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Four Papers: Technological Trends and the Building Industry

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Foreword

The Advisory Board on the Built Environment (ABBE) provides advice to government agencies as our part of the general mandate of the National Academy of Sciences/National Academy of Engineering/Institute of Medicine/National Research Council. A further provision of this mandate is to make the results of our work increasingly available. This publication gives us an opportunity to make available, in a highly readable format, representative material from four of ABBE's major areas of concern. ABBE's interests clearly range from the advanced building technology of Japan to the philosophies of harnessing silicon, and technology for urban redesign in the United States. Sharing such knowledge with others is a tradition of these Academies that we gladly further by extending it to the building community around the world.

John Eberhard
Executive Director

Introduction

The Building Industry of the Future

At their autumn 1983 meeting, the Advisory Board on the Built Environment (ABBE) sponsored a symposium titled "The Building Industry of the Future" at the National Academy of Sciences in Washington, D.C. Established in 1981 as the successor to the Building Research Advisory Board (BRAB), ABBE is the research and advisory unit of the National Research Council that is concerned with issues of science and technology as they apply to the built environment. The symposium's purpose was to show some examples of how new advances in science and technology may affect the way buildings are designed, constructed, and operated. These breakthroughs are occurring here and abroad, and are taking place within the building industry itself as well as within allied fields, such as electronics and telecommunications. The symposium was attended by invited guests responsible for construction programs in federal, state, and local government agencies.

Four speakers presented papers on various topics, all of them involving advanced building technologies. This booklet incorporates the complete text of each of the papers, with selected illustrations from each of the talks.

Etsuro Suzuki, executive managing director of engineering at Japan's Taisei Corporation, presented a talk on Japan's view of future building program possibilities, describing in the process many of Taisei's areas of expertise. Denos Gazis, who is the assistant director of semiconductor science and technology at the IBM Research Center in New York, discussed computer technology trends that will eventually serve as powerful tools for managing and improving the built environment. The third presentation, by Ezra Ehrenkrantz, president of The Ehrenkrantz Group, an architectural firm in New York City, described a building diagnostics case study, involving the historic Woolworth Building in New York. Chairman of the ABBE Board Philip Hammer addressed the desperate need of American cities for revitalization, discussing how advanced technology could affect urban forms and functions.

Although the papers represented a disparate group of disciplines and emphases, they had in common a view toward future technology. We hope that this document will prove useful for reference purposes. For further information, contact The Advisory Board on the Built Environment, 2101 Constitution Avenue NW, Washington, DC 20418.

Etsuro Suzuki
Executive Managing Director, Taisei Corporation, Tokyo, Japan

The View from Japan of Future Building Programs

Introduction

Dr. Etsuro Suzuki, executive managing director of engineering at Taisei Corporation, has been with the firm for 40 years, 10 of which he has served on the board of directors. He received his Ph.D. from Tokyo University and is a member of the Architectural Institute of Japan and the Japan National Committee for Engineering on Ocean Resources.

Taisei Corporation is ranked first among Japanese firms for its total awarded contracts, which amounted to $4.5 billion in 1983. In addition, Taisei was ranked number 11 among international contractors. Because 40 percent of Taisei's sales are in the design/build sector, the Building Design Department has approximately 900 registered architects and engineers.

One of the characteristics of large Japanese contracting firms is that they have in-house R&D departments. Taisei Technical Research Institute was created 25 years ago on the advice of the Japanese Ministry of Construction. The Technology Development Department was established 15 years ago and currently operates with a staff of 200. R&D expenses are roughly 0.7 percent of total sales, or $30 million each year.

It is important that we go back about 10 years to show how the Japanese building industry has developed in terms of art and technology.

Ten years ago Japan suffered an oil crisis when prices jumped from $2.80 to $12.00 a barrel. Oil had been the "water of life" for Japan since the country was industrialized, with imported oil providing more than 90 percent of its energy supply. People thought that industry would grind to a halt when prices quintupled, and they rushed to supermarkets to stock up on consumer products. The second oil shock came soon after in 1980.

Prior to the oil crisis, the Japanese economy was growing rapidly with investments in both the public and private sectors increasing greatly. Housing starts were also up. After the oil shock, all investments declined rapidly, with the decline most significant in the private sector.

As a result, many industries, such as petrochemicals and shipbuilding, were forced into drastic change. The production of aluminum, a high-energy process, has shrunk to one-third of its original production during the last ten years.

In spite of these events, the GNP did not fluctuate drastically. How did the Japanese economy recover?

Industries struggled to reorganize their production and management systems and to save energy. The automobile industry applied total quality control systems and robotic technology to production processes and achieved a high degree of success. Factory workers, as well as top management, tried hard to conserve energy and produce high quality cars.

Building Industry and Technology During the Past 10 Years

Let us look at the building industry and technological innovation during the past 10 years. High-rise building technology, which had been researched for a long time, was established in the early 1970s. Ductile moment-resisting spaceframe systems became the main type of structural design for the lateral force-resisting system for high-rise buildings. The steel frame prefabrication system was also firmly established. During the 10 years after the oil crisis, these technologies were widely used in middle-rise and low-rise buildings.

It takes about five years for technological innovations to be assimilated in the automobile or mechanical equipment industry where the production process is completed in the factory. It takes more than 10 years, however, for technological innovations to be assimilated in construction where field work is a major part of the job.

In Japan, public and private sectors usually cooperate to overcome economic crises, such as the oil crisis, and, as a result, technological innovations are accelerated. Therefore, in order to forecast the nature of building programs for the 1990s, it is helpful to predict the construction investment trend and new demands in the 1990s that will have a strong impact on future building technology.

Prospects for Construction Investment in the 1990s

The following is a forecast for construction investment in the next 20 years. Government investment will begin to decrease in 1990 due to a capital shortage resulting from a larger number of elderly people. Private industry investment will not increase until 1990, since major investment by industry will already be completed. Private investment will increase after 1990 because industrial facilities built in the 1970s will be due for replacement.

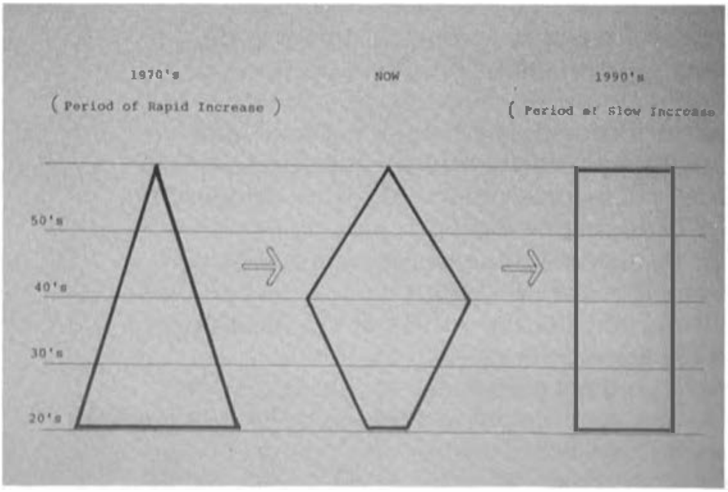
There will not be large increases in the housing industry. Renovation and improvement will make up most of the market because the number of housing units will be sufficient to accommodate housing demands. The Japan Project-Industry Council, JAPIC, will be expected to produce a large market for developers. JAPIC was established by the government and the private sector.

Let us look at the overseas market. Construction demand in developing countries is high, but prospects in the overseas market are not very promising due to the decline of construction investment by oil-producing countries. However, international projects, such as the second Panama Canal and the Silkroad Highway, give some hope. Therefore, Japanese contractors are relying heavily on the overseas market, especially because prospects in the domestic market are not very bright.

Japanese Building Industry in the 1990s

What is the future of the Japanese building industry? Leading Japanese building companies with engineering capabilities are headed for the international market. Major companies will reorganize their corporate structure by strengthening their international departments and creating or expanding their engineering and architectural divisions. Sales volumes from civil and building divisions now amount to 90 percent of total sales, and the sales volume from both the international and engineering divisions is about 10 percent. Currently, they are pushing hard to increase the sales from these international and engineering divisions to 50 percent of their total sales, reducing sales from the civil and building divisions by 50 percent.

Another significant change will take place in personnel administration. The bulk of the employees who joined their companies during the 1970s, the period of rapid growth, are now in the middle management class, with the average age in most companies being slightly less than 40. The triangular shape of the personnel age distribution structure in the 1960s has now become diamond shaped. This pushes up personnel costs and reduces productivity. We need to elongate this diamond into a more rectangular shape.



This chart diagrams employee age distribution throughout Japanese industry.

How can we do this? As you may know, we seldom let people go in Japan, and their salaries increase automatically as they get older. We feel that we have to change this system. We may not be able to lay people off, but we will be able to alter the salary structure. We will assign our employees to jobs based on capability, not age. Therefore, their salaries will be based on their achievements, which would signify a profound change from the present system.

To summarize the domestic market in the Japanese building industry in the 1990s: Public and private sectors will cooperate by initiating large development projects. In the overseas markets, leading companies will be strengthening their efforts by implementing innovative engineering techniques. One of the key factors in achieving this is changing the system of personnel management. There is a great need to challenge this controversial system in order to survive as leading international contractors in the 1990s.

Present Technology in the Building Industry

With this background, I will now go into a brief description of the research and development of building technology in Japan. First, let us discuss several of the results of research during the past ten years.

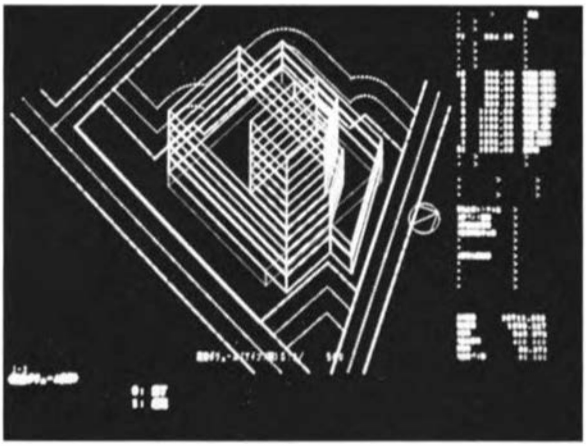
Computer-Aided Design Systems

Simultaneous computer-aided design and cost estimating is the first item I would like to cover. Taisei developed a computer program called "Spirit" that has the capability to:

1. Determine the building volume allowable by codes and other regulations;
2. Determine building layout; and
3. Produce an approximate cost estimate.

To operate Spirit, we first input site data (roads, neighboring lots, and so forth) and code and sunlight regulations. The latter place restrictions on the shadow time cast on neighboring lots by the new building. The output from the graphic display shows the allowable volume of the building.

By diagramming all of the requirements and obtaining the allowable volume, an optimum design can be produced. An isometric projection of the building can also be generated to aid in determining exterior wall materials and openings. By changing the command menu, various design configurations can be produced. After determination of building size, configuration, and exterior design, the cost per floor and breakdown data are calculated. A cost estimate with an error margin of 5 percent can be attained at this early stage without any time-consuming detailed planning. This frees



Taisei Corporation's "Spirit" program can determine the allowable building volume, determine a layout, and produce an approximate cost estimate.

the architect from the burden of these tasks and can reduce working time to less than 1/15 the time using conventional methods. In the 1990s, we plan to expand this into a total information system for the entire company.

Layered Construction System

Another recent development is the layered construction system. To develop it, Taisei started out with the following five goals:

1. To increase the speed of the construction process;
2. To reduce labor and materials;
3. To prevent noise and vibration;
4. To improve the quality; and
5. To improve safety.

Taisei considered the use of the prefabrication construction method that was best for achieving these aims and began using it in various limited applications in 1963. Feedback was continuously gathered and evaluated, and research was conducted on all sizes of buildings, and on the systematization of the construction process.

Through the construction of the Tokyo wholesale center, which made prefabrication of large buildings possible, and Nishihachioji Heights, which made prefabrication of high-rise buildings possible, a new system, the layered construction system, was realized.

With constant improvements being made, there has developed a variety of construction technologies to meet customers' diversified needs. Currently, prefabricated columns, beams, floors complete with ducts and pipes, exterior walls and bath units are built up simultaneously with the construction of the steel frame. The

A prefabricated exterior wall panel, complete with window, shown being lifted into place.

The Taisei Corporation headquarters building, the 54-story Shinjuku Center, was built by means of a layered construction system.

layered construction system was used in the construction of the 54-story Shinjuku Center building, the headquarters for Taisei Corporation.

Prefabricated Housing System

Taisei has developed a prefabricated housing method called Palcon, composed of a concrete detached housing unit which has been on the market over 10 years. During this time, approximately 10,000 units have been sold.

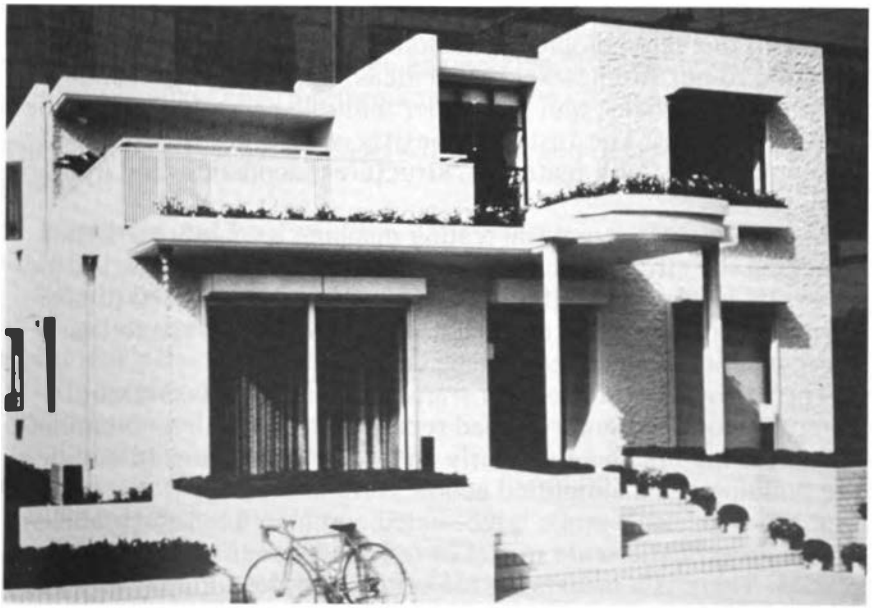
The new model has the benefits of increased energy conservation for the owner and increased productivity for the constructor. Exterior wall panels are insulated and are 30 inches wide by 90 inches high by 7 inches thick. The maximum temperature differential between the interior and exterior is 15 degrees. In addition to energy efficiency, these units offer excellent fire and earthquake resistance and are extremely soundproof and durable.

Funabashi Green Heights, the largest private housing development project in Japan, consists of an integrated multiple-home core of 2,200 units and various related service facilities such as supermarkets and variety stores. This development, situated on a 277-hectare plot, stands as testimony to Taisei's preeminence in the field of prefabricated housing.

One of the prefab housing systems on the production line.

Exterior wall panels (shown here being lifted into place) are insulated and are 30 inches wide, 90 inches high, and 7 inches thick.

This view is of the exterior of one of the prefabricated concrete detached housing units developed by Taisei.



Future Technology in the Building Industry

The Council on the Development of Construction Technology, which is a joint organization established by the Japanese government and private industry, has defined 10 guidelines for research by the government during the next 10 years. They are:

1. Land conservation safety and disaster prevention;
2. High utilization of space;
3. Efficient utilization of resources and energy;
4. Maintenance and management of public wealth;
5. Improvement of productivity in the construction industry by electronic technology;
6. Improvement of the living environment;
7. Conservation and improvement of the environment;
8. Integration and rationalization of transportation systems;
9. Improvement of information systems; and
10. Contribution to international cooperation.

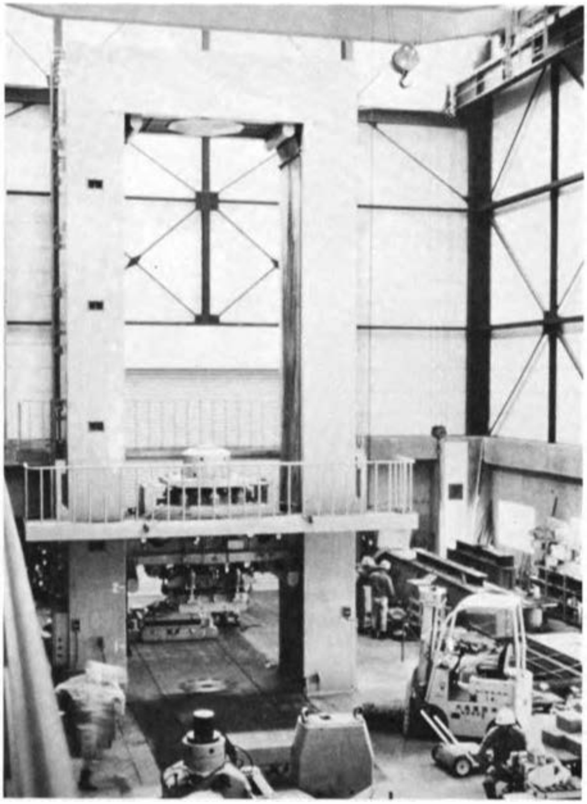
In addition, private companies are making advances in their own R&D programs.

The construction industry is about to enter an age of increased competition in technology and sales engineering. Under such circumstances, it must be able to provide better technology and services to meet a broadening range of needs that are expected to arise in the future.

The Technical Research Institute of Taisei Corporation is the first of its kind created in the construction industry in anticipation of the coming age of technology. The Institute works in cooperation with the Technological Development Department of the corporation to nurture new technical ideas, improve basic technology, provide services, and play other multiple roles to broaden the firm's prospects. The Institute consists of laboratories equipped for experiments with materials, structures, acoustics, and hydraulics.

The large-scale structural testing machine is mainly used for checking the strength and stress of various parts of full size structures. Its loading capacity is 500 tons sf (tension), $1,000 tons sf (compression), and it is equipped with a control device so that a low-cycle fatigue test can also be conducted.

The reverberation room for transmission loss measurement comprises a rectangular-shaped receiving room with a volume of 220 cubic meters and a similarly shaped source room. In addition, the building has a simplified echoless room (196.5m^3), reverberation room (52.5m^3) and a large-scaled common experimental room where an acoustic scale model or full-scale specimen can be placed. There is a measuring room in the center for centrally pro-



Taisei's Technical Research Institute consists of laboratories equipped for experiments with materials, structures, acoustics, and hydraulics. This is the large-scale structural testing machine.

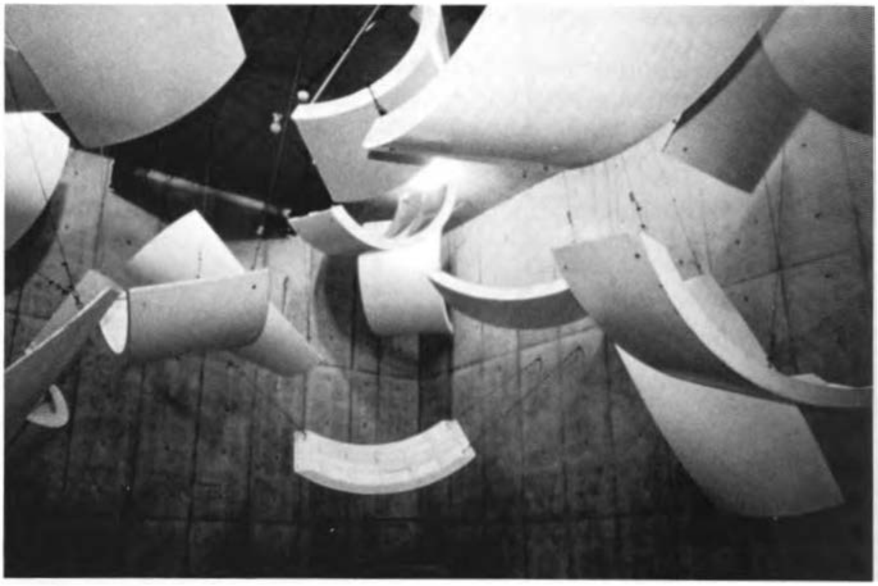
cessing signals from each test room.

Cyclic triaxial test equipment is used to investigate the dynamic behavior of soil for earthquake engineering. Maximum lateral pressure is 10kg^f/cm^2 and frequency can be changed up to 15Kz.

The following is a list of Taisei's research and development programs.

1. Resources and Energy

- Oil storage facilities
  - —Bedrock storage
  - —Underground tanks, etc.
- Nuclear power plants
  - —Underground facilities
  - —Prestressed concrete
  - —Containment vessels
- Nuclear fuel facilities
  - —Reprocessing plants
  - —Waste storage recommissioning
- Seawater uranium recovery systems



A view of the reverberation room, used for transmission loss measurement.

The three-dimensional vibration table is used for earthquake engineering tests.

- Offshore wave energy power plants

2. Offshore and Marine Structures
- Offshore airports
- Offshore platforms
- Road across Tokyo Bay
- Concrete barges
- Multi-cell structures

3. Building Environment and Energy Conservation
- Biological and industrial clean room systems
- Building computer control systems
- Energy conservation
- Information network systems
- Variable air volume ductless systems

4. Computerization
- Computer-aided design
- Computerized planning system
- Project management system

5. Construction and Civil Engineering
- Mechanized construction
- Measurement and control systems
- Robots (spraying robot, etc.)
- Water jet systems
- Long-span bridges
  —Measurement and control systems
  —Concrete suspension bridges
- Reinforced concrete
- Layered construction systems

6. **Plant Engineering**
- Pharmaceutical and food plants
- Automatic storage systems
- Production facility engineering
  —Automatic plating systems
  —Ice plants
- Parking systems

7. Housing
- Prefabricated houses

In order to strengthen further its research and development capabilities, Taisei has constructed a new Technological Research Center in Yokohama that is fully equipped with large-scale testing facilities.

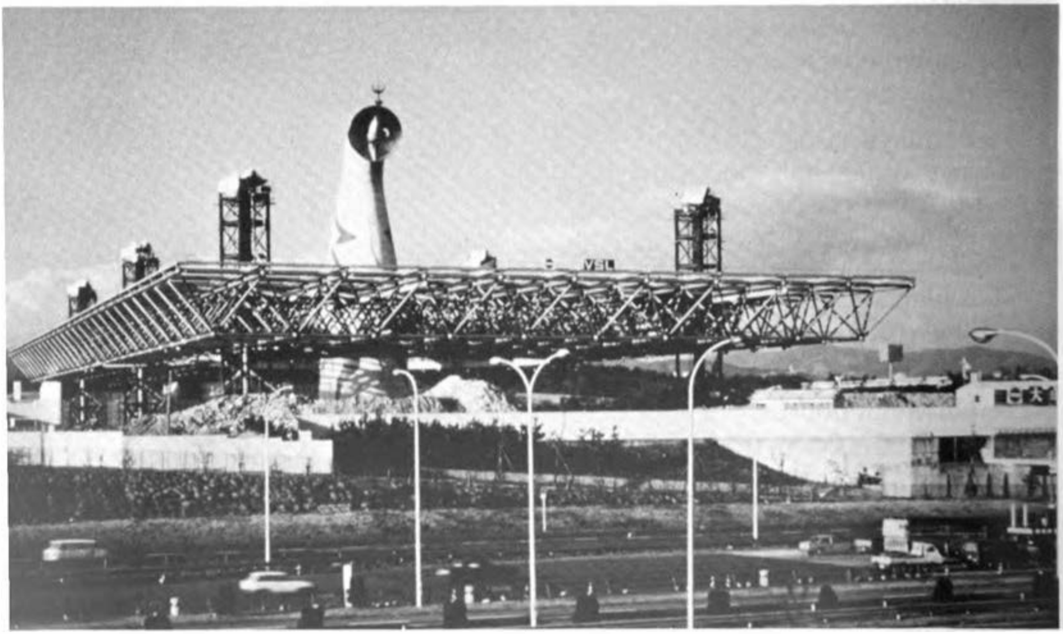
Robotic Technology and Computers

Robots and computers will play a significant role in the construction industry in the 1990s. Recently, the Ministry of Construction has taken a leading role in promoting a joint program for the development of robots and computer systems for construction.

The following is a list of some of the possible uses of robots projected for the near future:

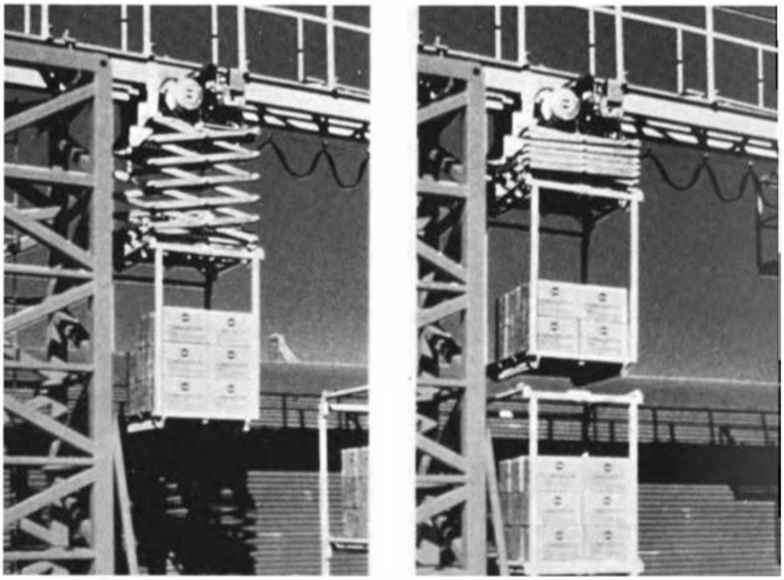
1. Construction Technology
- Robots for erecting steel structures
- Robots for welding at site
- Conveyor systems for precast concrete plants
- Robots for finishing concrete floors
- Robots for erecting and dismantling scaffolding
- Robots for cleaning onsite
- Robots for applying sealant to exterior walls
- Robots for painting exterior walls
- Robots for decommissioning

2. Supplementary Technology
- Systems for cleaning floors in factories
- Robots for disaster prevention
- Robots for extinguishing fires

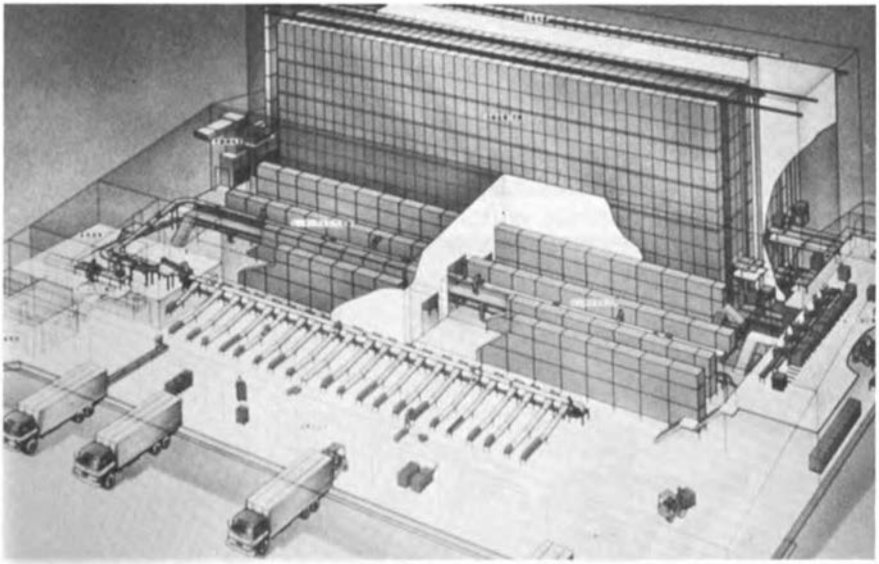


The roof on this building was lowered using robot-operated jacks.

A conveyor system using robots.



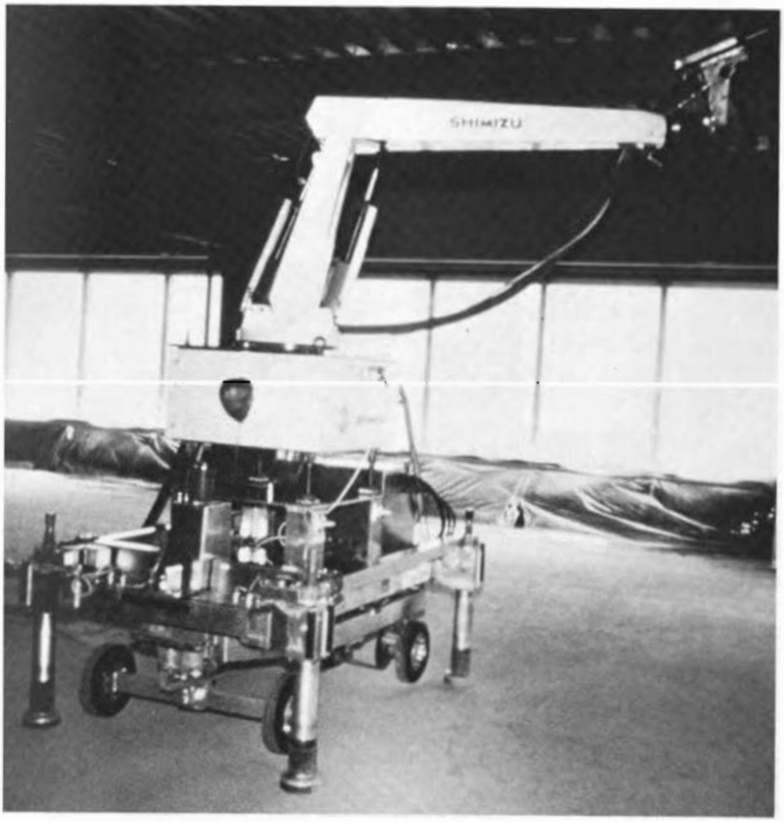
The "TASH" system is an integrated storage system using automatic conveyors and control systems.



Taisei has developed several robotic systems, two of which I would like to describe.

The "TASH" (Taisei Automated Stock Handling) system is an integrated storage system using automatic conveyors and control systems. TASH can be installed in multi-stage rack warehouses (maximum height of 28m) or medium- or low-rack warehouses.

Taisei's "Overhead Carrier Parking System" operates in a manner similar to the TASH system, but by adding an elevator, a high-



A robot spraying fireproofing materials.

A robot employed in spraying lining material in a tunnel.

rise storage system can be achieved. Cages can be stacked providing efficient use of space and an average retrieval time of 2.5 minutes.

Other Japanese firms have developed robots which provide various functions. Shimizu Construction Company has developed a robot which can spray fire-proofing materials twice as fast as a man. Similar robots are used in applying the initial lining of tunnels.

Conclusion

In my view, these are the prospects for Japanese building technology, with the application of robotic and computer technology in the 1990s. These projections are based on three very important assumptions.

1. The Japanese economy will not face any drastic changes because Japan will be politically stable due to the strength of the liberal Democratic Party.
2. The land system will not change. Land in the cities is divided into small parcels and is individually owned. The employment of eminent domain is rarely used which makes it difficult to assemble large parcels of land for urban development. If the land system were changed, development activity would increase, thereby increasing construction demand.
3. There will not be a devastating earthquake. The 1923 earthquake in Tokyo destroyed three-fourths of the city and killed more than 200,000 people. If another earthquake with a magnitude of 7.9 were to occur, it is projected that 100,000 people would be killed or injured, and more than 500,000 of the housing units would be destroyed or damaged. In order to predict strong earthquakes, more than 1,500 seismic monitors are installed throughout Japan. I hope that this will not occur and that Japan will maintain its steady growth.

Denos C. Gazis
Assistant Director,
Semiconductor
Science and
Technology, IBM
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Yorktown Heights,
New York

Trends in Computer Technology and Their Possible Impact on the Building Industry

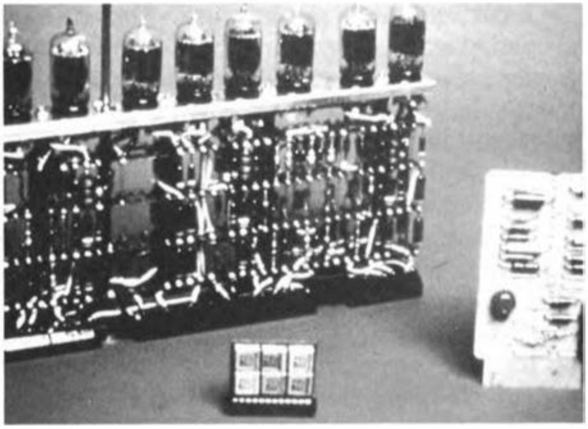
I would like to approach the subject of my talk as an optimization problem. For that we need a statement of objectives, an enumeration of constraints and control variables or tools, and finally a blueprint for the use of these tools to achieve the objectives. In view of my background, I will be brief in my discussion of objectives and rather effusive in my discussion of computer technology as a tool. My blueprint for the use of this tool will also be rather sketchy, since I see the definition of this blueprint as the task for all of us in this room during the coming years.

Let us start with a statement of objectives. At one end of the spectrum, the objective of the building industry is to provide adequate shelter for everybody. Indeed, this has generally been accepted as a primary duty of the government, even more so than the private sector. At the other end of the spectrum, we have Toffler's message of the "third wave." In our case, the message is one emphasizing the diversity of opportunity and choices which can be made possible through advances in technology.

There are many examples indicating that people often want to be different in the design of their habitat. A related observation is that the longevity of architectural styles has been decreasing over the years. The Roman style lasted some 800 years, the Gothic 400, the Renaissance 300, the Revivalist 100, and current modern ones last less than 50 years. I submit that computers can help make this change, and the diversity of choice, easier for everyone.

This brings me to the discussion of the tools at hand—technology and, particularly, computer technology. Let's see where this is going. Let me say at the start that if you make one very key observation in the computing industry, it is going to be the following: over the years we have been improving the existing technology in order to build better computers. At the same time we have been preparing alternatives to the technology in use. Someone estimated that had we stayed with vacuum tubes, one of our big computers, the IBM 3081, would be about as big as the Houston Astrodome and require the Gulf of Mexico to cool. Unfortunately, it would be unusable because the mean time between failures would be shorter than the machine cycle. That shows the need for alternative technologies.

Now let's go through some of the elements of the computing industry and see what's happening—starting with logic and memory. In logic and memory, the nuts and bolts of computing, the existing technology is silicon semiconductor technology. This is being pushed very hard, at the same time that alternatives are being sought.



Vacuum tubes at left, discrete transistors at right, microchips in front—this photo shows how computer technology has changed over the years.

Let's examine silicon technology first. The main objectives are to make things smaller, faster, put more functions on a chip, and lower the cost. Incidentally, by making things smaller, one achieves most of the other objectives, because when you put more function on a piece of silicon real estate, it becomes cheaper and intrinsically faster. You also stay on the same chip instead of wasting time traveling from chip to chip. So smaller is the name of the game.

Another key observation, however, is that all computers are not created equal. There are different kinds of them. Sometimes I am asked, "What is the difference betwen a microcomputer and a mainframe in view of the fact that a microcomputer today has the power of a mainframe of yesterday?" In fact, my own personal computer, I estimated, has about as much power and storage capability as IBM Research provided to the entire lab when I joined IBM—and I'm not that old. It is true that we have made so much progress that the lines between large and small computers appear to be blurred, but they are not really. We really have a spectrum of computers. At one end we have what we call the power-limited computers which have a lot of MIPS—million instructions per second capability. The silicon chips for these computers have a relatively low level of complexity of integration. They are the simple ones, but also the powerful ones. At the other end of the spectrum, there are few MIPS but very complex chips in order to drive down the cost and space. So, if you look at the insides of the computers, at one end you have the few, fast devices per chip, that are easy to design, costly to manufacture, and optimized for low volume. At the other end, you have the chips that are optimized for high volume and for millions of units. They are complex chips that take a lot of effort to design but can be produced relatively cheaply.

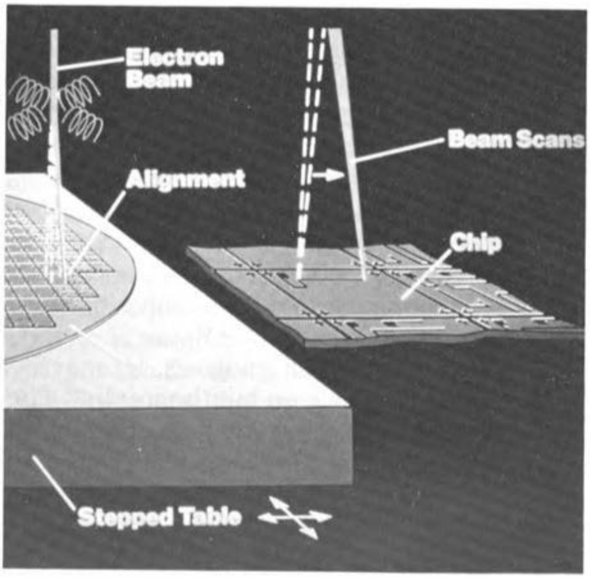
Generic families of chips are substantially different in these two areas. At one end we have the so-called bipolar devices—the high-power chips. At the other end, we have the low-power chips, mostly field effect transistors. I'll give you just a few highlights of their rate of improvement.

First, let me give you a few numbers. Currently our bipolar devices have minimum line widths of about 2½ microns. That's about 1⁄40th of the diameter of a human hair. Their switching speed is on the order of about one nanosecond. I don't know if you have ever stopped to think how small a nanosecond is; there are as many nanoseconds in a second as there are seconds in 30 years. So it's a very small quantity. We are driving these switching speeds down further by using better designs, making them smaller and packing them closer together. We are moving toward speeds measured in a few hundreds of picoseconds. By the way, the picosecond is *really* a small quantity. There are as many picoseconds in a second as there are seconds in 30,000 years. We are driving these devices to the point where we expect that long before the end of this decade we are going to be using devices with dimensions half as thick as what we have today, 1½ microns, 1¼ microns, or even less than that. Their speed will be hovering in the range of 100 picoseconds.

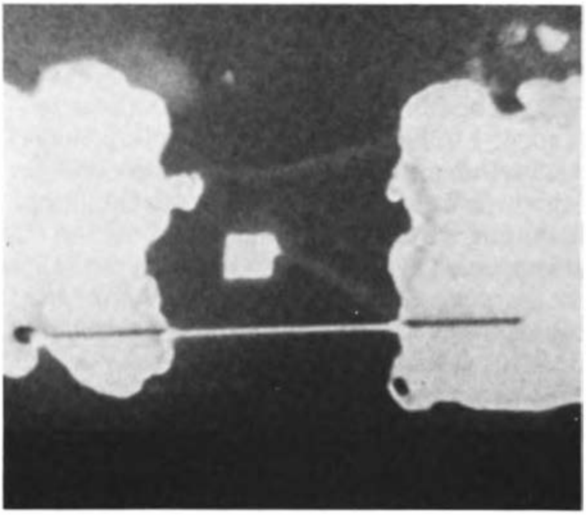
Let me just point out that in 100 picoseconds, light travels only 3 centimeters. Unfortunately, Einstein proved that nothing travels as fast. In fact, electrons travel half as fast or less. So we are running into another bottleneck. The speed of light is excruciatingly slow for our purposes. In order to capitalize on the speed of our devices we must pack them very close together, so packaging is becoming the battleground. How do you pack all of those devices into a small space and dissipate the heat that they generate? Let me give you some interesting numbers. Currently, the chips in our big computers dissipate four watts per chip, and we have them enclosed in something that we call the Thermal Conduction Module that has a hundred of them, 400 watts altogether. By slightly later than the middle of this decade, we are talking about having 25 watts per chip and by the end of this decade, maybe 100 watts per chip. That will translate into 10 kilowatts in a volume just bigger than a fist. Silicon would bake very rapidly at that temperature unless we are able to remove the heat. We are going to do it, of course, and we are going to gain a factor of roughly 10 in raw speed of the circuits in less than 10 years.

Let's go to the other end of the spectrum, the field effect transistors. They have been shrinking with their linear dimensions scaled down roughly at the rate of about a factor of two every three to four years. I should mention in passing that scaling is a tricky business; that's why an ant doesn't look like a miniature elephant. You've got to do it right and solve all sorts of associated technical problems. But we are doing it, and currently we are already moving past the 64 kilobit chips to the 256 kilobit memory chip. By 1986 you can expect 1 million bits per chip, and by 1990 to 1992 you can expect something on the order of 4 million bits per chip. You can see how this will translate into greater availability of memory at any level, including that of a personal computer.

How do we achieve this progress? We achieve it, of course, with all sorts of associated processes that have to be developed. One key process is lithography. Currently, most of the chips are made photo-lithographically, by etching patterns of successive layers on a chip. Sooner or later we will run out of steam in optical lithography. I should mention, by the way, that optical lithography, when challenged, improved even beyond our expectations. About five years ago, we thought that 1½ micron would be the limit of optical lithography. We are now projecting that we will go down to ¾ of a micron or below. Because of the wavelength of light limitation, we are going to run out of steam some day. So we are developing alternatives—X-ray lithography is one promising alternative. One particular configuration involves an intense X-ray beam which is spread with an oscillating mirror in order to expose the "resist" (an X-ray sensitive material) on a chip and produce patterns. The beam is produced by a synchrotron radiation in an electron storage ring. There are very few of these in the world. In this country there is one in Brookhaven, where we've instituted a



This photo is an enlargement of a photolithographically etched silicon chip.



Shown here is one of the thinnest lines created in a laboratory with an electron beam.

joint study in order to develop this technology. Once we do, we expect to scale the storage ring down from 15 meters to something more appropriate for a manufacturing facility. I should say that X-ray lithography appears to be extremely promising even for not-so-small dimensions because it has good depth of field, much better than that of optical lithography.

Beyond X-rays, the ultimate shrinkage of dimensions is obtainable with electron-beam lithography, which has been developed extensively over the years. We now have the capability of writing directly within an electron-beam pattern on a special resist that can produce the patterns of semiconductor devices. This is a computer-controlled arrangement, of course. It is not as fast as optical or X-ray lithography in terms of turn-around time. That's why it hasn't been used extensively. It is already, however, being used at the last stages of chip personalization, and some day will probably be used to achieve very small dimensions.

As I said earlier, this is the story of silicon; we are pushing it, and we are going down to dimensions of a quarter of a micron, and maybe slightly below that. At some particular point, we all suspect that we are going to reach a point of diminishing return. The question is, what next?

Before discussing alternatives, let me ask a parenthetical question: How far can we go in lithography? The line in the photo is 12 nanometers wide, or, as it is better understood, 120 angstroms. A good comparison is that it's about the thickness of a virus molecule. This line, incidentally, was created accidentally at Yorktown. We call this capitalizing on new opportunities in research. It so happened that we had some impurities in a vacuum chamber that created this fine mask in conjunction with an electron beam. It allowed us to create this micro-bridge which is very thin compared to the white areas which are one micron thick. Now, at those very small dimensions, materials have different properties. We are currently doing some basic research in order to understand what you can do with those bridges. It is conceivable that somewhere down the line one might expect to use those extremely small bridges in order to make devices.

Now, let me go on to a more viable alternative to silicon which is gallium arsenide. Gallium arsenide is pursued because it is intrinsically faster than silicon. The mobility of electrons is more than five times greater than that of silicon over a given range of the electric field. Let me just say at this particular point that silicon is here to stay for a long time. Sometimes I think that God was trying to give us a message by giving us so much sand. Sand is mostly silicon, and it's there for us to use. It's cheap, it can be fabricated into single crystals, and then baked and processed in order to make all of the things that we need. So don't expect silicon to be displaced too soon. Gallium arsenide, however, as I said, has a possible role to play for applications where we need its high raw speed. It will be used, undoubtedly, for special devices first of all, and later for computer-like devices.

Let us go on now to something more interesting. How do you translate this technology into a system? There is a lot of work going on in order to improve the large systems used for general purpose applications, or for engineering and scientific computations. Then, of course, there is work going on in communications, data bases, and other ancillary technologies.

Let me backtrack a little bit to show what has been happening to computer systems over the years. The early von Neumann computers were relatively simple things. They had a simple central processing unit (CPU) and a simple memory box. Everything was done by the central processing unit—input and output included. Everything was done one operation at a time; one instruction was requested, executed, results were stored, etc. Pretty soon it became apparent that this was not the way to run a computer. Currently, a typical high-end computer has a much more complex configuration. There is another level of memory that is known as cache, which stages the flow of information from the main memory to the CPU. Some vestigial processing elements, called the channels, do the input/output to relieve the CPU from this onerous task. The entire orientation of the design of computers has been to utilize the machine cycles as efficiently as possible.

There are two things that make a computer fast—how small its cycle is, and how few cycles are required on the average to execute a single instruction. For example, the IBM 3081 has a cycle of 26 nanoseconds, and executes an instruction in about 4 cycles. That gives it the power of 10 million instructions per second—10 MIPS. We know where technology is taking us and we know that by 1990 or so, we will be talking about cycles of well under 10 nanoseconds. That is not enough, though, because the demand for computers is increasing at the rate of 40 percent per year in terms of required MIPS in a single installation. The only way we can make up for the deficiency in a uni-processor is by cutting down the number of cycles per instruction. There is a lot of work going on in order to improve the so-called "pipelining" inside the computer, to do things concurrently as much as possible, to off-load the input/output into a full-fledged processor, and so on, aiming at something like two cycles of instruction by 1990. When this is added to the improvement in technology, it can give us a possible factor of 10 in overall power. If you make an extrapolation on what the computers will look like, instead of being the simple boxes that we started with, they will be very complex. They probably will be very complex assemblages of CPU's, each one with its own memory; one for applications, one for input/output, one for telecommunications. All of them will be glued together with another level of storage that we're beginning to call the system memory, which will manage the flow of information from one of these CPU's to the other.

Let me say something else about a development that is beginning to affect everybody—the PC. PC's have surprised even their staunchest supporters with the ease with which they were introduced into our lives, particularly in the offices today. Currently, most PC's have dual usage. One of them is as a stand-alone computer; the other one is through a public exchange or through cable connection, accessing a mainframe as a dumb terminal. In switching from one mode to the other, you have to switch environments. You have to go from the DOS environment (the Disk Operated System of the PC) to the mainframe environment.

A trend is beginning to emerge, leading to a "single system image" in which we are going to be using a hierarchy of computers transparently. We are going to have a much more powerful PC before too long, which will be able to pass upward to various levels of a mainframe hierarchy "virtual system commands." Without having to take any special action, we will move from one level of the hierarchy to the other and do our thing.

Let me now switch gears a little bit and talk about another topic. There are certain things in life which are constrained by human dimensions. Cars are among those things. You cannot micro-miniaturize cars. The input/output devices that we use in computing are also in the same category. Unless we make tremendous breakthroughs in genetic engineering and shrink the dimensions of users, we can expect to be constrained by the dimensions of the input/output devices as we know them today. But we can make their insides better, and there is a lot going on toward improving displays, printers, and special terminals with more human, or friendlier, properties.

Let me talk about displays first. In displays the existing technology is cathode ray tube (CRT) technology for a number of reasons: improved phosphorus so we can have a better picture, improved storage capability to eliminate the need of refreshing the picture, and multi-beam CRT utilizing thin-film technology. In the latter, you can actually have several electron sources in the space where we now have a single electron gun. In this way we can achieve higher resolution, less flicker, better human factors in general, or a combination of all of those things. Another interesting alternative is the gas panel display which appeared recently in the marketplace. In fact, some special experiments are going on using that display in our laboratory. Since it is flat, we have integrated this into the surface of a desk. By putting a writing surface on top of the display, we can have both an input and an output capability in a configuration familiar to us, the surface of a desk. This is what we are beginning to call an electronic desk, which may give you the capability of communicating with a computer using a familiar desk top surface as an interface. If you do not like it, you can always cover it up with paper and have an ordinary $10,000 desk.

Another interesting alternative to the CRT display is the Laser Liquid Crystal Display developed in our San Jose Research Laboratory. It consists of writing on a liquid crystal with a laser in combination with optical fibers and then projecting the contents onto a large screen. The display is capable of very high densities of information, about 64 million picture elements, almost two orders of magnitude higher than that of a CRT.

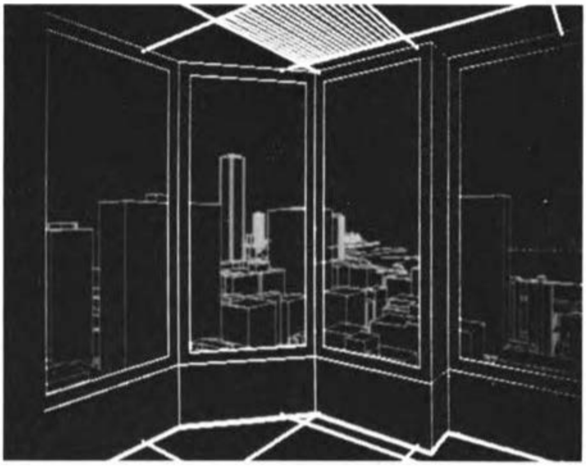
As far as printers are concerned, I will only mention some recent progress in a relatively new class of printers, the ink-jet printers. Most of the commercially available printers use a single nozzle to generate the stream of droplets that are selectively placed on paper after being electrically charged and guided in the proper direction by an electrically charged plate. An obvious improvement would be to use an array of such nozzles in order to increase the speed of printing. One could then sweep across the page and paint it all black. By deflecting the unneeded droplets, you could leave only the needed information on paper. I call this using the Michelangelo principle: he said once that in every piece of marble there is a masterpiece—all you have to do is remove the pieces that you do not need.

An even better solution, which eliminates the unnecessary movement of ink, is the so-called Drop-on-Demand ink-jet technology in which droplets are generated only when and where needed through piezoelectric excitation. We have already produced experimental printers of this type, some with color capability, which promise to revolutionize our printing facilities and the associated copier hardware.

Let me now close with a discussion of some computer applications, virtually all of which are likely to affect us in the coming years. Teleconferencing, combining computer and communications capabilities, will permit a "live" link between two or more establishments, making possible the interaction of varying subsets of the residents of these establishments to suit the needs of an evolving conference need on a minute-by-minute basis if necessary. Audio message services are already making it possible to have access to an audio mailbox back home in real time while traveling around the world, without the frustration of unsuccessful attempts to establish a "live" connection with colleagues. Speech recognition of increasing complexity is being developed, as sophisticated as the recognition of continuous speech, although with a vocabulary of only 1000 words and requiring the expenditure of considerable processing power.

Some applications are closer to the heart of the building industry. One of them is robotics. We already heard from our Japanese visitors about the extensive use of robots in the Japanese construction industry. Within the next 10 years, we can expect this use to expand and become more versatile through two important developments: the coordination of two mechanical arms and some form of vision. A related application is the modeling of three-dimensional shapes for display on a screen or for guiding the path of a mechanical arm. Such modeling has already been introduced in architecture, allowing for the viewing of the results of architectural changes in short turn-around time, and also such valuable aids as "the view from within" a proposed structure before it is built.

Finally, I would be remiss if I did not mention what is viewed by many as the ultimate evolution of the computer, the infusion of some human-like intelligence in computing systems. An interesting and very promising implementation of the concept is known as the expert system. It consists of capturing the knowledge of an expert on some subject and organizing it in the form of a decision tree along which an inference path can be followed using a sequence of if-then statements. Not every aspect of human activity



The modeling of three-dimensional shapes for display on a screen is very useful in certain disciplines, such as architecture and engineering; shown here is the "view from within" a proposed high-rise structure.

appears to be reducible to such a logical structure, but the ones that are give promise that computers can at least multiply the availability of expertise by large factors. Once the expertise is captured, a non-expert may use the expert system as a consultant, supplying data, and receiving partial answers as well as requests for additional information needed to resolve ambiguities. The expert system even explains its reasoning, in order to gain the confidence of the user, all in conversational English. Some expert systems have already been built and used in medical applications, in oil exploration, and in diagnosis of faults of computer hardware.

We do not know how far the evolution of computer systems with reasoning power can go, but we know that we only have scratched the surface thus far. "Intelligent" computers will not duplicate human intelligence exactly, but will supplement it in a way that is certainly going to change our approach to many tasks in our business and private lives. Perhaps I should conclude with a remark of Herbert Simon's concerning intelligent computers. He said that in the long history of mankind there have been some momentous events that had a profound influence on the human race. Agriculture was one of them, since it changed humans from roaming predators to social animals. Simon thinks that space exploration was another, since it gave us a dramatic view of the feebleness of our little planet, the "spaceship earth," when we saw pictures of our planet taken from thousands of miles away in the vastness of space. Simon feels that the emergence of intelligent machines will be another profound influence since it will change our image of ourselves as the only intelligent entities on this planet. I may add that perhaps it will also give us the proper degree of humility to prevent us from blowing up this little planet of ours prematurely.

Ezra D. Ehrenkrantz
President, The Ehrenkrantz Group,
New York, New York

Building Diagnostics: The Woolworth Building

I am very pleased to have the opportunity to present our work on the Woolworth Building in New York City as an example project. Building diagnostics played a significant role in determining the methods and details through which this building could be effectively restored. It is most gratifying to me that this ABBE Symposium is presenting papers dealing with both new building techniques and technologies, and the rehabilitation of existing facilities. In any given year, perhaps two percent of the total building stock is added by way of new construction; the other 98 percent must be maintained, renovated and, in some cases, restored.

With regard to both new and existing buildings, which I have the pleasure of dealing with as chairman of the ABBE Committee on Building Diagnostics, we are searching for new methods and tools to determine building performance. The determination of what is a healthy building in terms of the building fabric, its environment, and the services that support human activities creates a significant area for new work, and perhaps even the establishment of a new field. It is in this regard that I believe that our efforts in restoring the Woolworth Building will be of some interest.

Our work on the Woolworth Building was initiated by a material failure; a few pieces of terra cotta fell from the top of the building to the street. Fortunately, it happened at a time of day when nobody was on Broadway so there were no injuries. The Woolworth Company immediately called the Turner Construction Company and The Ehrenkrantz Group. Together with Turner, we brought on board Wiss, Janney, Elstner and Associates as engineering consultants and set up a team to take a look at what was an extremely interesting problem. The work was spearheaded primarily by three individuals: Glenn Little of the Turner Company; Jerry Stockbridge of Wiss, Janney, Elstner and Associates; and Carl Meinhardt, one of my partners in The Ehrenkrantz Group. This trio, working with an interested and enlightened group within the Woolworth Company, was the core team through the entire diagnostics and repair process. We were faced with a situation where it was necessary to diagnose what was wrong with the building, and then to develop a solution for the exterior repair.

At that point, the Woolworth Company had to consider replacement strategies, such as vacating the building totally or shielding it in other materials, and the disruption that those strategies would cause. There was also tremendous concern about damaging the visibility, the aesthetics, and the landmark attributes of the building (although it was not then an official landmark structure).

The process was very much like an auto mechanic's analysis, in that we had to check out one item after another. We developed

The Woolworth Building in New York City.

procedures for doing this analysis, which we have since used on many buildings. In some ways there is a very close relationship to the medical field in terms of diagnosis; we have drawn many analogies and, as we take a look at the Woolworth Building, we think of it more in terms of pediatric medicine or veterinary medicine than human medicine, because the building obviously cannot talk to you and describe its pains. We can only look and analyze the symptoms and try to determine what the problems are.

When the terra cotta pieces fell off the building, there were a number of possible causes. We were particularly concerned with the freeze-thaw problem, so we looked at different orientations of the building to see from which direction the winter winds came. We took a look at the south side and tried to identify patterns of deterioration. The building would freeze at night and thaw during the day for a good part of the year and go through many more freeze-thaw cycles on certain facades. We were looking at the implications of wind, moisture penetration of the building, localized failure through rusting of steel—a variety of things that may have been associated with differential movements, settlements, the building up of pressures in the skin of the building, etc. There were many different possibilities that could contribute to such a failure. At the beginning of the project, we put a large mesh "body stocking" over the more exposed and deteriorated parts of the building, and a bridge over the sidewalk to protect pedestrians.

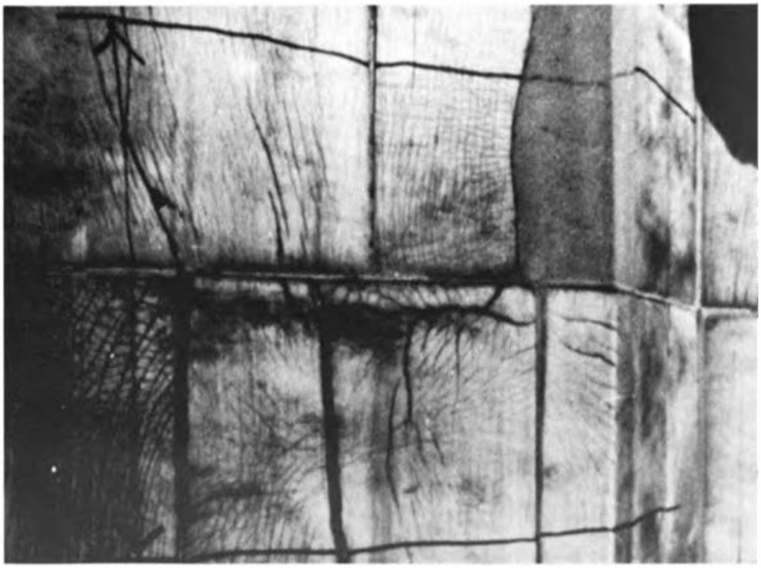
With this introduction, I would like to explain the process through which the team analyzed and restored the building. Construction on the Woolworth Building, which was designed by Cass Gilbert, began about 1911, and the building was completed in 1913. At that time it was the tallest building in the world. We were able to gather a limited amount of information on the design of the building in the form of photographs and some shop drawings, but almost none on the actual construction process. However, the materials that we did find were crucial to our process. We learned that the Woolworth Building was built without expansion joints (which were only developed in 1920), making it perhaps the tallest building that ever was, or ever will be, built without expansion joints.

The construction was very rapid, using masonry terra cotta for exterior cladding material. The building itself is composed of a base, the tower, and a series of different decorative elements like the turrets and balconies that you see at the top. Decorative elements of different levels of complexity were applied at certain conspicuous points. Many of the overhanging elements were more significantly deteriorated than the main body of the building. As we analyzed the building, however, we did not find wind motion, freeze-thaw cycles, or rusting to be critical factors. We found that the original terra cotta consisted of a poor quality material.

The basic clay bisque was coated with a glaze and fired. The glaze had a higher coefficient of expansion and contraction than the bisque itself. When it cooled, the glaze contracted more than the bisque, which caused hairline cracks to occur throughout the terra cotta material. At that time, limited knowledge about this material permitted it to be accepted under those conditions. Tests done by Wiss, Janney, Elstner showed that the terra cotta absorbed water as quickly with the hairline cracks as with all of the glaze removed. As a result, the building turned out to be an extremely wet building.

Other types of failures were typical of what we found throughout the building: bulges and gaps caused by the rusting of steel supporting members underneath the terra cotta surface. These bulges occurred in many places, because the material was in relatively poor shape. Repairs had been made in localized areas over periods of time but, in spite of that fact, many cracks opened up in those locations.

One of the things we discovered is that people who maintain buildings but do not understand the root of the problem actually exacerbate the problem. Filling in a crack without getting to the cause of the problem may result in a widening of the crack, and the cycle of rusting will open it even further. By sealing portions of the crack but leaving other places where water can still get into the building, you may accelerate the deterioration process.



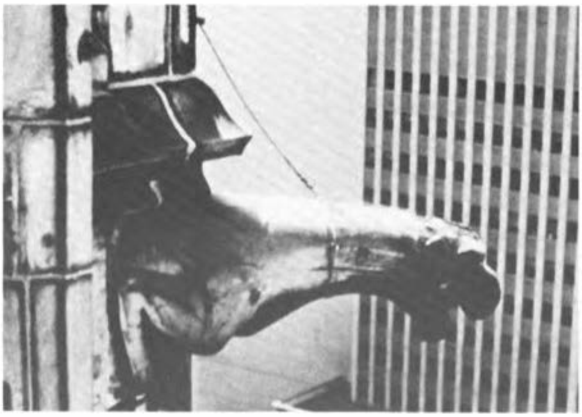
This closeup photograph shows the hairline cracks appearing throughout the terra cotta.

The building did have a considerable amount of consistent maintenance work performed on it, but the repairs did not work over time. In many places, wiring was found holding pieces in place. In one case, a steel member underneath the sill was rusting. An attempt was made to tie down the sill against the forces of the rust that were raising it. Again, the repairs didn't work over time. Ultimately, we inspected and actually tapped every stone in the building. As a result some material was removed by hand.

We began to investigate a series of analytic approaches, checking out reasons for bulges, the extent of rusting, and the deterioration of both structural and exterior members. We recognized that when clay products get wet, they frequently expand. When they dry, we hope they contract as much as they expanded.

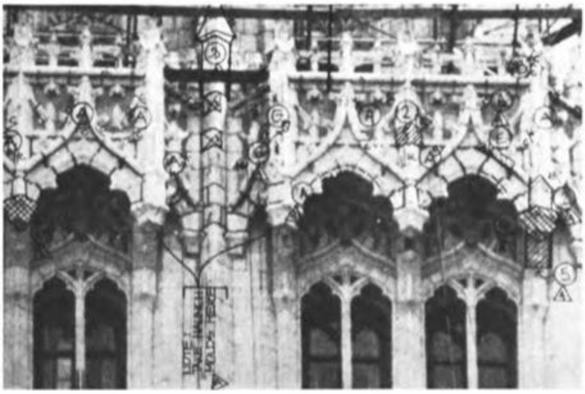
We also found that the clay used for the terra cotta bisque in this case did not contract as much as it expanded, and it grew over time. By checking out all of the possibilities that could cause a pattern of deterioration, we came to the conclusion that the terra cotta loaded itself. We went through a series of stress-relieving tests to determine the extent of the pressure that had built up within the material. We found pressures as high as 5100 psi in a material that should be no higher than 2200 psi to meet code requirements. It was extremely overstressed.

We examined possible substitute materials for the deteriorated terra cotta. Eventually, 20 percent of the terra cotta blocks were removed. Since we did not have many supply sources to replace the deteriorated material, we looked at methods of using concrete blocks, aluminum, and other panels providing finishes that would keep the color of the terra cotta when wet or dry. We went through a detailed program of accelerated weathering tests to determine the properties of the materials as well as the finishes that would be compatible with the building.



The "leash" on the gargoyle, pictured here, is an example of the band-aid method of building repair and maintenance.

During the repair process, literally every stone in the building was marked, as in this photograph of the building.



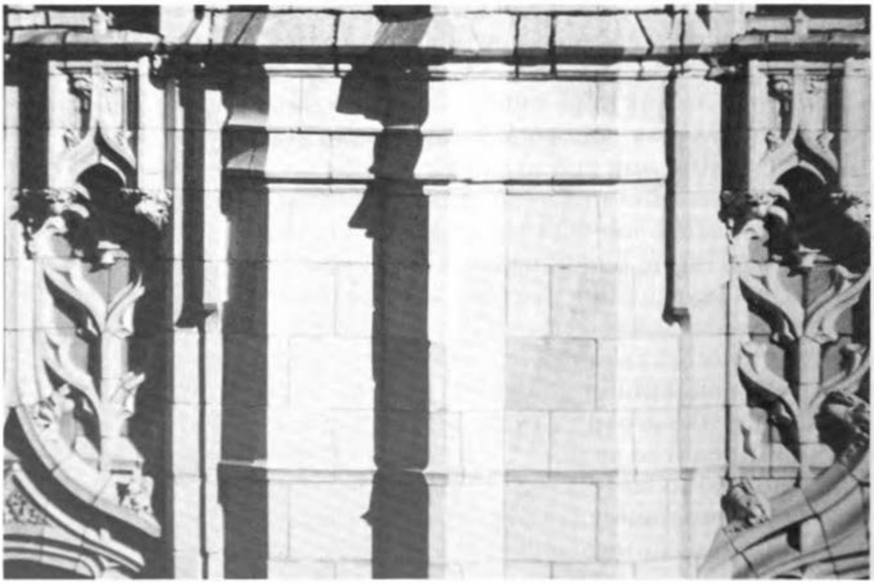
We also conducted a series of analytic studies on techniques for anchoring the material into the masonry backup so that we could safely install replacements. There are a number of different techniques for different sizes of panels, or replacement blocks that would be tied together. These ranged from epoxy pinning to an inset-poured concrete panel. We studied a portion of the building using different methods to relieve stress and had different techniques for replacement of the terra cotta. After choosing our preferred technique, we tested a section of the building three bays wide and three stories high. We relieved the stresses and let it sit for a year. At the end of the year, it remained as per its performance at the beginning of the year, so we felt we finally had a method for the job.

Performing the work while the building remained fully occupied required detailed coordination and scheduling of construction management tasks. We had to schedule men and materials for masonry work on this large building while keeping the building operative at all times. We worked three shifts around the clock. Turner Construction had to assure that the workers and the materials were there for any contingency that could have arisen. It was a major logistical job with scaffolding being erected on many different parts of the building at any given point in time.

In effect, every other course had to be cut to create a gap into which the compressed terra cotta could expand. The extent of the pressures are revealed by this type of cracking. When stresses were revealed within the building and the forces redistributed themselves, the groaning movement of the materials was very substantial. Localized spalling took place in many places and then materials had to be removed. Every stone was literally marked; we used photographic techniques for our drawings and, in order to be accurate, went through the process of repairing the building in an extremely painstaking way. The detailed overhangs are an ex-

In some cases, whole portions of the building needed to be replaced.

Deterioration on some of the overhangs and balconies was so severe that original portions were removed. In the instance shown here, the terra cotta had fallen off, leaving only the steel support. After the original drawings were consulted, latex molds of the missing parts were developed, and the parts were poured on-site.



ample of those areas where epoxy pinning made sense for the existing terra cotta blocks instead of replacing them.

Where replacement was necessary, we developed latex molds and cast blocks that could be filled in as required on the building. A range of sizes and types of blocks had to be manufactured and inserted in the building, necessitating the difficult process of tracking all of these elements so that the right block would be at the right scaffold at the right time. The materials had to have a level of detail compatible with the building itself. Portions of the building, with exposed steel structural members, required backup and insertion of materials, and wire mesh to tie parts back. In some cases, whole portions of the building had to be replaced.

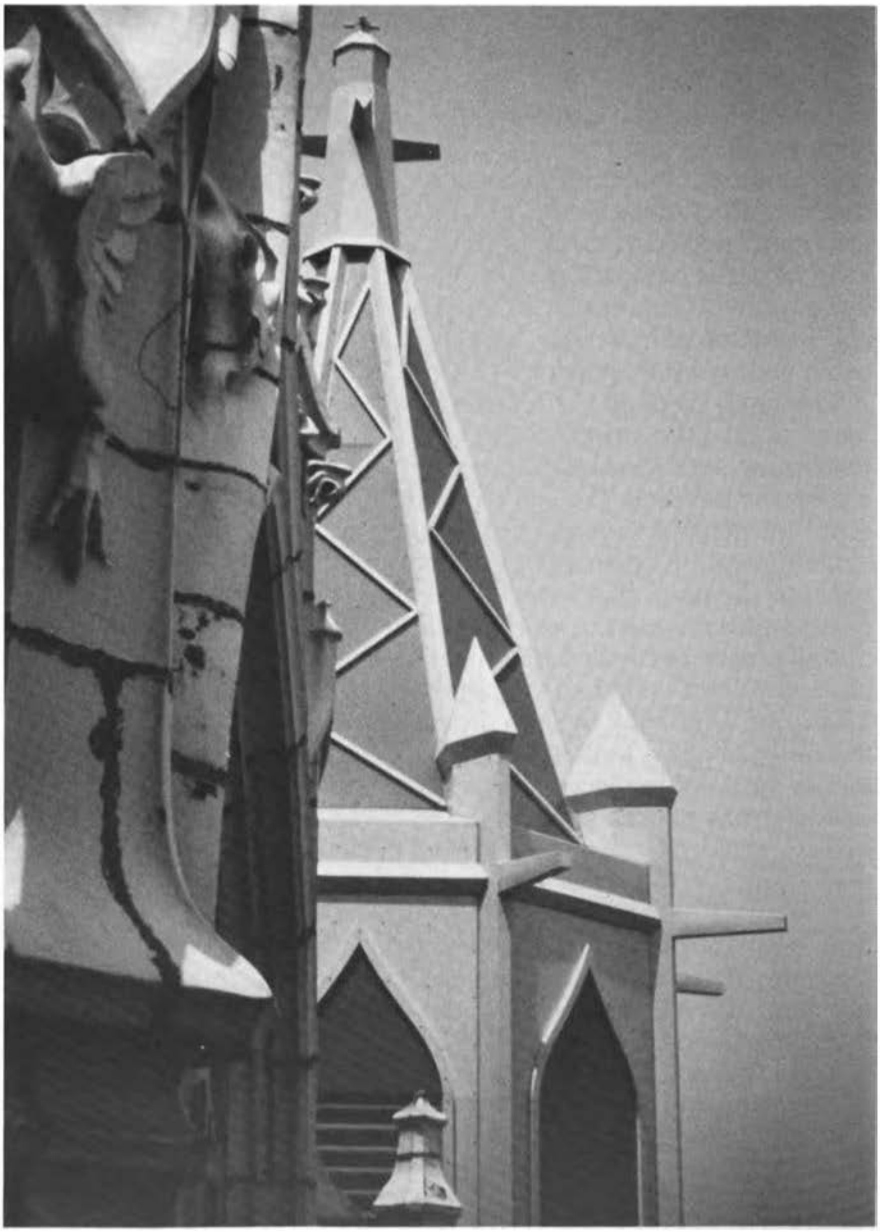
The analysis of all of the parts, the development of the replacement panels, the stripping away of the broken materials, and replacement with the new panels occurred within the process of fixing up the building. We worked at different levels of detail at different heights within the building.

Deterioration on some of the balconies and overhangs was severe, to the point that some of the original buttresses had to be removed. When we were working within the detail, what was found initially were portions wired together that were exposed. In one case, the terra cotta had fallen off and only the steel strut was left. Then, we went back to shop drawings, developing latex molds in the field, taking a look at the places where one worked. The molds were set in place for pouring on the building, and after the material was poured you had the total replacement. Again, on the turrets, material had to be removed because of its very poor condition.

At the top of the building where the extent of detail was not fully visible from the street, we used an aluminum panel system to keep the general configuration and profiles of the building. It was not economically feasible or technologically possible to rebuild all of the elements.

Each technology used for a specific problem was reviewed separately, and solutions were developed for remedying each problem. We tested those techniques on the building, doing hundreds of laboratory tests for compatibility of materials, weathering factors, etc., as part of a total process to restore the building.

The building was nearly fully occupied for the duration of the construction. This project provided us with a major introduction into the whole area of building diagnostics, the testing and analytical work, which we have since used in many other projects. It also became obvious that the problems we found in the building were not related to a single area or a single discipline. If you were a structural engineer looking at the problems of the terra cotta,



This turret is one of the spots at the top of the building where the aluminum-panel replacement system was used to preserve the original profile of the building.

For the duration of construction, the building was almost fully occupied. Since then, techniques developed on this project have been used on many buildings.

then the moisture problems would not have come to the forefront. If you looked at the problem from other points of view there may have been no solutions. The sense of what we believe in our building diagnostics committee—essentially a need to develop a more integrated diagnostics discipline—began to grow in my own mind at this time in response to this project.

Philip G. Hammer
Chairman of the
Advisory Board on
the Built Environment

Technology and Urban Revitalization

Let me first set forth a basic proposition. It is this: the current rapid pace of technological change could—and maybe will—significantly affect both the forms and functions of American cities. It behooves us to explore these effects, both inexorable and potential, so that we can determine if and how we might take advantage of their dynamics to help cure some of our basic existing urban dysfunctions.

There is a special context to what I have to say—the potential link of new dynamics generated by technology with the deep-rooted problems of cities. Within the framework of the broader forces that shaped our industrial society, technology was largely responsible for the creation of the modern city in America. Other powerful forces—economic, social and political—have since created the stubborn problems that face the built environment today. What role might technology play in shaping and reshaping the cities of tomorrow?

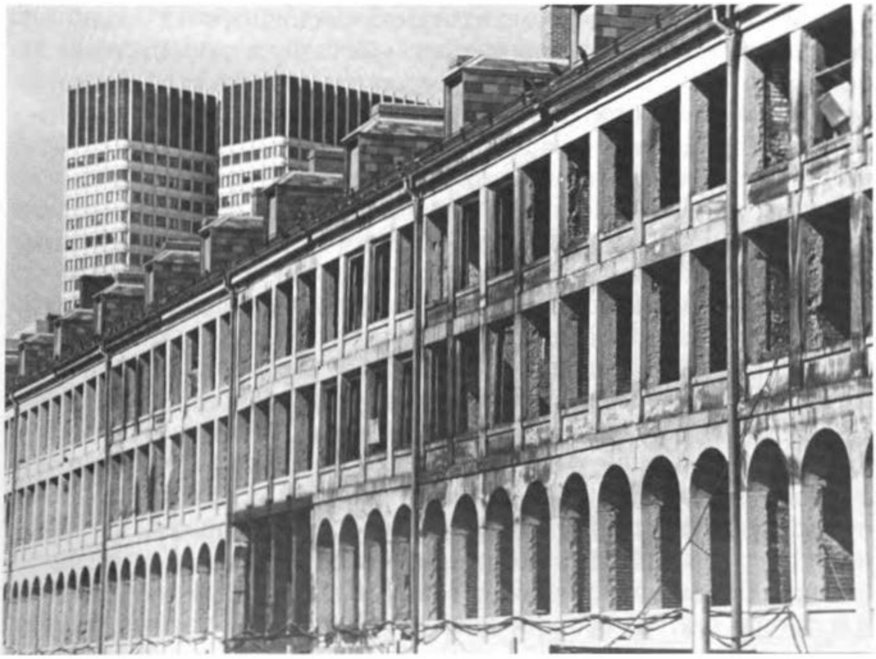
The Advisory Board on the Built Environment (ABBE) is already deeply concerned about the technology of building design, construction and maintenance. ABBE has undertaken projects on computer graphics, building diagnostics, hazard mitigation, fire research, energy conservation, and advanced technology for building design and engineering. Other projects currently being considered cover subjects such as building deformation, indoor air quality, worker safety, design criteria and post-occupancy evaluation, and the building design innovation process.

I would like to focus, though, on two broad aspects of technology and urban revitalization. One is the possible implications of technological change on the form and function of the built environment itself. The second is the possible implications for public policy—or I should say public/private policy—that might respond to this technological change and take advantage of it.

One of the most positive and exciting happenings on the domestic front is the joint public and private effort to revitalize urban America. As a citizen and a professional, I have personally been deeply involved in this effort, as have many of you. I can attest with some wonderment and satisfaction to the scope and effectiveness of what has been going on. Bankers, businessmen, developers, investors and property owners have teamed up with local public officials, planners and other professionals to fashion new approaches to local economic development. This has happened in city after city from one end of our country to the other. New financial and institutional mechanisms have been created to put development projects into place and get them to work. Rehabilitation and historic preservation, as well as new construction, have

Baltimore's downtown is one location that has been successfully revitalized. This is a view of the Inner Harbor area, with Harborplace and the World Trade Center visible.

A row of 19th century commercial buildings in Boston, prior to their renovation into the overwhelmingly successful Quincy Market.



brought new life to many parts of the built environment. The profit motive has been combined with civic purpose to create an effective bottom line for public improvement.

But these efforts have made little headway in the gut problems of cities. A large part of our built environment is still locked in a syndrome of underemployed people, underutilized physical resources, environmental blight, and municipal fiscal stalemate. The costs of resource waste and functional inefficiency have been enormous.

Let me start backwards and talk about these problems before talking about the potential impacts of technology. It is not that these problems have not been given attention. For several decades now, more programs have been undertaken, more policies made, more conferences held, more books written and more words spoken than one would dare try to recount. These efforts attest to the importance attached to the issues and the seriousness with which they have been taken. But the problems remain and indeed could be getting worse.

I hesitate to repeat the familiar litany of these problems, but it's important to my proposition to get at some of the meat in the situation. I'll try to focus on what might be most relevant to what's up ahead. Let's first take the economic forces, starting with the interregional shifts in economic activity. The massive transfer of some of our major industries to new geographical locations has left large numbers of our older urban areas in a bad way economically. Some have found ways to regroup around new activities built upon strong local assets; others—actually most—have not been able to do so. Moreover, in recent years there has been serious attrition in some of our largest industries as a result of technological and competitive forces. The direct impact of this attrition upon some areas has been nearly devastating. The ripple effects on other cities linked through supply and service networks have been almost as great. More recently still another unbalancing factor has developed: the restructuring of locational patterns in critical economic functions resulting from the applications of high technology, new management and control operations, and the internationalization of industry. Those cities capable of providing effective command-and-control functions have taken on new muscle; those without these strategic capabilities have lost out, or are losing out.

From the standpoint of the central cities within the invisible municipal boundary lines, however—and it is here where the major urban problems are concentrated—this interregional restructuring of the urban economic base is not the biggest issue. The intraregional shifts in economic activity have had even more profound effects. Within the boundary lines that separate central cities from suburbs, the economic base has been deteriorating for several decades. The growth in service activities and employment has not filled the void in the central city's economy. The economic base of many, if not most, central cities has shrunk. This has happened even in areas where the broader metropolitan economy is expanding. With this shrinkage has come the threat of municipal bankruptcy, a threat that has been dissipated in most cases only by costly infusions of federal funds.

But again, these *economic* dislocations are only part of the story. Long the staging area for America's potentially upwardly mobile population, the central cities have had to absorb countless thousands of people with minimal incomes and limited skills. Although the great wave of rural to urban migration has subsided, tens of thousands of those who moved to the cities are still locked in central-city enclaves of only marginal personal productivity. Their numbers are being added to by new immigrants, both legal and otherwise. In the meantime, the inner-city job base has declined. The suburban flight of affluent population has carried the commercial and service base with it, along with the industrial base. There is frightening evidence that we may be building a permanent underclass in America's central cities, a class of dependency, disaffection and underproductivity. A powerful contributing force is the rising level of skill requirements in our changing production, processing, and service occupations. Even as central-city employment in some job sectors expands with the restructuring of our national economy, it may be beyond the reach of those who most need the work.

I know this is a familiar scene, and I won't go into more detail describing it. These are simply the facts, not all of them, but sufficient perhaps to make my point: The problems of our cities are a national problem, and they are highly significant for our interest in the overall built environment. In short, a large part of that built environment can be described in terms of millions of square feet of vacant and unproductive buildings, thousands of acres of dead land, thousands of underproductive and relatively dependent people, a limited and often shrinking tax base, vast evidences of environmental blight, serious issues of crime and security, and a changing local political structure in which the demands for improvement and redress will become increasingly strong in the days ahead.

What I'm addressing is not how to solve these problems of cities. Instead it's to examine, in sketchy form, the extent to which our technological advances might affect those problems and perhaps become part of the solutions.

The modern American city was born during the last two decades of the 19th century. The remarkable set of inventions, which made the physical reality of the modern city possible, included: the development of steel skeletons for buildings (with which we could "reach for the sky"), the elevator (a necessity in skyscrapers), the electric light (and more completely the entire system of generating electricity, distributing it, and using it), indoor plumbing (which had been around for centuries in preliminary form but took off with the invention of the "water closet"), the telephone (and again the system which made the individual phone possible), the internal combustion engine (and its incorporation in autos and buses), and the subway (the earlier trolley car designed to run underground). All of these inventions were patented between 1880 and 1892. We spent the next 40 years redesigning cities and villages to incorporate these inventions. These efforts responded to the needs of a growing industrial society for large concentrated populations of workers to match new capital investments. Out of World War II came new technologies—new products, new processes, new materials—which were applied to the exploding post-war urban demand for housing, schools, plants, hotels, office buildings, shopping centers, and an unprecedented range of new consumer products. It was also a time when facilities such as had never before been imagined were designed and built—nuclear power stations, linear accelerators, deep-dish astronomical observatories, and space-launching facilities.

It might be interesting to add—now that we've run out of banks to build shiny new downtown towers, and despite the fact that there are a dozen new dizzy skyscrapers in the making that boggle one's mind—that an embryonic trend has already set in to gut, refurbish and reclad some of the huge inventory of vacant buildings in many of our cities. Today, many, if not most, cities are issuing more building permits for remodeling and rehabilitation than for new buildings. This has a significance that I will later discuss.

What are today's new inventions and innovations that may affect the economies of cities, their buildings and infrastructures, and—perhaps most important for my purposes here—possibly their form and function? Do they offer the prospect of seminal impacts comparable to the inventions that created the modern city nearly a century ago? Even if they don't, will they create new dynamics, new forces of change in working and living patterns that might put efforts to solve urban problems in a new light?

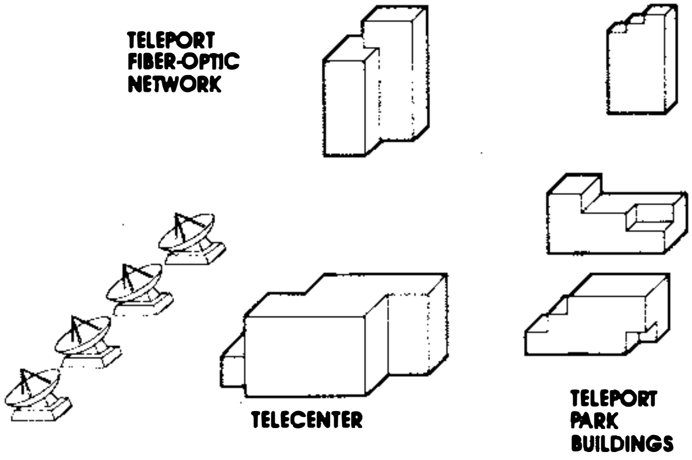
It is clear that we're talking about telematics, the central physical technologies of our post-industrial society. These are the technologies which, by virtue of affecting the production, storage, handling, use and dissemination of information, are central to our knowledge-based economy—microprocessors, robotics, lasers, fibre optics, video discs, microcomputers, integrated circuitry, satellite communications, to name only some within a broad range of new devices. It is quite likely that their primary effects will be first, and in the short run, on the functions, and in the longer run, on the structure and organization of the built environment. No one can doubt that we are in an electronics revolution. Through telematic breakthroughs, new methods of task assembly are replacing the traditional assembly line models in manufacturing and processing. Entirely new industries are emerging from the silicon chip technology; today's growth industries are clearly the knowledge industries. A plethora of electronic-based products is flooding consumer as well as business markets. We may indeed be on the verge of the wired city, wired regions, and even a wired nation.

Let me explore, crudely and simplistically, some of the implications I see for these technological developments within the context of urban problems set forth earlier. I can only be suggestive, of course. My purpose is to make the case for a major undertaking—hopefully through the offices of ABBE—that would explore and evaluate these implications in a systematic and comprehensive way. When the experts assemble, I would hope that they would be told that their "client" is the composite mayor of the composite city who asks them: "Tell me, what can I expect to happen and what, if anything, can I and my public and private leadership cohorts do to work it to the advantage of my city?"

First I address the continued effects of rapid innovation on the economic system itself. Clearly, our new technology will exacerbate some of the trends that are already giving many cities so much trouble—specifically, to partly recap—shifts, both inter- and intraregional, in the locus of many types of plants and employment; upgrading of the skill requirements in the labor force, concentration of management command-and-control functions in selected areas to the disadvantage of others, and further declines in some of our basic industries under the impact of technologically generated competition.

From a different perspective, however—and this is my point of emphasis—one can see the creation of new dynamics, that could generate new activity patterns leading in other directions. There can be widespread site decentralization in a range of consumer service functions—shopping through home-to-store television networks, for example, and a similar provision for medical care and education (including job training). Warehouses, laboratories, and classrooms that serve these networks might advantageously choose central-city rather than suburban locations. The locus of service establishments could become less fixed—away from strong present orientation to the suburbs—and more foot-loose. The prospects of the wired city could open up immense new possibilities, including even the creation of home industries to provide new entrepreneurial and employment opportunities not now available.

What happens if time/distance factors in the functioning of the urban environment become virtually "non-factors" because of the almost instantaneous capability of telematic devices? Perhaps I should substitute "as" for "if," because the direction of the trend seems unmistakably clear. Does this mean a further automatic dispersal of functions, adding to the forces of decentralization already underway? Within the intraregional framework, at least, and possibly also in the interregional context, why could this also not mean some reconcentration—a greatly increased flexibility in the siting of new activities? If the consumer does his or her shopping by television instead of at the nearby regional shopping center, for example, why can't the retail warehousing and service centers be located at key points within the central city but accessible to traffic arteries with outgoing regional coverage? If the capabilities implicit in telematics are, as Joseph Coates suggests, "particularly adaptable to the vagaries of human culture," why can't *some* of these vagaries, at least, be replaced by purposeful public and private decisions that will meet the practical needs of the changing economic system and at the same time help reverse the negative investment syndrome plaguing the cities?



This diagram for a teleport combines state-of-the-art telecommunications technology with office buildings in a park setting. The telecenter building is the control center for all teleport communications activities.

A range of new specialized buildings and facilities is coming on the scene—computer service centers for industrial and financial institutions, for example, and regional and national marketing and management control centers with optional locational requirements. Even small cities might compete for these new facilities (as witness the dispersal of credit card control operations). The point is that new facility demands are being generated even as others are removed; the alert cities are aware of this fact and some are already moving to take advantage of the opportunities.

Note also the development of central-city recreational and entertainment facilities and of new residential and commercial enclaves along central waterfronts. This is no mere happenstance. Much of what is happening has a strong technological base. I am familiar with this because I am working on an innovative one-of-a-kind high-tech Oceans Study Center for the Cousteau Society on the Norfolk, Virginia, waterfront near the new Waterside festival market, which also incorporates design and construction innovations.

Let me cite another example, possibly the most significant of all. It is the teleport, the new electronic complex of high-technology communications gear that through fibre optics, microwave, and satellite networks can not only tie together information-based metropolitan functions but also link urban nodes to national and even international networks. Some 20 of these innovative facilities are being planned around the country. Their siting within urban areas could be a critical factor in local development patterns. Will they become the hub of related activities that will be the railroad stations, rail yards and airports of the future? What are the factors that will determine their siting? Why would not central cities, who lost the railroad terminal and never got the airport, get their share?

These are only a few of the "inventions" that are already visible on the urban and central-city landscape. There may be markets for countless others as new "supply creates demand" forces become effective. Housing is a case in point. The exploding numbers of high-income, double-breadwinner households with no or only a limited number of children represent a strong market potential for new types of close-in housing fitted to their specialized needs. This demand will be met only as innovative design and construction produces what is desired.

There is another range of potential that might be created by purposeful responses to specific social and economic needs, where the muscle of public intervention and joint public/private enterprise might be mobilized. I'm talking about city revitalization with a purpose. I have already alluded to the immense interest that has already been shown in both the public and private sectors. The implications of technological innovation here are significant. There are the escalating needs of the elderly to be met—for housing, services, activity facilities. There are the needs of the disadvantaged for basic educational and job training opportunities, calling not only for innovative teaching methods and facilities but also for physical access to the workplace.

There is a need for a much greater recapture of the vast inventory of vacant urban structures, a process that has just begun. This could offer an immense technological as well as political and economic challenge. The numbers traditionally put forward for the cost of rehabilitation have most often been totally out of line with any reasonable and acceptable amortization schedule. But that poor alignment in part results from assumptions about what refurbishment means. Computer-assisted design focused on specific re-uses, plus innovative devices in new project development packages, might produce some startling new results. High technology, despite its primary implications for large-scale, even multinational production, might also add to rehabilitation and reuse by opening up new opportunities for small incubator industries. In addition, there are the prospects of rehab occupancies by some of the new service facilities that may be generated by the wired city, as already mentioned.

Let me give you an interesting example of rehabilitation at work. The second largest employer in downtown Norfolk is now a minority-owned, high-tech, computer processing company. It occupies a building that once housed a Penney's retail outlet and a Marriott restaurant. Note again the significant characteristics of this new occupancy—a minority firm in the computer field in a refurbished ex-retail store building in a downtown area. I don't say this is going to happen everywhere, but I call your attention to the juxtaposition of new technology-based enterprise and several aspects of the problems of central cities.

We're not going to rub out any city limits very soon; for a long time we're going to have to deal with fiscally strapped municipal corporations run in many cases by a new group of basically inexperienced leaders. The disadvantaged underclass is not going to disappear very soon, and no one should expect any mass return to the city of entrepreneurship, private investment and affluent population from the suburbs. But there might—repeat might—be a rash of new opportunities that have not been available before that will give our leadership a lot more to work with. I have tried to suggest a few and to emphasize that we have the leadership tools in place—the commitments of bankers and businessmen along with City Hall, and we have fashioned experimental devices such as enterprise zones and local development corporations capable of use in generating reinvestments if the opportunities present themselves.

What I want to emphasize here is not necessarily the counterpart to the electric light or elevators but change. The telematics revolution means change, and change means dynamics, a word I've used a number of times in my remarks. I don't know how we can watch what is happening in the fast pace of telematics—in its already obvious effects on our industrial processes, our management and control devices, our competitive status in the world economy, our approach to service delivery, our consumer gadgetry—without raising basic questions about its potential effects on our environmental systems. All of our living and working activities have a physical locus; do we know how the forces of telematics could affect the patterns? Simply to mention the idea of the wired city conjures visions of vast changes in the way people will work and live. Will the central city take advantage of this? Will the implications be the same in both the city and suburbs? If the implications are different, will the central city be worse off than it is now? If implications are the same—at least potentially—will new uses be generated for vacant land and buildings and new opportunities for vacant people? I've suggested that the answer to this last question may be "yes" because I think new dynamics might be created that can be translated into something constructive by good leadership. Of course, I may be wrong, but we need to know.

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