that while superconductivity is of great interest in instrumentation, working at extremely low temperatures in computing and signal switching is "too irksome." Chairman Gordon Moore of Intel adds that he is always suspicious of new technologies "where everybody seems to be excited about it for somebody else's application. You know, 'My view is that it doesn't impact the kinds of things we do much but the power generation people will find it great.' "

AT IBM, Gomory draws a sharp distinction between new superconducting materials as scientific discoveries and their possible technological applications. He says, "A door has been opened into the unknown and we don't know what's on the other side. We're in a whole new world of materials. History has shown us that over time that tends to amount to something." But he guesses that most of those breathless forecasts about superconductivity powering 300-mile-per-hour trains and carrying electricity cheaply over long distances probably won't come true.



Vastly improved body-scanning techniques will aid both diagnostic and surgical accuracy.

The impact of new technology on everyday work and life in the year 2000 will be more subtle than the dramatic transformations wrought in the lifetime of Gomory's father by automobiles, airplanes, movies, antibiotics, television, spaceflight, and other marvels. Some of the changes computers will bring about will be more intellectual in content, while in biotechnology the great advances in diagnostics and treatment will be readily apparent. Says George H. Heilmeier, chief technical officer at Texas Instruments: "In the medical field alone, the ability to bring the best medical care in the world to any local hospital will represent as big a jump as going from the horse-drawn cart to the automobile."

There are limits, of course. None of the technological possibilities that scientists and engineers are pursuing today suggest that man will soon decipher such fundamental mysteries as the workings of the human mind or the fate of the universe. Ecclesiastes also declared, "No man can find out the work that God maketh from the beginning to the end." The Preacher may not have been right about new things under the sun, but on this one he hasn't been proved wrong—yet. ■

...heißt, kein ge-
Vorteile, sondern ge-
und langfristig Haut
Tieren komme es zu
. degenerativen und
Veränderungen der Haut.
... an den Augen die
...digt und der graue

Zu den Mitteln, die auf Licht reagieren, gehören unter anderem blutdrucksenkende und harntreibende Präparate, Antibiotika, Sulfonamide, Herzmittel und Psychopharmaka. Außerdem sind Patienten bedroht, die zu Krankheiten neigen, die durch Sonnenlicht ausgelöst oder verstärkt werden. F.A.Z.

streck... im Interstitium können vielfältige Veränderungen auftreten, von Ent-

also im Lungenmar... lokalisiert sind, war es nur konse...t, Verfahren zu

Fortsetzung nächste Seite

...lekularer Wasserstoff im Weltraum

...Materie anders verteilt / Analyse der Gammastrahlung

...ten Raum der Milch-
...für atomaren als mole-
...stoff. Darauf deuten
... einer Gruppe
...r Universität von Dur-
...en bisherigen Analysen
...nommen mit mehr mole-
...stoff gerechnet. Das ge-
...ist deshalb von Inter-
...ue Sterne vor allem in
...bilden, in denen mole-
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...lden, bringt vom Zu-
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Wasserstoff der Milch-
...recht leicht anhand der
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Umständen von den
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Temperaturnullpunkt in
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...usammenstößen andere
...enen bislang etwa fünf-
...e gefunden wurden, zur
...bislang wurde der Was-
...ichlich anhand der An-
...ohlenmonoxyd nachge-
...e Stärke der Strahlung
...oxyd hängt stärker von
... der Gaswolke als von
Wasserstoffmoleküle ab.
... sind deshalb nicht sehr
...", Bd. 314, S. 495).

Einen Ausweg bietet die Beobachtung der Gammastrahlung, die aus der Milchstraße zur Erde kommt. Die energiereichen Gammastrahlen (mit Energien von mehr als fünfzig Megaelektronenvolt) entstehen vor allem, wenn die sogenannte kosmische Strahlung auf interstellares Gas trifft. Das haben Untersuchungen in den siebziger Jahren gezeigt. Da die Astronomen den Anteil an atomarem Wasserstoff in interstellarem Gas kennen, läßt sich mit den Messungen der Gammastrahlung auch der Anteil an molekularem Wasserstoff bestimmen, wenn man über die Verteilung der kosmischen Strahlung hinreichend genau Bescheid weiß.

Anfangs bereitete dieses Verfahren Schwierigkeiten, weil die Meßergebnisse der Gammastrahlen-Satelliten, vor allem des amerikanischen SAS-2 und des europäischen COS-B, nicht miteinander übereinstimmten. Das lag zum Teil an systematischen Fehlern bei der Analyse der Daten. Auch wenn noch nicht alle Probleme gelöst sein dürften, sind die neuen Untersuchungen doch sicher weit zuverlässiger als die früheren Analysen. Wenn sich das von den Forschern in Durham gefundene Ergebnis bestätigt, gibt es im inneren, etwa 20 000 Lichtjahre vom Zentrum fortreichenden Bereich der Milchstraße molekularen Wasserstoff mit einer Masse von etwa 600 Millionen Sonnen, während die Masse der neutralen Wasserstoffatome 800 Millionen Sonnen entspricht. G. P.

Ahnenreihe des Menschen weiter unklar

Australopithecus africanus Vorfahr des Homo oder Nebenlinie? / Kind von Taung war nur drei Jahre alt

Die immer noch unbeantwortete Frage, welche der einige Millionen Jahre alten hominiden Fossilien direkte Vorfahren des Menschen repräsentieren, hat auf einem internationalen Symposium der Universität vom Witwatersrand wieder zu heftigen Diskussionen geführt. Dabei stand vor allem das „Kind von Taung" im Vordergrund, ein gut erhaltener Schädel, den Raymond Dart vor 60 Jahren in einer Kalksteinschicht in Bophuthatswana/Südafrika entdeckt hatte. Dieser Schädel galt bislang als Überrest eines etwa sechsjährigen männlichen Australopithecus africanus, der vor rund zwei Millionen Jahren gelebt haben soll.

Nach den neuesten Untersuchungen scheint das Kind von Taung aber nur ungefähr drei Jahre alt geworden zu sein. Tim Bromage vom University College in London hat zusammen mit Christopher Dean die Wachstumslinien in den Zähnen eines anderen australopithecinen Fossils analysiert, das auf derselben Wachstumsstufe steht, und ist dabei für dieses Exemplar auf ein Alter von 2,7 bis 3,7 Jahren gekommen. Länger dürfte auch das Kind von Taung nicht gelebt haben.

Das Alter des Kindes von Taung ist wichtig, wenn man aus der Entwicklung gewisser Merkmale beim Heranwachsen Rückschlüsse auf die zugehörige Gattung ziehen will. So unterscheiden sich Menschen und Affen unter anderem dadurch, daß sich beim Affen der Kiefer nach der Geburt nach vorne schiebt, während er beim Menschen hinten bleibt. Für Affen sind außerdem die stark hervortretenden Brauenbögen charakteristisch, die beim Menschen und beim grazilen Australopithecus fehlen. Dagegen haben die robusten Australopithecinen, der Australopithecus robustus und der Australopithecus boisei, schon eher Ähnlichkeit mit Schimpansen. Sie haben sich von der zum Menschen führenden Linie fortentwickelt. Ungeklärt ist bislang, ob der Australopithecus africanus schon zu diesem Nebenzweig gehörte oder noch gemeinsamer Vorfahr des Homo und des robusten Australopithecus war — oder ob der ältere Australopithecus afarensis, der vor rund drei Millionen Jahren gelebt hat, den letzten gemeinsamen Stammvater darstellt.

Nach den Untersuchungen von T. Bromage entwickeln sich beim Australopithecus africanus nach dessen Geburt viele Schädel- und Gesichtsmerkmale ähnlich wie beim Schimpansen, allerdings sehr viel langsamer. Das führt dazu, daß der Kiefer in fortgeschrittenem Alter nicht ganz so weit hervortritt. Es gibt aber auch wesentliche Unterschiede, die die zur Erklärung der flachen menschlichen Gesichtsform oft angeführte These, eine langsamere Entwicklung deute auf einen Fortschritt in der Evolution hin, fragwürdig erscheinen lassen.

Daß der robuste Australopithecus sich von der Linie zum Homo fortentwickelt hat, scheint unter anderem mit seiner Ernährung zusammenzuhängen. Als Vegetarier bildeten sich bei ihm starke, als Mahlmaschinen dienende Backenzähne aus, die in einem kräftigen Kiefer saßen. Damit ging nach Yoel Rak von der Universität in Tel Aviv ein Umbau der gesamten Gesichtsfront einher, die eine Umverteilung der Kräfte beim Kauen bewirkte („Science", Bd. 228, S. 42). Beispielsweise bildeten sich neben der Nasenöffnung Stützen aus, für die es beim Homo keinerlei Anzeichen gibt. Ein gemeinsamer Vorfahr müßte so beschaffen sein, daß er für die Evolution in beiden Richtungen noch offen ist. Nach Y. Rak trifft das für den Australopithecus afarensis zu, aber nicht mehr für den Australopithecus africanus, der sich schon zur robusten Linie hinentwickelt habe.

So überzeugend die Argumente auch sind, so wenig reichen sie aus, die Geschichte unserer Vorfahren durchschaubarer zu machen; denn bei allen Unterschieden weist der robuste Australopithecus auch bislang unverstandene Ähnlichkeiten mit dem Homo auf. Einige Paläanthropologen halten zudem weder den Australopithecus africanus noch den Australopithecus afarensis für einen geeigneten Stammvater des Homo. Sie meinen, man müsse nach einem anderen Kandidaten Ausschau halten, zumal der Australopithecus africanus zwar einige Merkmale zur robusten Linie hin entwickelt habe, insgesamt aber eher als gemeinsamer Vorfahr in Frage komme als der ältere Australopithecus afarensis.

Zu den Schwierigkeiten der Paläanthropologie gehört, daß es nur recht wenig Funde gibt. Außerdem lassen sich die Merkmale an den Fossilien unterschiedlich interpretieren. So ist selbst beim Kind von Taung keineswegs unumstritten, daß es in die Reihe der grazilen Australopithecinen einzuordnen sei. Von einigen Wissenschaftlern wird der Schädel vielmehr als relativ robust angesehen. Ähnlich schwanken auch die Schätzungen seines fossilen Alters. Während die Mehrheit der Forscher rund zwei Millionen Jahre dafür annimmt, halten andere ein Alter von einer oder drei Millionen Jahren für richtiger. GÜNTER PAUL

FAZ 24.4.85

Venus

224.7 günde güneşin etrafında dönüyor

Dünya ile uzaklığı 41 ~~[illegible]~~ milyon ile 257 milyon km arasında değişiyor.

Güneşten ortalama uzaklığı 108,21 · 10^6 km

Äquatordurchmesser 12 104 km (0,960 Erddurchmesser)

15.12.72 de ve 22 ve 25. Ekim 1975'te Venus'a inen sovyet Venus 8, 9, 10 araçları atmosferinin %97'sinin karbondioxyd CO_2 olduğunu, basıncın 90-95 bar, ısının 465-485°C havadan 65 kere daha koyu (dicht) bir atmosfer

Bulutlar sülfrikasid

30 km den 70-80 km'ye kadar [illegible] kaplı

Büyük bir Vulkan var.

S(W) ~~2:40=~~

$Z = W - 1024$

$X1$ = Zeile = $INT(Z/40)$ =

$X2$ = Spalte = $Z - Z/40$

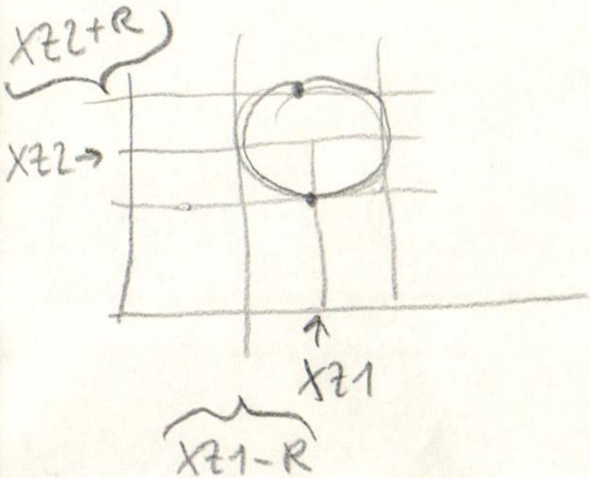
$$(X1 - XZ1)^2 + (X2 - XZ2)^2 = R^2$$

$$(X1)^2 + (X2)^2 = R^2$$

$$(X1 - XZ1)^2 = R^2 - (X2 - XZ2)^2$$

$$X1 = XZ1 \pm \sqrt{R^2 - (X2 - XZ2)^2}$$

$$X1 = \sqrt{R^2 - (X2)^2}$$



Hafızaya yazı yazmak için

100 Z = 49500
110 Z = Z+1
120 GET B$: IF B$ = "" THEN 120
130 A = ASC (B$)
140 POKE Z,A
150 GOTO 110

oluyor! 14.9.84

Sonuç: 49500 den başlayarak hafızaya istediğin şeyi yazıyor.

Variable olabilir ↓

200 I = 5
~~210 Z = 49500~~
210 FOR Z = 49500 TO 49530
220 POKE 1424+I, PEEK(Z)
230 I = I+1
240 NEXT

oluyor! 14.9.84

Hafızadaki yazıyı ekrana yazıyor.

```
30  X=1 : Y=1
40  DX=1 : DY=1
100 IF X=0 OR X=39 THEN GOTO 200
110 IF Y=0 OR Y=24 THEN GOTO 180
120 POKE 1024+X+40*Y, 81
130 FOR T=0 TO 10 : NEXT
140 POKE 1024+X+40*Y, 32
150 X = X + DX
160 Y = Y + DY
170 GOTO 100
180 DY = -DY
190 GOTO 100
200 DX = -DX
```

Son bitHn SPIEL

```
30  X=1 : Y=1
40  DX=1 : DY=1
50  IF X=0 OR X=39 THEN GOTO 120
60  X = X + DX
70  IF Y=0 OR Y=24 THEN GOTO 140
80  Y = Y + DY
90  POKE 1024+X+40*Y, 81
100 POKE 1024+X+40*Y, 32
110 GOTO 50
120 DX = -DX
130 GOTO 60
140 DY = -DY
150 GOTO 80
```