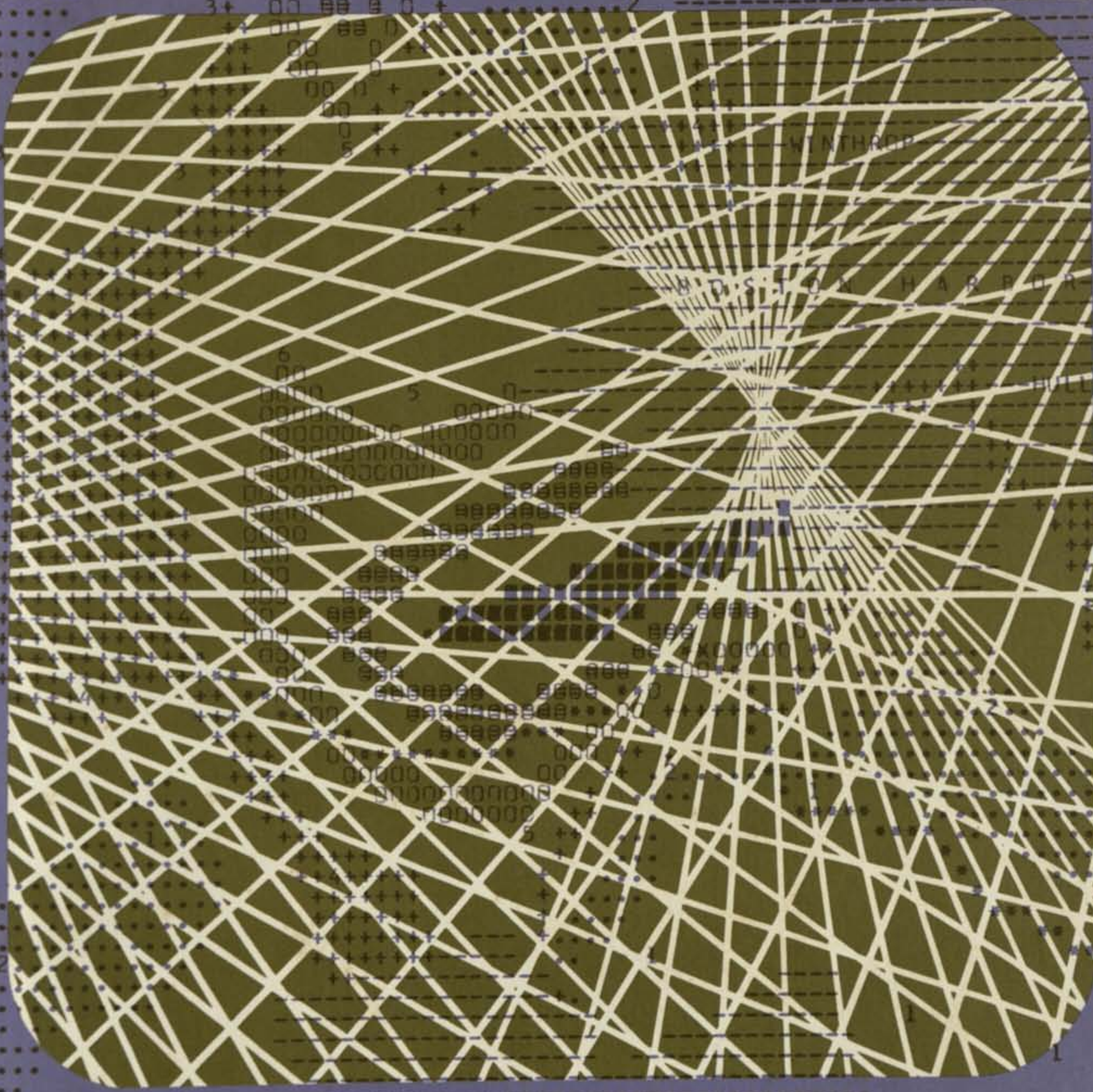
Architecture and the Computer



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Architecture and the Computer

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Phokion Karas

Preface

For seventy five years the Boston Architectural Center has operated an evening School of Architecture for talented young men and women financially unable to afford tuition at either Harvard's Graduate School of Design or M.I.T.'s School of Architecture. The Center's School is staffed by professionals willing to donate their time. Most of the students live in greater Boston, work in local architectural offices during the day, and receive their education at the Boston Architectural Center three evenings a week. The Center is authorized by the Massachusetts Department of Education to conduct classes on a certificate-granting basis, and both Harvard and M.I.T. have given full credit for its courses.

It has long been felt that the Center should provide an educational program not only for young people apprenticed in architects' offices throughout the city, but for the senior members of the community of architects as well. This conference initiates a projected series of educational programs for the local professional community.

The subject, *Architecture and the Computer*, was decided upon after stimulation from a number of sources. It is perhaps obvious from the program that we are greatly indebted to the staffs of M.I.T. and Harvard. An initial meeting with Professor Charles Miller, Chairman of the Department of Civil Engineering at M.I.T., suggested that there was sufficient activity in the field to make it a fruitful area for exploration. Peter Floyd, who participated in the Conference, "The Building Construction Industry Viewed as a System" at Andover, New Hampshire, in August, 1964, gave us a firsthand report of the discussions there.

We could make a long list of all the individuals who have made intellectual or administrative contributions to the realization of this conference and we can name only a few. However, we must acknowledge the help of M. B. MacIvor of IBM, who arranged for the installation of software at the conference site, connected to the 7094 at M.I.T. for a "live" demonstration of STRESS and time-sharing, as well as the closed circuit TV installation which made it possible for the large numbers in attendance to view the demonstration; of Daniel Beltran, a graduate student at M.I.T., who programmed the STRESS demonstration; of Ted Johnson of the Digital Equipment Corporation for use of their equipment in a demonstration by Clark and Souder; and of Irwin Stone of Brogan Associates for the use of a California Computer Plotter and the ADP drafting demonstration. IBM has donated $1,500, free of all restraints, and the Graham Foundation for Advanced Studies in the Fine Arts has granted $3,000 to insure this publication of the conference proceedings.

In addition to 467 advance registrations from all parts of the country 117 persons registered on the fifth of December. In sum, attendance consisted of approximately 250 architects from the Boston area, 230 from outside the area, and 100 students.

In the future we hope that the Boston Architectural Center will hold additional conferences, lectures, panel discussion series, and work sessions in design analysis. All of these can be structured to stimulate and maintain the intellectual growth of architects who have finished their formal education.

First Boston Architectural Center
Conference Committee

Sanford R. Greenfield, A.I.A., Chairman
Harry P. Portnoy, A.I.A.
David D. Wallace, A.I.A.

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Phokion Karas

Foreword

The intentions in planning this conference were two-fold: first, to provide information about the current use of the computer in architecture and related fields, and second to explore the possible relationships of computer use to the creative processes of architectural design. At no time was it our purpose to accelerate computer use or to try to apply the computer to architectural design.

The most obvious examples of current use of the computer are to be found on the periphery of the architectural profession, among structural and mechanical engineers, city planners, contractors, etc. Even among architects, except for Clark and Souder whose use of the computer is concerned with a single architectural variable, we find that the computer is mainly used in non-design areas; information retrieval, building programming, visual presentation of statistical data, and automated drafting.

The morning and afternoon sessions were devoted to exploration of the work now being done by engineers, architects, and computer experts. I would guess that the reports on computer graphics were most significantly related to architectural design. Professor Coons of M.I.T. demonstrated with SKETCHPAD that it is possible to communicate with the machine by drawing, a language in which architects have been trained. With SKETCHPAD, automatic data processing may be utilized by the profession with relatively little prior preparation and thus become a practical extension of the architect's capabilities. The Computer Graphics work of Fetter shows how the architect can test his visual hypothesis in a computer-created three dimensional graphic environment, through which he can move and anticipate the spatial sequences he would experience in reality.

It is not unique for a profession today to find that it is faced with a constantly increasing number of variables which must be resolved in the solution to a problem. Architecture shares this characteristic with medicine, engineering, politics, and many other disciplines. It is perhaps unique to architecture that the resolution of these variables must express itself in a three dimensional form, and in the last analysis it is this form which is of principal importance. While it is possible to use automatic data processing equipment in fields which lend themselves more naturally to an analytic, systematic problem-solving approach, it may be as readily applicable in architecture even though the problem must resolve itself in formal terms.

It is, perhaps, ironic that SKETCHPAD and computer graphics, the two tools most readily adaptable to the architect's work, themselves pose the greatest threat to his traditional role. The conference failed to discuss this aspect and for that reason I would like to touch on it here. The role of the architect requires him to make functional decisions (analytically at best), discover visual relationships, and express both in formal terms. The use of computers suggests the possibility of simultaneous analysis of many functional variables, and the use of computer graphics makes it possible to examine visual relationships in a manner impossible with our present handicraft methods. Unless the profession educates itself to programming and computer use, might it not be possible for people outside the profession, without a basic understanding of the formal problems but with a sophisticated grasp of ADP techniques, to produce competent buildings? The widespread regard for and almost universal involvement with computers in other fields suggests the ease with which they might be adapted to architecture by non-architects.

The evening panel discussion was intended to provide a forum for contemplative ideas and it did deal with many aspects of the creative processes in architecture and the computer. However, I would guess that due to the absence of certain invited panelists, a prevailing idea of architectural creativity was not discussed. Many people hold that the creative act occurs early, perhaps initially, in the design process. The architect is an artist whose brain serves as the ultimate computer, programmed by years of experience and sensitivity to visual phenomena. Intuition serves to limit and reduce the number of alternative solutions (and variables) and therefore eliminates the need for a logical testing apparatus. Form is derived from the extra-sensory qualities of the architect, and economic, social, and technological problems that the architect traditionally deals with are resolved (or if not resolved, made to conform) within the aesthetically correct solution. This point of view offers much room for debate, but it merits a hearing because it is prevalent in the profession.

In retrospect, the conference seems to have served at least to alert the profession to an irresistible force which will radically alter the practice of architecture whether we plan for it or not. It is a force which can be controlled and directed to fulfill those values we judge essential, but only if we understand it and its relation to our traditional role. Material published since December 5, 1964, suggests that the First Boston Architectural Center Conference did, in fact, serve its purpose: the profession appears concerned with the problems that have been raised. The issue is no longer dormant.

Sanford R. Greenfield, A.I.A.

Boston Architectural Center

Morning Session

Phokion Karas

H. Morse Payne
Welcome

Welcome to the First Boston Architectural Center Conference, entitled "ARCHITECTURE AND THE COMPUTER." The Boston Architectural Center is known to most of you in this room for the exceptional role it has played throughout the years in the education and training of architects. The conference today is the first step in its program of senior education and will undoubtedly be followed in years to come by other such gatherings.

Our topic, the computer, seems the most timely, the most urgent, the most serious subject that we could bring to the profession. Those of us who have had a small glimpse of the computer in operation have been startled by its amazing talent. We are even more startled when technicians tell us that this instrument will make a major penetration into our profession within five to ten years, aware as we are that we know so little of its potential and its uses. Our profession is steeped in time-honored traditional methods of approaching architectural assignments, but this machine, a product of our day and our time, might require us to change and approach our task in some new manner. So, we must begin to explore the subject immediately.

Because of the broad importance of the subject, it was decided that a conference was necessary. I would like to commend the members of the subcommittee who organized today's conference, Sanford R. Greenfield (Chairman), Harry Portnoy, and David Wallace for the amazing depth and professional responsibility they have shown. This gathering is entirely indebted and grateful to these men.

This committee received encouragement from many sources. On the national level, the American Institute of Architects informed us that our subject was of the utmost importance and of great concern to many people. This conference is the first in the United States where our profession shall come to grips with the problem. Every other profession had absorbed the computer some five years earlier than our own, and we are the last to pay attention, and indeed, we may have lost an opportunity for leadership, as the computer industry is not directing itself towards our profession, but coming in through the back door directly to the building industry, while the architect takes a back row seat.

So, here we are today, to see what is in store for the future and to see what, if any, is the role of the architect in the computerized world of tomorrow, recognizing that tomorrow is here today. At first we had questions as to the interest of the profession in our subject, whether anyone would attend our Conference. You may be interested to know that our worry was quite needless; as of last night, there were some 467 advance registrations, including 76 students. We are here today from all over the country, all sorts and types of representations.

We would like at this time to openly express our appreciation for two major financial gifts which have helped make this Conference possible. First, thanks to the Graham Foundation for a grant of $3,000, and to I.B.M. To these organizations we are truly grateful. We would also like to express our thanks to California Computer Products, Inc., Digital Equipment Corp., and I.B.M. for their demonstration equipment. And now, of course, a special welcome for all our guest speakers and the various members of our evening panel, and a grateful thanks to all who participate in this day's activities.

We have no idea where this Conference will lead. We do not have the answers, but we must walk up to this new dimension, explore it, and debate its future in our profession. Your host, the Boston Architectural Center, is proud to play this role in senior education. We hope you find your day worthy of your participation and that we will establish a new direction and responsible role for the Center to follow in future years.

D. Kenneth Sargent
Introduction

This Conference is indeed noteworthy since it is indicative of effort expended in behalf of professional progress in this age of change and technical development. John T. Redpath of the Ministry of Public Buildings indicated that the building industry missed the industrial revolution and hoped it would not miss the important possibilities of automation. Perhaps the discussions of this group at this conference may influence the profession toward recognition and ultimate use of this new source.

I have been concerned with the public opinion which has indicated far too many instances of inadequate performance by professionals. The client too frequently questions the architect's ability as a result of an unfortunate experience during a building project. It would appear that the computer and related analysis leading to its use might serve as an important tool to aid in revising public opinion and improving what might be deemed deteriorating professional status.

To determine how the computer can be used to the greatest advantage of the industry and the profession required not only studies and continuing development of programs but also measurement of the most immediate and pressing needs of the architect. In what specific applications can the computer assist the greatest number of architects, their consultants and staff? This question, if answered by a broad segment of the profession, would result in divergent opinion, yet its answer is essential to the ultimate use and development of computer assistance to the profession.

As a result of several meetings of the A.I.A. Task Force on Information Retrieval and after lengthy discussion, it was determined that building science information retrieval and automated cataloging of building products and systems including properties and performance would give the whole profession the greatest immediate benefit. Perhaps this opinion was influenced by the individual interests of members of the group yet it did represent diversified opinion. The cost of any program and the possibilities of financing these projects also were considered during these deliberations.

This opinion as expressed by the Task Force was by no means a restriction on the research and development of programs currently being tested and utilized to a limited extent and computer uses yet to be devised.

It was a statement of judgment that immediate development of these two projects could be of greatest aid in improving and perfecting professional design and engineering judgment.

The services necessary to provide this aid to the profession and building metier would of necessity require the combined efforts of a large technical or professional society or a federation of these organizations to support them. The extension of these services to all professionals and segments of the building industry is a problem of colossal proportions and finance. To record title, author, publisher, and abstracts of building science information and research in order to enable professional use is in itself a large undertaking.

There is every indication that the building metier must at once secure means of keeping pace with the current technical development. In this matter, the architectural profession now lags behind the progress of the engineering profession.

Foreign technical building science information is received in this country with no means now available for its dissemination to users. The amount of information and research reports currently available and the mass yet to come makes the library or card system of retrieval clumsy and inadequate. It appears that only the computer can provide for the storage and systematic search of larger quantities of data. If you reflect upon the amount of technical reading that you now do and what you conscientiously believe you should do to meet the demands of improvement in design of current projects, the value of information retrieval becomes more clear. However, until the real value of building science information becomes more apparent to a majority of the architects and the administration of our technical societies, little can be done to improve our information and research services.

The architects have been far too prone to expect some other organization or enterprise to furnish technical information and data and have always demanded it in capsulized format. It is high time that we become more independent and seek methods to provide this knowledge for our general use. We cannot depend on the building producers, no—not even the libraries, to provide us these specific services. The architects must now undertake to define their needs and to organize the means of utilization of the computer to meet both our present and future demands for building information.

The importance of information retrieval and a method of organization for its implementation has been admirably demonstrated by the Engineers' Joint Council. Although many of its sources, abstracts and titles are architectural and related to building engineering, this service does not yet provide the breadth necessary to fill our requirements and permit more creative thinking.

As previously mentioned automated cataloging is obviously a project that must be undertaken by both industry and the profession. However, the architects must exactly define their needs if any progress is to be realized. Such a project could be commercially and immediately undertaken utilizing existing programs.

The greatest difficulty that I foresee is the inadequacy of current tests and performance standards of the thousands of materials that are now available. I believe the observation might be made that any preliminary steps to automation of product information are essential before a sophisticated automated system of product search is feasible. Certainly a limited start might be made on such a method of cataloging but the industry must proceed to the far greater refinements of product and assembled component information before the degree of perfection is reached to make this step of real value to the architect and the consumer. In other words, the building product manufacturing industry has much to contribute if the construction industry is to move forward comparable to the other industries and realize the advantages of this new tool. Similarly the education of the architect must include more adequate technical background if the profession is to make use of this procedure. It must include training in what computers and advanced methods of analysis can do to provide the architect with more rigor and more complex considerations in the solution of problems.

The future of a system of cataloging which will include automatic searching for materials to meet weighted criteria of usage is both possible and probable in the future.

Obviously the use of the computer is far from being limited to information storage and retrieval. The use of the computer for complex engineering problems, the comparison of methods, or scheduling, might be now considered as in the initial development stage. Far greater perfection can be expected. As this development proceeds, simplification of programming and usage will certainly be accompanied by changes in cost of services and more general understanding.

Although amazing developments in this field of electronic computers are occurring, two simple facts might well be restated that are restraining in concept. The computer at best can only weight and process the figures or facts in a procedure recorded and determined by the user. With certain problem scopes, this process can sometimes more simply be accomplished by using current manual procedures which utilize the most amazing computer ever devised, the human mind. Therefore, we must be discerning in our use of the machine. This does not mean that we should not continue to study, learn of new procedures, weigh the possibilities and take advantage of its use when promising.

The advent of the use of the computer as a device of the building industry will be amply demonstrated by today's program. I am certain that papers will indicate that professionals of tomorrow must be better prepared and that professional education must include greater breadth without undue emphasis of any single facet of architecture.

William J. LeMessurier

Use of the Computer in Typical Building Engineering Situations and its Future Development

Good morning. My position as the first speaker is appropriate. I am at the bottom of the ladder of computer expertise and do not pretend to great knowledge. The gentlemen who follow must supply that. Nevertheless my office and I have become part of the ferment. While others make the wine, we trod the grapes, and in this way we have become surrounded by the bouquet of the machine and led on to the heady thoughts of the future vintage.

As most of you know, our office is exclusively devoted to the structural engineering of buildings. Since architects have a never-failing ability to create unique designs, our activity has been devoted to solving hundreds of non-repetitive problems. For several years, this state of affairs convinced me that the computer was not for us. The development of individual programs for solving a series of variable problems was economically out of the question. Of course, we were aware that other civil engineers designing highway bridges and doing cut-and-fill computations were using the computer effectively, but except for doing masses of repeated computations, the computer did not seem to fit our needs. Part of this initial attitude, which I hope we have outgrown, was a rationalization based on fear and conceit. We are all wary of the unknown, especially if it looms as an intellectual competitor. We learn just enough about it to explain it away and go on about our business. Now if you think of the computer as nothing but a fast way of doing arithmetic, you, too, can explain it away, but you have missed the point and will ultimately be left behind.

Fortunately, a number of things happened to get us out of our rut. First and foremost, a few young men arrived at our office, fresh from a modern civil engineering education where training in computers has become standard. Their talented presence demanded action, if only to prove that modern education wasn't all ivory tower. Then the local IBM salesman decided that we were a potential customer for a computer. Naturally we were flattered enough to take a serious look at the possibility. The result was a greatly increased knowledge of systems and mechanics, although we decided not to install a computer in the office. The third influence was a design problem sufficiently complex to require a computer solution while the project itself was valuable enough to stand the cost of a special purpose program.

The problem was the wind analysis of a 34-story frame, braced both with diagonals and rigid connections. This is the sort of problem whose exact elastic solution would be hopeless without a computer. The alternate approach was the standard approximate method which we knew would be safe, but wasteful of material. With the help of outside consultants, a special purpose solution was prepared which worked beautifully. It saved $300,000 worth of steel at a cost of approximately $5,500 for man hours and $500 worth of machine minutes.

This cost-to-savings ratio of 2% was attractive. We were pleased with the results and sat back to take stock. Could similar results be obtained in ordinary size jobs? Could the use of the computer in building design prove itself, where no material savings were involved? The answer to these questions appeared to be "no." The high cost of getting ready appeared to make the computer useful for only large projects or repetitive design, and we went back to our sliderules.

One day, just about a year ago, all this changed at a conference similar to this one sponsored by M.I.T. The community of practicing structural engineers first learned of a new approach to the use of the computer. Imagine that you were told that the computer had been trained like a graduate student in civil engineering, not how to solve special individual problems, but trained in the general classical methods of solving indeterminate structures; and that this graduate student could be talked to in simple English and that he stood ready to go to work on any problem. All that he needed was a geometrical description of the problem with some verbal requests for the analytical information required. Wouldn't you think that the millenium had arrived? Well, in a way it had.

This graduate student is a genie called STRESS. This is an acronym which stands for Structural Engineering Systems Solver, and it is well named. At this meeting a year ago, everyone present was able in one afternoon to learn the STRESS language and use the computer program with STRESS to solve a problem of his own choice. Mind you, all these people at this conference were novices like me, and perhaps like yourselves. Program writing was no longer a necessary step to solve each new problem.

In retrospect this occasion appears to have been a real breakthrough, and its effect on our own practice has been extraordinary. A whole area of engineering activity has been permanently changed. Let me suggest an example. Taking the 34-story building frame I mentioned earlier, to analyze it for any system of loads, it is only necessary to number and locate the joint using any convenient coordinate system, to describe the cross-sectional properties of the members connecting the joints, and describe the applied loads. With a few simple commands, requesting the kinds of information wanted, the machine is ready to go to work. Answers are available as stresses in all members and deflections of all joints.

And what of the cost? Whereas the development of a special program less than two years ago cost $6,000, this use of the STRESS program today would accomplish the same work for about $300 or 1/10th of 1% of the materials saved in the actual building. How does all of this actually work in the detailed operation of an office? Since STRESS as originally developed was used on a machine whose time was worth $600 per hour, no building professional could keep the machine in his office. We find that renting a machine to punch cards is a practical way to prepare material for solution by a commercial computer used elsewhere.

Now what kinds of problems can this STRESS program deal with? Well, just put your minds to work and imagine all the structures that have passed through your hands or what you have seen—three-dimensional space structures for example. In the last year we have dealt with church steeples, space trusses, cantilevers from rigid frames. One of the central problems which arises in many concrete buildings today is the combination of a shear wall interacting with rigidly connected beams and columns. Suddenly, in effect, the problem has evaporated. We now have a tool at hand which can solve each day unique building situations, very economically, whereas five years ago, all we were able to do was solve one general case in a decade. This program will handle, without knowing what it is of course, a Vierendeel truss; we can examine a building for the effect of differential settlements. We can posit that the earth will drop at one point in the building one inch and evaluate, in advance, the influence of that differential settlement throughout a building frame. Another problem that has come up daily in planning tall buildings is the effect of differential temperatures between outside structures and inside structures. The master program is capable of handling this problem with no readjustment.

Now, does all this represent any kind of restriction on design? I think the answer is very definitely, no. Design is free from dependence on standard solutions. Instead of having to live with classical methods of wind analysis which were approximations, instead of having to live with flat slabs which had regular bay sizes, instead of giving up the use of a space truss, except for a very special high budget project, all of the unusual solutions that come to mind can be evaluated as easily as the standard ones. It is possible even with unusual structures to optimize them by economically analyzing a variety of approaches, varying parameters, and within the design of one building seeing a panorama of solutions from which one can choose and make better judgments than perhaps were possible only after a whole series of experiments.

What is the effect of this kind of approach on our thinking about structure? One thing that the computer does is give too much information. This is a problem. We now can find out in advance in great detail how a building frame will move, how much it will rack from differential settlement, for example. But we don't really have any criteria for racking. The computer has posed, in effect, a lot of new questions. How rigid should a building be? Now that we can predict it precisely, how much should a cantilever deflect? This will challenge us all to find out new knowledge.

It's now possible to analyze almost anything, more possible this year than last, by a factor of 10, I would say. The question of "what to analyze," is still our question, and your question as architects. I'm frightened, however, that we will build more monsters before we mature to the point where we can be satisfied with developing a single line of effort in some simple buildings. I hope we don't, because of this tool, generate a rash of spectaculars. We had them last summer in New York, and that's enough for a while.

Now, I have talked of the impact of an individual special program in our office. This has had enormous side effects. With one major program to get us going, everyone in the office has become involved. Every engineer has become a programmer, has gone to school at night and has learned how to get at the machine and, as a result, many, many problems that we would have solved the hard way, or not solved at all, we have found it easy to write programs for.

The Boston City Hall, for example, was an ideal situation for the use of the computer. In the architectural dimensions, as far as cross-sections were concerned, all of the columns were identical, yet there were innumerable combinations of bending moments and axial load, literally thousands throughout the building. The processing of all this information to get an optimum design of each column would have been hopeless, and yet it was possible for one man, using some of his education in graduate school and an additional few evening courses, to write a program for this job and save money in the process.

We have found that everyone is constantly looking for a new application. The business partner in the office has developed a program for handling payroll, a program for relating the worksheet weekly to budgets. Another partner has developed a way of dealing with the drudgery of specification writing, using the computer as an assistant. In the lobby outside, you can see some exhibits of this material and I am not going to go into any further explanation here. We are stimulated by this, I might say, and I think that one of the major reasons for architects getting involved is just to get the stimulation, to find out about it, even though you don't have any immediate massive practical in your work.

Now what is going to happen in a professional office, such as yours or ours, in the near future? One of the developments you will learn more about from others this afternoon is the use of the computer through means of a console which is located perhaps in your own office, and through which you can communicate with the computer on a back and forth basis.

You can pose a question, for example, get an answer, evaluate the answer, decide that wasn't the question you wanted to ask, ask another question, and have an interplay back and forth. At M.I.T., the development of the hardware for this kind of use of the computer is well advanced and I think that everyone connected with that development confidently predicts that it will be available to all of us within five years.

We had a situation in the office where this interchange between man and the computer in solving a structural problem was extraordinarily valuable. You may be familiar with the State Street Bank building downtown which has lots of cantilevers, and we had some questions that arose during construction on how much deflection of any particular cantilever in relation to the precast concrete might occur. This is a very complex problem because a particular cantilever might deflect as a result of loads in many different places in the building, and one is interested in finding out what pattern of loading, what combination of events, is necessary to apply to produce the maximum relative deflection of one cantilever to another. One doesn't know in advance what is the pattern of loading to test; at the same time, one doesn't want to take hundreds of patterns; one would like to somehow find a converging process that helps to find the answer.

A young professor at M.I.T. handled this problem through the use of time-sharing interaction with the computer. He described the profile of the building that he would put the loads on, and immediately found out what deflection these caused. He found that a beam in one part of the building went up and another one went down, so he knew he must add load to the one that went down in order to make the cantilever deflect more. Through a feedback process, he arrived efficiently and rapidly at the correct solution. This kind of interchange will be possible for everyone in a relatively few years.

This general program for solving structural analytical problems is something that is called a problem-oriented language. This means that one is able to get at the computer in the vocabulary of his own special interest, and the computer is programmed with the basic principles involved with that particular professional area and internally, in effect, generates the programs necessary for solving specific problems.

There is a whole family of such problem-oriented languages being designed. These are being developed for estimating and quantity surveys, and for problems in foundation design. One can speculate that they would be used for planning illumination, or for computation of zoning envelopes, dealing with any building code. A language for the design of circulation elements in a building could be developed for the design of stairways through a multi-story building with different floor-to-floor heights and successive levels, for example. It is possible to anticipate a program for the planning of automobile circulation and parking, and the simulation of the behavior of a parking garage under various kinds of loads of cars coming and going. All of these things would seem to be possible problem-oriented languages.

The great activity of architects, of course, is drawing, and you're going to learn much more about that this afternoon. In effect, the machine will take over the information storage presently accomplished by drawings, and be in a position to operate on this information directly, and the machine will even become a communications device between the architect and a consultant that he is working with. One can imagine a central computer filling in a description of the building as it is developed in the design state and correlating the various additions to the design and pointing out the various conflicts that arise during the design.

How do we make the best use out of all of this? I think that as Dean Sargent and Mr. Payne suggested, perhaps architects are behind in this area, and I think that the leadership must come from the universities of which we are blessed with many in this community. The Boston Architectural Center has shown the way and I think that the architectural schools should make a conscious formal effort to think about the use of the computer in architectural work. We have, as engineers, already received enormous benefit from efforts made by universities in this direction, and I would like to close with a suggestion that the architectural departments of the universities have the same responsibility to the profession of architecture that the engineering departments have already shown. Thank you.

Lisle G. Russell
New Methods of Environmental Analysis

Few people realize the long and difficult hours that the mechanical consultant spends just to get to the position of making a design decision. With great volumes of calculations and charts, he must make a decision based mainly on experience and horse sense. That fleeting little character called "conscience" keeps reappearing and asks, "Are you certain that you didn't forget something?" The only way to answer this fundamental question is to evaluate all the variables and factors affecting the mechanical design in a detailed and scientific approach; then try on "for size" the various mechanical systems for a given building; and, then, if you are accurate in getting the data, a method of making an optimum decision is possible. This was our goal in developing a computer program.

Our work was divided into two distinct phases. In the first phase we determined the building design heating load and the building design cooling load through detailed analysis of all factors affecting heat transfer. In the second phase we considered the combination of time, using the 8760 hours of a weather year, and the structure's physical factors in order to simulate the hourly building load. This changing load is applied to the mechanical system being studied. Then the input energy and work done to compensate for this hourly load is carefully determined and recorded by the computer.

Let me discuss the nature of the design program. Here our objective was to accurately determine the design heating and cooling loads of the structure, define the load on each zone or space as to its time of occurrence, its magnitude, and the factors creating this load in such a manner that:

(a)
Design changes can be easily made,
(b)
Control systems can be defined,
(c)
Mechanical components can be selected,
(d)
Air quantities can be determined, and
(e)
Preliminary system selection is possible.

Here are some of the input data which are necessary for the design program:

(a)
The solar azimuth and altitude for each hour of the months being studied are programmed into the computer.
(b)
The solar radiation and diffuse radiation are considered for the building location. We use the clear day values on the design program.
(c)
The detailed orientation of the building zones and any projection, reveals, or shade contributing factor of the building structure is programmed. The distance and height of adjacent buildings is measured in order that their shading effect is determined.
(d)
The walls are described in detail as to construction, thickness and types of materials. The mass, specific heat, conductivity, absorptivity, time lag, first and second harmonic, and orientation are all carefully evaluated and programmed.
(e)
The hour-by-hour outside design day's *temperature* and humidity is described for each month analyzed.
(f)
Internal loads are defined as to their time of occurrence, their magnitude, and heat make-up.
(g)
Electrical loads are defined as to what part of the mechanical cycle they apply.
(h)
Outside ventilation and infiltration are described.
(i)
Glass fenestrations require complete detail and the many basic types are considered as to transmissivity, reflectivity, and conductivity all determined from the manufacturer's data. The glass, orientation, shading, and outside air films are factors which are analyzed.
(j)
The physical dimensions and identification of each building zone are noted and programmed.

These are some of the typical input data that become criteria for computer load estimation.

Just imagine the work required to analyze 100 different zones for 24 hours each day of six months. The computer will print out these loads and analyze the hour and month of the maximum coincident load on each zone. It will determine the hour and month that the maximum coincident load occurs on the building and the structure and magnitude of this load. This load is further analyzed to determine the contribution of walls, glass, people, and solar radiation. We also print out the quantity of air for heating and the quantity of air for cooling by programming a temperature for the supply air.

The entire computer program was developed using formulas and data described in ASHRAE papers, tests conducted over the years, and present data published in the ASHRAE Guide. This was necessary in the design phase to obtain acceptance by the mechanical profession. I hasten to point out that there are cases where the actual testing data is different from the recorded data in the Guide. Here we reviewed and generally used the data which was actually recorded on the testing program.

The value of this information to the consulting engineer is self-evident. This tool can present clearly and accurately the loads and factors which must be satisfied by the design of the mechanical system. Better system integration is now possible because of the timeliness and scope of the computer print-out.

Now that the use of a computer has clearly defined the nature of loads on a building, the task of arranging mechanical components to function as a system to offset these dynamic loads acting on a building is exacting. Industrial technology has produced mechanical products that seem to solve almost any mechanical need, but which mechanical product in which mechanical system solves the building requirement best? Which system has the lowest first cost? Which system has the lowest operating cost? How can a manufacturer with responsibility to his customers define and build into equipment the performance characteristics that best satisfy their needs? The present practice of recording historical operating costs and system performances on other buildings and concluding that this proposed building will behave the same way may cause many financial problems. It was evident that there must be a more accurate method of predicting the performance of a mechanical system in a proposed building than existing manual techniques will allow. For this reason we developed the computer capability to evaluate the dynamic performance of the mechanical system when actual load creating conditions are simulated over a typical operating year.

The second phase of our computer program was to determine the building factors and variables in a dynamic condition and print-out the effectiveness of the mechanical system and the loads it experienced through a complete weather year.

I will briefly describe some of the factors which analysis indicated were necessary and thus were programmed in this phase.

ONE

The first main factor was time. Here we obtained the hour-by-hour Government weather data for the location of the building being studied. The values of temperature, relative humidity, absolute humidity, cloud cover, wind velocity, barometric pressure, and cloud layers are indicated.

One of our major efforts was to make a correlation of the solar radiation value from a given condition of clouds, temperature, humidity, and visibility. This correlation was a major step in measuring the solar contribution to building loads throughout the year. There is great need evidenced for a more complete recording of weather data to include the actual radiation value.

The weather data as presently recorded emphasizes temperature, humidity, wind and cloud cover but no definition of actual solar intensity is made. It is apparent that with the present use of glass in today's structures, solar energy generally affects the size of the mechanical system more than transmission through the wall materials. It affects the control and operating characteristics of the system due to its independence of outside temperature, and, it practically nullifies the accuracy of manually estimating mechanical system operating costs.

One of our major efforts was to make a determination of the solar radiation density by using the cloud cover data and humidity levels indicated on present weather data. The fact that the shell of every building receives energy either direct or diffuse from the sun and re-radiates some of this energy back into space and absorbs some in the shell or transmits some through the glass to the interior indicates the complexity of the problem. The input data as to actual intensity becomes a major factor in solving this thermal problem. We have achieved accuracy up to 1% in this correlation but if an accurate solar measurement were made as an input this energy variable could more easily be integrated into the control and design of mechanical systems. Manual errors of 20% or more in operating cost estimates could be eliminated.

TWO

The second important data category is the complete description of the building structure and occupancy schedule. Essentially most of the information required is taken from the design phase. Zones are collected and programmed to the system that will serve them. The operating characteristics of the building must be defined, such as the hours of occupancy, both day and night, weekends, holidays, and night set-back temperatures if desired. The building volume and mass are estimated since the heat transfer rates are calculated every half hour considering storage and time lag. To get the instantaneous rate of heat flow, a most difficult set of heat transfer equations were developed to describe this dynamic behavior. The load lag to ambient change can be interpreted for most typical walls.

THREE

The third main *important* data category is that of the specific mechanical system being studied.

It is necessary for the engineer to select, using design data, the mechanical components of the mechanical system and its control sequence for fans, pumps, cooling towers, compressors, and boilers, and any necessary component of the system.

The equipment performance curves at various conditions of capacity and temperatures must be translated into the program. The more complete the manufacturer's details, the easier this task becomes. The details of ducts and piping are only important in obtaining an accurate equipment selection. The electrical contribution to building load and useful work is determined and programmed. In essence, the complete mechanical system is described so that when the weather and building usage create a specific load and this load is handled by the mechanical system, a measure of the load and system capacity will be stored in the memory of the computer.

After the three basic data categories are programmed in detail the computer is given the task of mathematically relating all of these variables. The IBM-7094 may spend one or two hours doing this mathematical work to solve and analyze this dynamic thermal problem. The print-out or the computer results would require thousands of man years of mathematics to accomplish the same result and it undoubtedly contains less errors than man would make.

This load simulation and system analysis allows the designer to try the system out for a typical weather year and under design building load conditions before the plans and specs go out for bid.

The computer print-out contains such information as:

(a)
The hourly temperature in each zone for the entire year of operation. From this the analysis of the control system, the air quantity, the zone equipment capacity, the operating schedule for starting and stopping equipment are some of the elements of the design which are easily reviewed and verified.

(b)
The total monthly energy required is expressed in kwh or cubic foot of gas or gallons of oil. This phase summarizes the quantities of energy from each source that the total system requires.

(c)
The rate at which energy was used is defined as to magnitude of each energy source and, also, the day and the hour that this peak demand occurred. The analysis of each system's effect on the maximum demand is possible. The need for design changes can be determined from this information.

(d)
The percent of each system's capacity which was used during the maximum requirement of the month is printed out and the hour and day this occurred. This verifies the system selection and also allows the designer to see when over-design or under-design may occur. The effect of unusual weather, unusual loading or poor control programming can be diagnosed from this information.

(e)
The application of the local energy costs for gas, oil or electricity can be applied to determine the monthly and yearly costs for operating this specific mechanical system.

(f)
The comparison of various mechanical designs for the same building in the same geographical location makes it possible for the designer to optimize the selection of systems. If the performance is verified by the zone temperature print-out and the operating cost is verified by the energy costs, the only factor unsolved is the first cost determination and total economic evaluation.

(g)
Manufacturers can determine what performance characteristics are justified in system equipment and what characteristics are only sales propaganda.

(h)
Architects can evaluate the effectiveness of their physical design. The glass, wall construction, the shape of the structure, the building orientation, the usefulness of the space, are some of the features which can be extrapolated.

(i)
Owners can use this tool to justify the total economics of their proposed building.

The areas of present structural thermal data will require more definition and physical properties will require more clarification.

Integrated architectural mechanical systems can be developed because of the depth of understanding afforded by a computer.

We feel that the years of programming, research and continual program verification on these computer programs will be justified as a useful tool to the building design team.

The present status of the various computer programs which my company has developed indicates that the future of this computer application is bright. The engineers have great individual capability; the architects have unlimited creative talents, but the element of time poses a restriction on how much of man's talent can be applied to a given design. The computer, as a tool, can allow the designer the flexibility of prior knowledge and hopefully free them to make significant advances in the creation and control of man's living and working environment.

George Swindle
A Computer Project Control System

I would like to outline a project control system for you this morning which is applicable not only to contractors who have been using it for some time, but to you and your clients in day-to-day operations. Today's modern data processing system, capable of processing engineering as well as accounting functions, provides management with the information necessary to control the operation of a project. Data processing is more necessary now than ever before because the growing complexity of construction projects has enormously increased the amount of information to be digested. Former methods of reducing progress and cost data to understandable management report are no longer feasible.

Increasing costs give a double reason for mechanization of the data-capturing and analysis functioning. Rising costs at the job site dictate that management have timely information upon which to base project control decisions. In addition, clerical costs for administration of control systems at the home office have kept pace with increasing field operation costs.

Increasing competition throughout the industry is reflected by a rising bid ratio for new contracts. Thus, estimating operations are affected by the necessity to submit more bids for each successful contract award, and those estimates must be low enough to get the job but high enough to insure a profit. "Seat of the pants" estimating is simply not good enough any more.

The scope of reporting to owners in governmental agencies, unions, and insurance companies, has expanded tremendously in recent years. To contend with these requirements, many firms must maintain duplicate records, one for warehouse control, the other, contractual specifications and governmental regulations.

The last, and probably most important, reason for utilization of data processing is the low-profit, high-risk nature of the business. I need hardly remind you of the dangerously thin gap between profit and loss.

Let's see how data processing can serve you and your client in an increasingly competitive atmosphere. The first general area is in cost control, which encompasses all budgeting, capturing of cost data, analysis of that data, and presentation to management in a form that facilitates quick, sound decisions. A second area of major importance is estimating. More and more contractors are realizing the benefits of mechanization of estimating functions. But the most dramatic strides in recent years have come in the area of approved scheduling techniques. The critical path method of scheduling has already had a tremendous impact on traditional concepts of construction scheduling. Now it is being accepted as an important tool in scheduling operations within the architect's office. I'd like to call to your attention an excellent article by Mr. Gustaf Keene, A.I.A., in the March 1963 issue of *Architectural and Engineering News*.

When discussing scheduling, let's take a look at the basic concepts of the critical path method or CPM. When two or more simultaneous operations originate with one event and lead to another event, that operation taking the longest time is critical. In a project consisting of many events, the longest path of successive events is known as the critical path. Any delay along this path of critical operation will lead to a delay in the overall completion of the project.

The critical path method is a technique for planning and scheduling complex projects, as well as a way to monitor adherence to a schedule once the project is underway. An activity is defined as something that has to be completed as part of the project. (Here Mr. Swindle showed diagrams.) The activity is represented by a single arrow in the network, and each activity must have a starting point and an ending point. The circles at the ends of the arrows are called "nodes", the "I" node at the tail of the arrow represents the point in time when an activity may begin. And the "J" node at the head of the arrow represents the time when the activity ends. Each activity is referred to by its "node" numbers or by its IJ Number. Thus, we refer to Activity A (shown here) as Activity 9-10.

Each activity is also assigned a duration, that is the estimated time to complete the operation. Each "node" of an arrow diagram other than the first one and last must initiate at least one activity and terminate at least one activity. Multiple activities may begin or end at the same "node". Since the "node" serves as a starting point for Activity C, the logic depicted dictates that C may not begin until both A and B are completed. The "node" terminating C serves as the starting point for Activity D and E. This logic allows D and E to begin after the completion of C. This example shows activities that can be performed concurrently.

The project overall must begin and end with single nodes as shown here. Two or more activities cannot begin and end with the same two nodes. In this example, Activities A and B would be identified as 10 to 20. A rule of arrow diagramming states that each activity must be uniquely numbered. To conform to this rule, a new type of activity is introduced into the network as shown below. Activity 15 to 20 shown with a dotted line arrow is referred to as a dummy. A dummy activity requires no time or resources, and is present for the sole purpose of preserving the uniqueness of Activity IJ number. Other types of dummies, known as activity restraints are all necessary to define the network sequence. However, they are really necessary for our understanding of the critical path technique as we are going through it today.

This example shows an error in network sequence commonly referred to as a network loop. A loop like this is illegal because the logic constitutes a continuous non-ending chain. We could classify this, perhaps, as the world's longest construction project.

With the diagramming conventions in mind, we can discuss how a network is developed. There are three questions to be asked about each operation in the diagram. First, what immediately precedes the activity? Second, what immediately follows the activity? And, third, what other activities can be done parallel with this one? We begin by compiling a list of all activities that must be performed to complete the project and assigning duration to each activity. This results in a list of predecessor and successor activities.

Here you see a network constructed from the list of activities and their dependency relationships. There are many computer programs already developed which convert the list of activities to a critical path network. In fact, it is possible, with the plotter attached to some computers, for the computer program to actually draw the network for you. Once the network is numbered, the scheduled calculations can then be performed.

The result of the planning and scheduling process is a schedule which describes the sequence and time each activity is to be performed. Analyzing the schedule tells us the earliest, as well as the latest, time an activity can start—without extending the length of the overall project. We are also shown the slack time, which is the total time an activity can be delayed without extending the project completion date. Any delay in an operation on the critical path causes the project length to be increased by the amount of that delay.

There exists a more simplified method for graphic description of a series of activities and their inter-relationships. The precedent method of diagramming does away with no numbers dummy activity, and other extraneous items required in conventional arrow diagramming. As opposed to an arrow diagram, the lines in the precedence network do not represent an activity. Rather, they are used only to define sequence and relationships. The flow is always assumed to be from left to right; therefore, no arrows are required. Rectangular boxes represent the operation and the lines connect successor items with their immediate predecessors. The logic of the precedence method appears similar to arrow diagramming. This is the same project, diagrammed with arrows. The only difference is that a dummy activity has been inserted to fit the logic requirements. As contrasted with IJ numbers, a precedence operation identification code can be identified by any combination of numbers or characters.

It is possible to use this identification code, or some part of it, as a cost accounting code. In this manner, we could tie our schedule and job progress reports directly into the accounting system, simplifying communications and reducing many potential errors.

To continue our comparison of the two techniques of network scheduling, here is a very common condition found in project planning. Activity C may begin following completion of A. The D cannot begin until both Activities A and B have been completed. Note: Dummy Activity 2 to 5. With the precedence method artificial activities are needed. The sequence shown is implicit and leaves no room for doubt as to when Work Items C and D may begin. A typical project will reflect many dummies or restraining activities in an arrow diagram. The precedence method not only reduces the number by eliminating extraneous activities, but also reduces significantly the time required to prepare a network.

This sample problem is specifically designed to point out the ease of preparing precedence diagrams. From this table of activities and sequences, we can prepare both an arrow diagram and a precedence diagram. Here we have presented a correct solution to the list of operations in both arrow diagram and precedence notation. Note especially the number of dummy activities required to depict the sequence of activities. The differences in understandability and difficulty of preparation are obvious.

Lets make one more comparison of the two methods. Here we see the same 15 activity projects represented in the arrow diagram form at the top, and in the precedence method below. In the precedence method, only five activities are required to establish the desired working sequence. In effect, precedence diagramming allows you to network diagram by the bar chart method, while maintaining all the sophistication of the critical path method. This makes it possible for the people who have to operate under the schedule to contribute to its initial creation and to fully understand it. The precedence method truly qualifies as a second generation critical path method.

Although these examples were of construction activities, the activities could easily have been surveying, drafting, viewpoints in the design process, client sign-offs or any other event in the total design cycle. It is not required to have a 7094 computer or even your own large computer to make use of the critical path technique. As a matter of fact, it can be very useful on a relatively small project to use a manual method of setting up a critical path. This could be something as simple as a drawing on a chalkboard or any device such as that, because the important thing is to force yourself to list all the activities to make a logical drawing, to consider all of the loopholes, and to have your manager or your worker sit down and outline each event in the process. This kind of logic forces you to be reasonable and set up a better defined schedule and prevent some costly unpredictable mistakes.

In summary, the project control system starts with the critical path network, whether it's arrow diagramming or precedence, expands it to include estimating with feedback in both directions, and goes on to actual cost control during the project itself. The project control system, or the use of something like it, can be of immense value to you and your design, for your client and his surveillance of the project, and to the contractor in his overall efficiency in getting the job done.

July 20, 1966

Dr. Howard Fisher, A. I. A.
Department of City and Regional Planning
Harvard Graduate School of Design
Harvard University
Cambridge, Massachusetts

Dear Dr. Fisher:

We are interested in obtaining a copy of the complete SYMAP computer program you described in your lecture entitled "A Technique for Processing Complex Statistical Data into a Meaningful Graphic Form" presented at the first Boston Architectural Center conference on 5 December 1964. Kindly also inform us if there are recent modifications to this program which enhance its utility. Your assistance in furnishing the program will be appreciated.

Very truly yours,

BOOZ·ALLEN APPLIED RESEARCH Inc.

William N. Nawatani
Scientist

jd

Howard Fisher

A Technique for Processing Complex Statistical Data into Meaningful Graphic Form

Not long ago I was talking to a regional planning director who had devoted more than a year of effort to building up what he called a "data bank"—namely, a collection of factual information pertinent to his activity and organized in a form suitable for machine processing. Upon finally completing everything in good order, he asked the computer what he thought was a relatively simple question regarding the data. In reply, according to his story, he received a stack of folded paper about an inch thick, consisting of tabular data, page upon page. He accordingly narrowed his question substantially, submitted it again, and got back about a quarter-inch pile of paper. Repeating the process once more, he finally received a reasonably limited volume of tabular data which he then gave to a draftsman—who, three or four days later, presented him with a map conveying in comprehensible graphic form the significance of the computer's output in relation to his study area. This story is here reported as an illustration of the inadequate use of today's high-speed computers.

To comprehend the trends of the variability to be found in a large quantity of data the human mind can usually benefit from having the information organized in graphic form. It is frequently impossible to draw any meaningful message from long tables of data, or even short tables of data. And even maps or diagrams may be inadequate if significant data is not presented graphically. Let me illustrate: a few days ago I was attending a conference at a leading midwestern university. One of the speakers passed out reproductions of the State of Kansas, in each county of which there was written a several digit number. "Now," he stated, "you will be able to see just what I am talking about"—but no one in the audience was able to follow him, for without the hours of study that he had devoted to the matter, the figures presented could be grasped only at the crudest level. All of which is to stress the fact that, for a great many purposes, we need to have information presented to us in the form of a graphic display if we are to achieve any significant degree of comprehension. Data available only in tabular form is all too frequently worthless data.

The particular computer program that I will describe was designed to aid in meeting this problem. All development work in regard to it was carried out at the Technological Institute of Northwestern University, where I had the privilege of working during the past several years. I think it may be appropriate at this point to stress the fact that I am not mathematically trained and that I am very much of a newcomer to the field of computer work. Yet the basic concept involved and the required mathematical model were conceived by me within three months after first exposure to the computer, a fact which I mention only as a possible encouragement to any of you who are wondering how practical it may be to break into this new rapidly expanding field and to start making day by day effective use of the computer in your work. I think that all of you will find that you *can* benefit regardless of the extent of your background in mathematics or your prior exposure to so-called computer science. It will take some effort on your part plus a little faith and determination, but it should be fun—and richly rewarding.

For identification and your possible future reference, the program may be referred to as SYMAP, short for "synagraphic computer mapping." It is a package program, which means that it is designed to serve a generic need without internal adjustment. For example, it will deal equally well with past data, current data, or future data. The computer has no preference and the program is just as prepared to deal with imagined facts—based on alternative policy or design decisions, for example—as it is with data derived from reality. Equally, it is as ready to deal with abstract space as any other, and may therefore be used for schematic charts and graphs as well as for representational maps, plans, or diagrams. I should stress also that the program is designed to operate on standard computer equipment of a type to be found today in practically every large metropolitan center. Perhaps by telephonic connection, but in any case by the use of regular air mail, rapid service can be available to almost everyone almost everywhere. I need not repeat what Mr. LeMessurier has already mentioned, that there is seldom any necessity for an organization to possess its own computer—for increasingly today's larger computing centers tend to act as public utilities.

To use the SYMAP program, no prior computer experience of any kind is necessary, and no special or advanced mathematical knowledge is required—though, of course, the more of the latter you may possess, the luckier you are for it can contribute greatly to more sophisticated analytical work than would otherwise be possible. The method of operating the program can be learned with considerable speed. A young architect from Australia came to my office with only twenty-four hours to spend in Chicago. He was bright and energetic, and by the end of his stay had acquired a good fundamental knowledge of the principles involved—yet he got plenty of sleep and we had time for a good visit. The more formal training courses that we have conducted require two working days. By the end of that time one should feel reasonably confident in applying the system to simple problems—and after a week or two of practice one should be equal to almost any assignment. For those of you interested in exploring the use of the computer but hesitant to tackle it on a more purely mathematical level, the SYMAP program can serve as an excellent general introduction. Certainly all architects understand graphic communication and feel thoroughly at home with it, in contrast perhaps to more abstract mathematical work.

In preparing a project for execution it is important to understand that there are two basic types of facts regarding which the computer must be informed: where things are, and what they are. Provided with little more than this information, the machine will take over and turn out a graphic display of the data in its correct relationship. Suppose, for example, that you wish to make a study of available and projected downtown off-street parking facilities in relation to some property to be developed. You will need to inform the computer regarding the spatial disposition of the various facilities involved and, in regard to each, the facts that may concern you. Supplied with this information, and appropriate supplementary instructions, the computer can produce for you a series of maps depicting the variability of the data throughout the area under study under all combinations of circumstances.

Location is specified by a simple coordinate system based on the spacing of characters in the computer printout. The type of machine employed prints eight lines per inch, each line 132 characters in length. Thus, to designate a given position by way of example, one might call for Row 37, Column 82.

Applicable data is specified by numerical values. If the facts to be represented are quantitative they will of course already be described in numeric terms. If they are qualitative they will or can be so described. If the facts are solely descriptive —as, for example, varying types of spatial use—they can be assigned identifying numbers to conform to computer needs. You can, of course, deal with any conceivable type of information—such as physical, economic, or social data. In feeding data to the computer, you may ask it to carry out any computations desired, such as figuring ratios or percentages. Or, for example, you may tell the computer to weight the data by applying different equating factors and thus be able to deal with relationships among a variety of subjects, or merge them into one final aggregated display.

Finally, if you wish, and subject to your providing the necessary information, the computer will provide a title with supplementary explanation below each separate display. It will also print words or symbols directly within the display area to indicate different kinds of physical or other features with which you may be concerned.

Two quite different types of output display are possible. You can have your choice of either or both. The first makes use of the principle of contouring, and thus shows, as on a topographic or weather map, the varying intensity or magnitude involved in the data provided. As it shows the overall trends of the data, it is, for many purposes, a most revealing type of display—yet one so costly to produce with accuracy by hand that it is employed relatively rarely for other than the two uses mentioned. The method is equally suitable for many other purposes and, by the use of the computer, this type of output can be procured at low cost. For example, a city planning map that might cost a hundred dollars or more to draw by hand can be produced more accurately by computer for as little as two to ten dollars, depending on volume, circumstances, and applicable computer rates. In addition to the contour type of map you can also procure what is called a flat-tone map. This is like most city planning maps in that a uniform tone or pattern is spread over each geographic area to indicate relative value. Wherever the shape or relative size of individual geographic areas is significant, it may be useful to employ this procedure. It does not, however, have the advantage which the contour type of map offers of organizing and showing the trends of the data.

At the operating level, the submission of data is facilitated by the use of standardized forms which have been developed to aid the work and minimize the likelihood of error. From these forms punched cards are then prepared to convey the information directly to the machine.

For any given series of diagrams or maps, information common to the whole series need be given only once. The material thus provided will then apply automatically to each subsequent individual display. To prepare this basic material for a simple study of average size and complexity might take two to four hours for an experienced operator, while a larger or more complex project might require a day or more—but, as indicated, this work need never be repeated no matter how many displays of varying specific data may later be produced. Thereafter, all that is required is the specific information for each individual subject to be run. Assuming the availability of a data bank, all one needs to do is to provide a few lines of information.

The SYMAP program has been operational for about a year, during which period from time to time various refinements have been incorporated in it. It is available to anybody interested in using it and willing to attend a short-course, such as has been given from time to time, regarding its operation. No royalties are required. To date, more than a hundred persons have learned how to use the program, the great majority of whom had no prior computer knowledge of any kind and no mathematical training beyond high school algebra.

The exhibition display at this conference shows the two kinds of output that may be procured, contour and flat-tone. It is, of course, possible to make a map of any required width by using multiple widths of paper. Any one printout on standard equipment is, however, limited to a width of approximately thirteen inches. Length presents no problem. The widest display run so far is about four feet; the longest, about twenty feet.

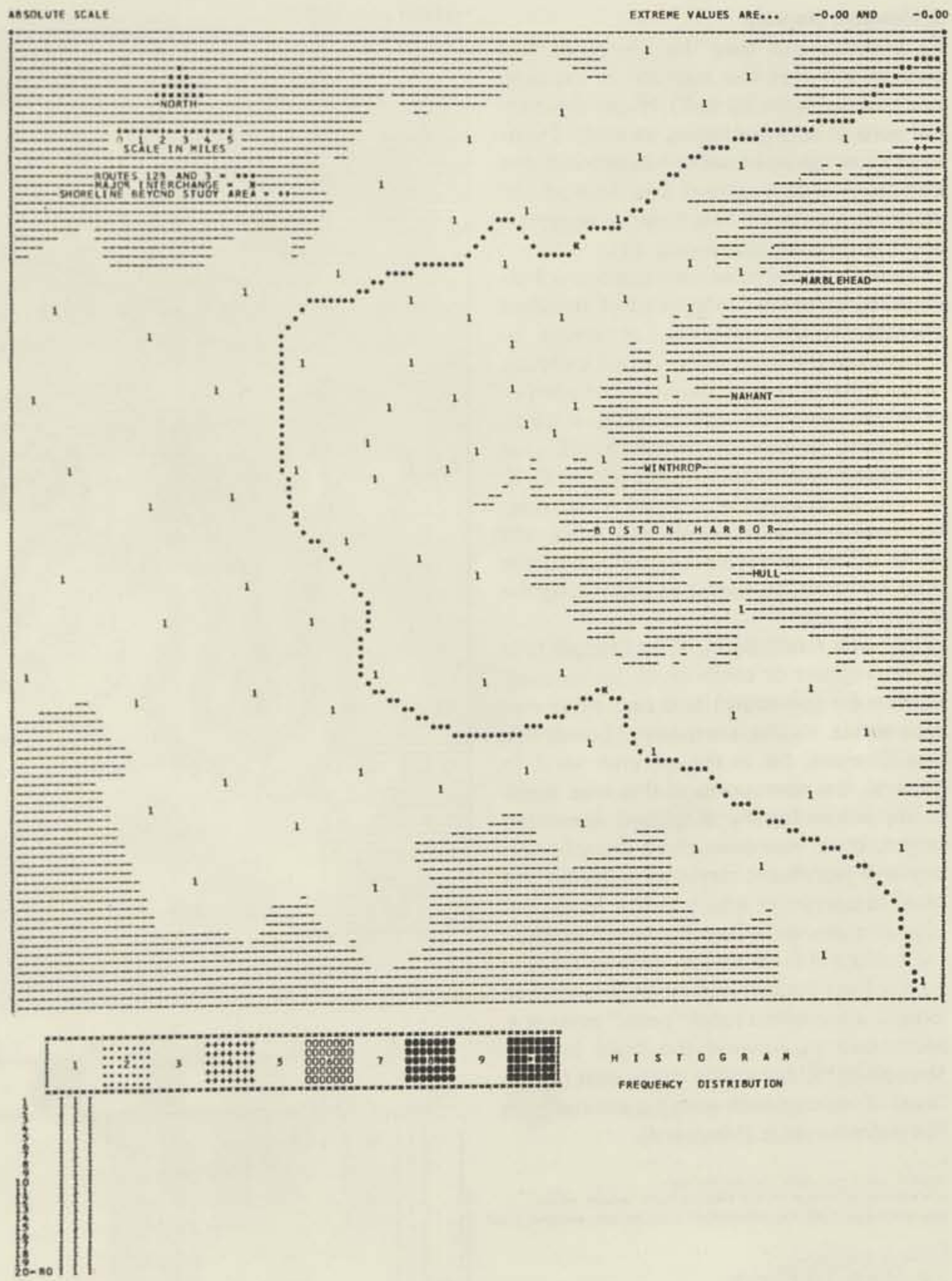
Summarizing the actual usability of the SYMAP program at this time: It provides a graphic display of spatially disposed data. It employs widely available computer equipment. It is designed for use by people without prior computer experience and without advanced mathematical training.

1. A Study of the Boston Region

The four illustrations here presented exemplify the application of contour mapping by computer to the analysis of a metropolitan region in terms of municipal data. The study was carried out by first-year planning students at the Harvard Graduate School of Design (the particular examples here presented having been prepared by Oscar Fisch, Daniel Shefer, and David Wilcox).

This is the "base map" for the region. It was prepared as a first step before the introduction of variable data. The overall study area is indicated in white. The approximate center of each of the region's eighty municipalities is designated by the number 1. (Between these, on subsequent maps, values will be estimated by a system of straight line interpolation.) As a dominant feature of the area, Boston's circumferential tollway is shown by means of asterisks, with x's being superimposed at its three major interchange points.

As the next step, pertinent data was provided in the form of a master "data bank" —from which information was drawn to produce the maps which follow and others for a wide range of subjects.

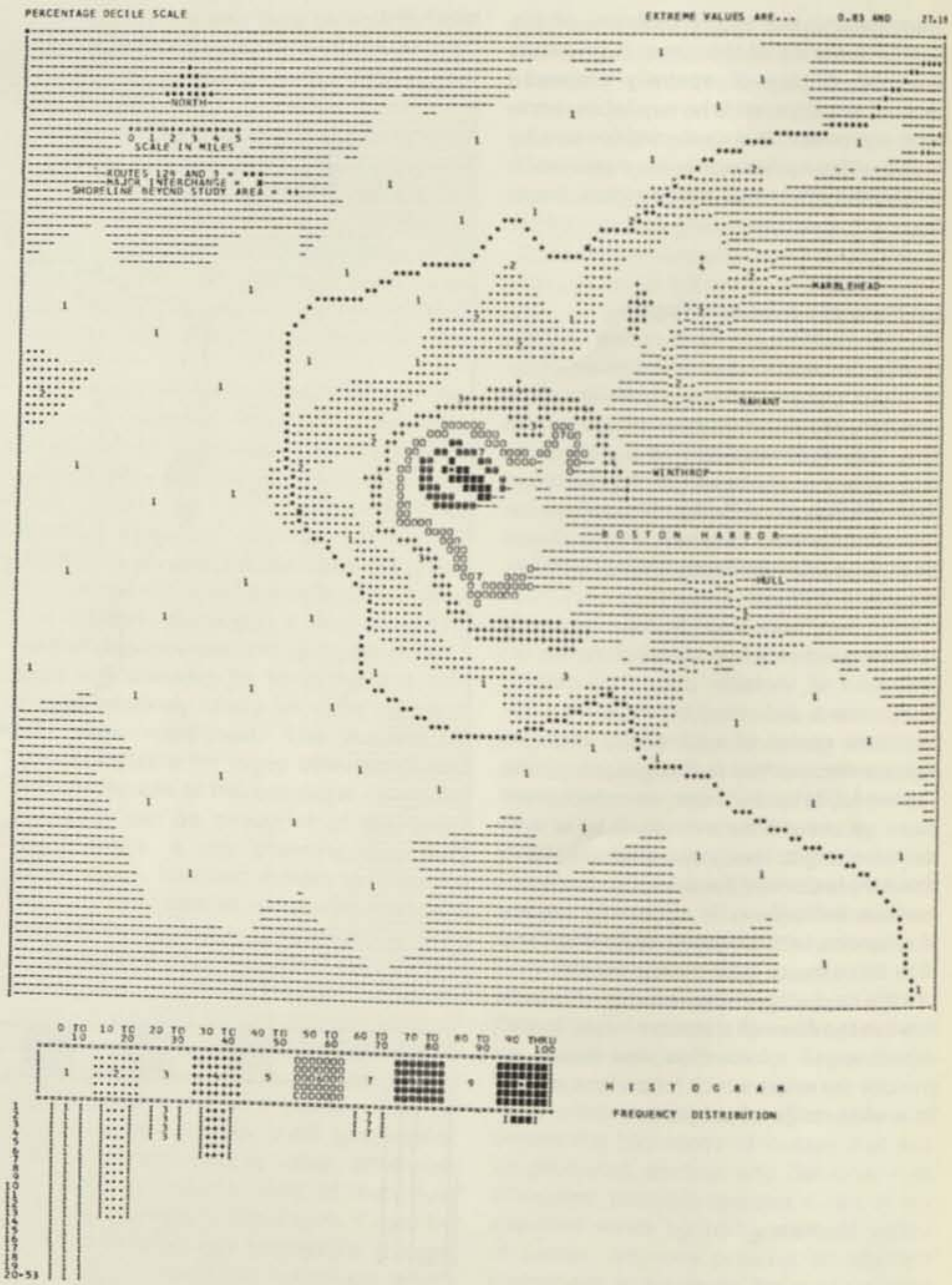


2. Housing Density

To produce this map the computer first determined that the number of housing units varied from .83 to 27.18 per residential acre of land (including streets). Treating this range as equal to 100 percent, the computer then mapped the data at ten value levels, as indicated by the numerals and the asterisk (signifying 10).

Even-numbered contour levels are indicated by patterns (composed of standard characters) the darkness of which increases as the applicable values increase —the lightest pattern being composed of widely spaced dots and the darkest being composed of closely packed rectangles (achieved by overprinting the letters O, X, A, V). To provide visual contrast, odd-numbered contour levels are here left white. (The selection of all symbolism may, however, be varied as desired by the individual user.)

Only one municipality (Cambridge) falls in the highest or tenth level. In contrast, Boston (to the south) and two other municipalities to the northeast (Somerville and Chelsea) fall in the seventh level. In general, the contouring of this map tends to be concentrically disposed about the central core. However, there are interesting and significant deviations, by far the most important of which is the "ridge" of intermediate value (level 3) which extends far toward the northeast. This is created by the long-established cities of Lynn and Salem, each with a local "peak" at level 4. Municipalities beyond the main loop of the tollway all fall within the lowest or first level of values—with a single exception at the extreme west (Maynard).



HOUSING UNITS PER GROSS RESIDENTIAL ACRE

* = HIGHEST 10 PERCENT OF THE RANGE BETWEEN EXTREME VALUES

FOR OTHER LEVELS SEE THE PERCENTAGES GIVEN ON THE HISTOGRAM SCALE

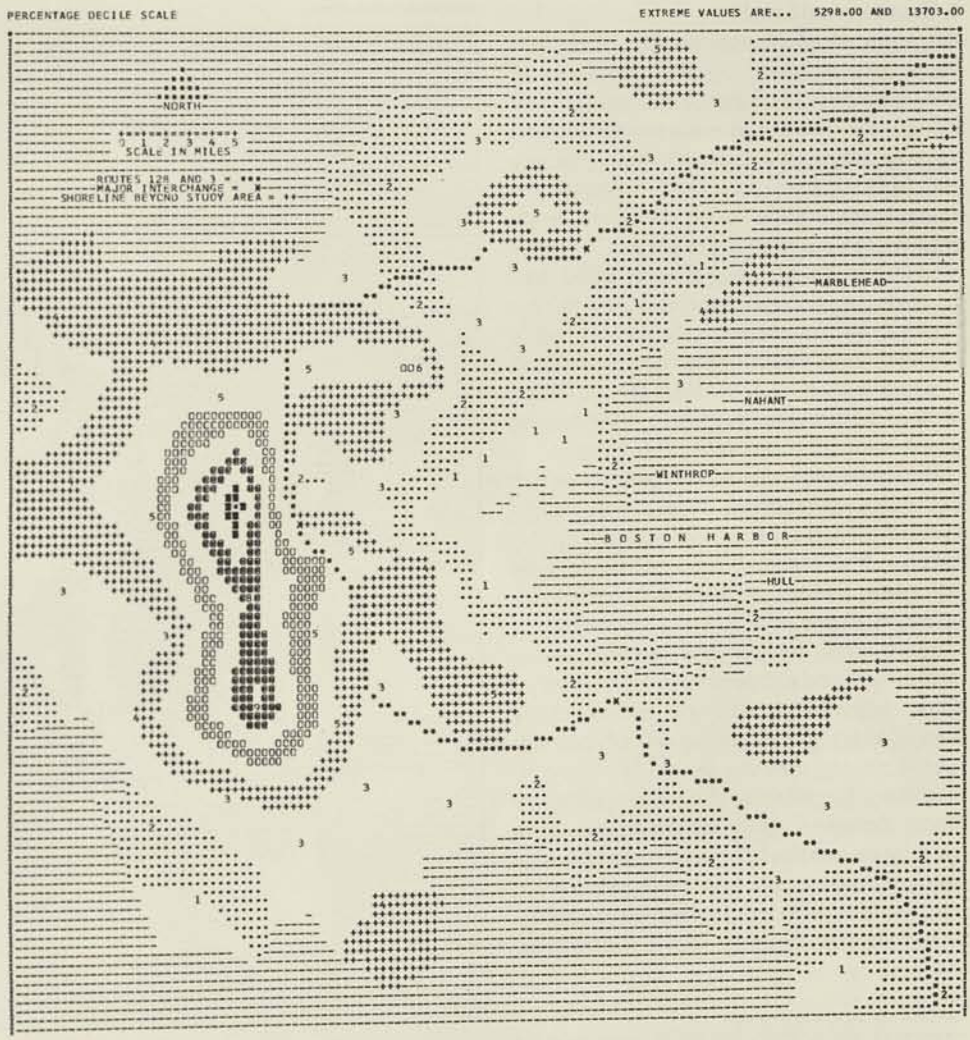
```
METHOD OF COMPUTATION
      READ(5,103)H18,S18
  103 FORMAT(///2X,F6.0/2X,F6.0)
      T=(H18/S18)*100.
H18=ALL HOUSING UNITS
S18=RESIDENTIAL LAND IN ACRES (INCLUDING LOCAL STREETS).
T=TITLE VALUES
(TERMINAL *100. SERVES TO ADJUST THE DECIMAL POINT INTERNALLY.)
U. S. CENSUS OF POPULATION AND HOUSING, 1960          (SHEFER)
GBESC 1960 LAND USE
```

3. Income Levels

Upon searching the data, the computer found that median family income ranged from $5,298 to $13,703. This map shows that the top thirty percent of that range (levels 8 through 10) is all to be found in three contiguous municipalities which lie a little west of the main tollway loop (Weston, Dover, and Wellesley). To the northeast of this high income area there is a "ridge" which terminates in a small local "peak" at level 6 (Winchester). With this exception, and the exception of three municipalities at level 5, the entire area within the main tollway loop falls in the lowest 40 percent of the income range. It may be of interest to note that Nahant peninsula, site of an historic prestige community, falls in level 3. Local depressions into the first level may be seen nearby (at Salem and Lynn).

Beyond the main tollway loop there are only two areas (Norfolk and Pembroke, to the southwest and southeast respectively) which go as low as the first level. Two local "peaks" to level 5 may be seen toward the north (Topsfield and Lynnfield).

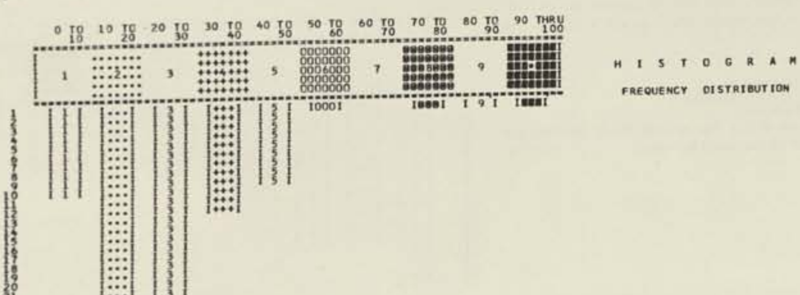
To accompany each map the computer provides a bar diagram which illustrates graphically the frequency distribution of municipalities at each value level. Similarly, a compilation of the areas of the map at each contour level may be called for.



MEDIAN INCOME - FAMILIES (IN DOLLARS)

* * HIGHEST 10 PERCENT OF THE RANGE BETWEEN EXTREME VALUES

FOR OTHER LEVELS SEE THE PERCENTAGES GIVEN ON THE HISTOGRAM SCALE




```
METHOD OF COMPUTATION
      READ(5,102)PIL
  102 FORMAT(62X,F5.0,5X//)
      T=PIL*100.
PIL=MEDIAN INCOME - FAMILIES
T=TITLE VALUES
(TERMINAL *100. SERVES TO ADJUST THE DECIMAL POINT INTERNALLY.)
```

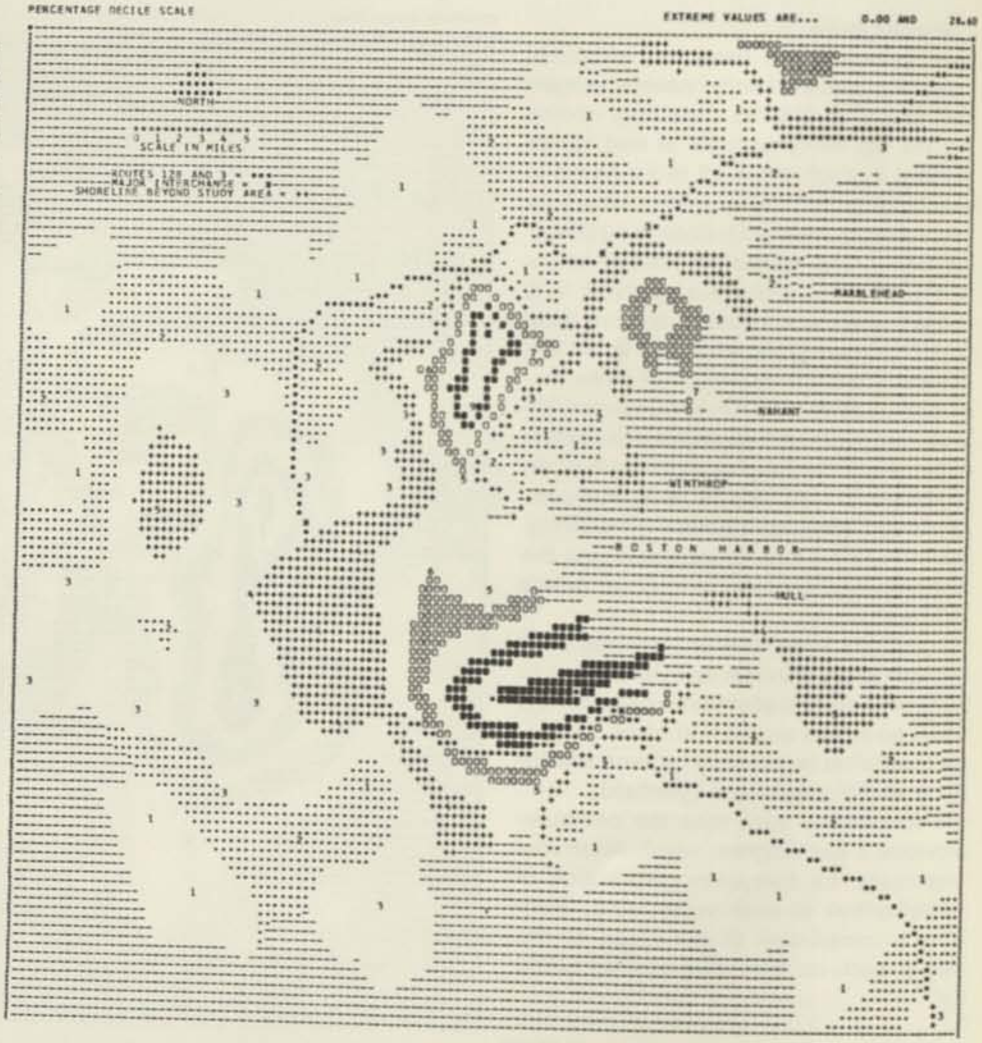
U. S. CENSUS OF POPULATION AND HOUSING, 1960 (WILCOX)

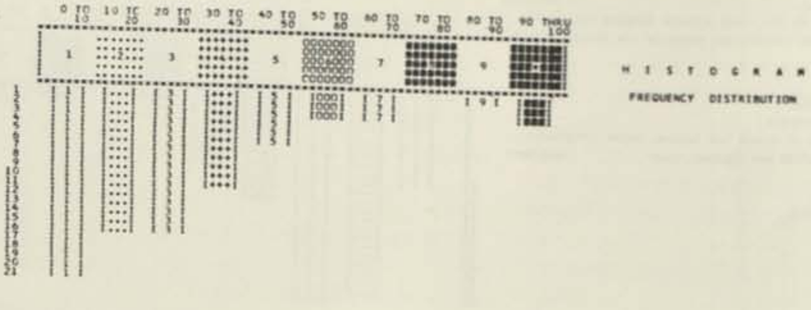
4. Recreational Land

The area of each municipality in recreational use is found by the computer to vary from 0 to 28.60 percent. Just south of the center lies a high-value area formed by two adjacent municipalities (Quincy and Milton). One may learn from an accompanying table, provided with each map by the computer, that these two municipalities have, respectively, 28.60 and 26.76 percent of their land devoted to recreation. To the north of the center lies a somewhat corresponding area involving two municipalities at levels 9 and 10 (Medford and Stoneham). To the northeast is an additional area at level 7 (Lynn).

Of the twenty-one municipalities which occur in the first level, all but three lie beyond the main loop of the tollway. Fortunately, the three which occur inside (Chelsea, Everett, and Wakefield) are located relatively near the more northerly of the two major recreational areas.

When desired a logarithmic type of value scale adjustment may be procured by simple option, or absolute rather than adjusted values may be depicted. Maps illustrating the effects of complex relationships between such variables as have here been portrayed may of course also be procured, as well as maps portraying anticipated future conditions based on alternative assumptions, policy decisions, etc.





PERCENTAGE OF AREA IN RECREATIONAL USE
* = HIGHEST 10 PERCENT OF THE RANGE BETWEEN EXTREME VALUES
FOR OTHER LEVELS SEE THE PERCENTAGES GIVEN ON THE HISTOGRAM SCALE

```
METHOD OF COMPUTATION
      READ(5,104)P1C,S10
  104 FORMAT(13X,F5.0///13X,F5.0)
      T=((S10/((P1C/100.)*640.))*100.)*100.
P1C=AREA (IN SQUARE MILES BY HUNDREDTHS)
S10=RECREATIONAL LAND IN ACRES
T=TITLE VALUES
(TERMINAL *100. SERVES TO ADJUST THE DECIMAL POINT INTERNALLY.)
```

U. S. CENSUS OF POPULATION AND HOUSING, 1960 (SHEFOR)
GBESC 1960 LAND USE

Questions/Morning Session

Most of the speakers have indicated programs that they have developed. I wonder if they could make a listing of these programs available to us.

Fisher:
The work we have done at Northwestern University is available to anybody at anytime at no royalty or charge of any kind except for costs of transportation or punching cards or expenses of that sort.

Russell:
In regard to the use of our programs at Westinghouse, we identify them as DESTEC, WESTEC, and SIMTEC. If anyone wants to obtain the use of these programs, contact me at the Pittsburgh office. We have set up a separate computer engineering service which can be purchased from Westinghouse to those qualified in the building industry. There is a nominal charge for the service, to cover computer time and programming time.

Swindle:
The critical path program and technique is not new, the precedence is new. There are many critical path programs available for a wide range of computers.

Question (to Mr. LeMessurier):
Would you care to define more precisely the implication of the term "BREAKTHROUGH" as applied to STRESS?

Mr. LeMessurier:
The ability to solve modest, but nonetheless unique, problems in a STRESS analysis without a special purpose program for each one. This to me is a BREAKTHROUGH. STRESS has made it easy for someone who has not had previous computer experience to do the job. I think it's important to emphasize that the breakthrough aspect of STRESS is its ability to perform for a person who has had very little computer background and to be applied to a number of different structures on the basis of a few hours experience.

Question (to entire panel):
If the computer will do your work, why do we need engineers, when we can have two computers in the office plus one programmer?

Millon:
I think the computer frees you to practice profession. None of us feel we practice our profession as well as we can or that we have all the time we need for each project. The computer makes it possible for us to do a far better job and gives us time for the important decisions and guiding principles that man's mind must provide.

LeMessurier:
I think the real importance, at least of the structural engineer, has increased. The net effect of so much more precise information, of being able to evaluate so many more schemes, makes the real decisions that we have to make more important. If we know how a building is going to move and deform we still have to evaluate the meaning of this, and these evaluations are the significant part of our work.

Russell:
To comment from the mechanical aspect, I would say that with the use of computer programs, a higher degree of skill in engineering is required than we originally thought necessary. Even though we reduce the time spent on design tasks, the detail required by computers is greater. I think we have acquired a vast amount of knowledge about mechanical system behavior, and hopefully, this will enable mechanical engineers and architects to obtain deeper insight into their problems and prevent them in construction.

Question:
What is gradation of computer work into the architectural profession? How rapid has its introduction been to date?

Millon:
I don't think it has had much impact today, but I think it is beginning to and will have a vast impact. I think this conference will be a landmark in the rapid acceleration of the use of the computer in architecture.

Dean Sargent:
I believe there are many more applications than anyone has yet determined. I hear of things being done without fanfare, such as *systems pressures* in development of new subdivisions, and I know there are many simple applications being made use of by professional offices. Of course, we all know critical path is becoming so common it is even being used in Syracuse.

Question:
What about first cost operating cost?

Mr. Fisher:
One of the early and significant developments of the use of the computer in city planning, I understand, took six man years of programming time. This sounds like a great deal, but may be a modest cost when compared to the value of the program provided. My own experience took several months of work on the basic form, the fundamental concept was hatched after several hours, and it took a brilliant woman about one man-week to do the detailed programming. In its present state the program represents approximately a three man-week, and in a new version expected shortly, I think she has another week or two of time to spend. So you see at least on this project, the time has been very modest.

Luncheon Speaker

Ivan Massar, Black Star

Arcangelo Cascieri

I welcome you as Dean of the School. It is indeed an honor for me to have the opportunity of introducing our illustrious speaker, whom I have known for many years as a scholar, artist, architect, writer and educator of international reputation. It is both an honor and a pleasure to present to you a person well qualified to lead the way, Professor Serge Chermayeff.

Serge Chermayeff

A great number of architects who appear to have some sort of monopoly hold that technology generally is there to be misused at will, others that programming, model building and computer use in particular are tools of the devil, the enemies of humanism, art, diversity and beauty.

That such anachronisms are still possible in a responsible profession give especial point to today's conference.

To keep up the myth of conflict between *Rationality* and *Inspiration* in an age of accelerated change and growth which require planning, the production of essential needs is one of the great absurdities in our time. It is the old "hen and egg" business in a new guise.

Rationality as a system of procedure does not exclude inspiration which acts as an accelerator on the path to the desired goal. Inspiration is a special moment in a rational process. The two are inseparable and complementary.

Is there not a chronic timidity among our artists, if not a definite fear, of having to adjust to new conditions and demands? Previously artists were thought of as prophets; as truth tellers.

The timidity I speak of is illustrated by the desperate clinging together in a sort of 19th Century Club of Architecture with the "Fine Arts" of Music, Painting, Sculpture, although it has become progressively more differentiated from the latter by elements of utility and service.

The Arts of Communication old and new, Literature, Drama, Poetry, Film, seem less inhibited and are joyfully exploring potentials of new media and opportunity. Architectural critics and historians perpetuate old myths all too often and too glibly—they "protest too much."

Architecture seen and interpreted exclusively as an *Art Form* is reverting back to formalism and eclecticism which some of us had hoped to see finally abandoned as a form-making process in complex organization. But no, cyclic ritual, to celebrate the latest arrival of conspicuous display, to follow this with sanctifying comment—to imitate it in schools—to squeeze what one may out of it in commerce, is now routine. And finally, of course, to bury last year's model and make way for the new product of the hucksters.

This closed system results, of course, in exactly the opposite result to that claimed by the culture-mongers: it breeds anti-variety and rapid vulgarization and is closely related in spirit and performance to *High Fashion*.

With all its components of commerce, Beauty has become a Business looking toward Nouveau-Riche consumers.

But the growing affluence, scientific and technological riches could, if properly used, produce an undreamed of new vocabulary of form: Not off the top of someone's head but out of the depths of need, potential and aspiration.

An illustration may be found of the former process in the ubiquitous economic immensity of the automobile industry, which employing great architects for the design of their plans and skilled designers for the sculpture of their cars, have chosen to introduce the 1965 models on the basis of "*Beauty*" almost exclusively in a year in which the road death and accident toll has broken all records. Not a word about safety, few on economy, fewer on convenience.

We are becoming more conscious, however, of three simple facts. First, that by far the largest segment of physical planning and building construction is concerned with meeting urgent needs of a utilitarian kind. Second, that the needs and means of supplying them have become infinitely complex. And third, that the Private Practitioner Architect in this country is responsible for an ever-decreasing percentage of the total expenditures in Construction.

The evidence seems to point toward a growing Architectural lag in a period of a widening and accelerating change: architects do not appear interested in or even aware of the meaning for them of scientific discoveries, technology of controls and communication, social redeployment and cultural metamorphosis. Innocence of the true nature of the decision making processes seems to extend even to the ranks of our most successful, favoured, practitioners close to sources of power.

Yet vast decisions have to be made, and the powers derived from rational exploitation of all available resources are immense, as is professional responsibility in relation to Environmental Design, the task of which is to manipulate them.

Mr. Buckminster-Fuller's current activity in preparing an inventory of world resources and concern with their proper use by "Comprehensive Designers" is a splendid antidote to culture-mongering.

Environmental Design must start with resources to be transformed through Planning, Construction, Control and Conservation. To achieve these immense tasks in the first place we need many functionaries, some new, yet to be created, to analyze, organize, synthesize, to shape. We don't have to worry about the creative genius: "Beauty will look after herself."

To resolve these extraordinary quantities, complexity and newness, we must recognize needs; we need to master the new tools.

I doubt if in so doing we shall be risking our humanity. Perhaps we shall match again, but on a greater scale, the genius and knowledge displayed by a handful of historic figures concerned with similar tasks.

Neither the willful artist nor the Sweets item-arranger can perform such tasks. It seems that we have to go about producing the needed functionaries quite deliberately. We must do so in our universities and professional schools, for the architectural marketplace is not likely to produce a sufficient number of 'truth-tellers', soon enough.

Christopher Alexander, who knows how to employ computer techniques to design, has stated that our survival depends upon our recognition of the pressures upon us and our ability to master new complexities with the best technology at our disposal. This may not be done without the employment of problem analysis tools of electronics. For the first time mankind is able to substitute rapid programming and testing for slow empiric method in design.

Can Architects remain aloof from this process which makes planning at last possible? We, we only, get an appropriate *Total Architecture* of a New Humanism by employing our *Total Resources: our Cultural Heritage* and our *New Knowledge*.

Data processing techniques have a hidden, but I believe an important, professional contribution to make: they exact a scrutiny of problem components which must be careful and comprehensive to produce important results.

This discipline is long overdue in a profession which has adopted attitudes, and made pronouncements on very slender evidence indeed. Whereas this superficiality may pass in the realm of broad generalities, it does not suffice in getting down to essential particulars.

Man has been vastly extended in *Vision* through: the microscope, telescope, electric light, X-ray. In *Communication*, through the telephone, telegraph, radio, television, radar and recording and projection techniques. In *Mobility* through: the wheel, the harnessed energies from the steam engine to the rocket.

The Computer and instantaneous feedback is an extension which exceeds all these a hundredfold, for it has extended man's *Understanding*.

It is in mastery of the most *Sophisticated Technology* that our hope lies for obtaining *Highest Culture*.

For the architect technology of resolution of problems produces an acceleration of useful functioning far greater than that of the print and photostat achieved above tracing.

The opposition to technology and its advantages could produce professional paranoia if allowed to go unchecked. The self-appointed defenders of culture are often culture mongers on a temporary bandwagon, pseudo humanists, whose fears, guile and sometimes outright deception are symptoms of paranoia, of which self-deception is the most pitiful aspect.

We can no longer afford to applaud the shenanigans of the playboys of the western world.

Afternoon Session

Phokion Karas

Albert Dietz
Introduction

There are obviously many services that the computer can perform, and many of these have already been talked about this morning. There are such things as data storage and retrieval, memories in which huge amounts of data can be stored and retrieved as necessary. Computers can make lightning fast computations, tremendous numbers of them in a short time, and give information very quickly. They can reduce drudgery; they can undertake repetitive tasks which the human mind can only do slowly and usually with considerable error.

Today we are exploring where computers might fit in the field of architecture, a field which has been notoriously resistant to quantification and handling by mathematics or other techniques of that nature. I think that we're beginning to see that the computer can be helpful in handling those aspects of architecture which are quantifiable, and there are many. It should be possible to use computers to handle such things as allocation of space and activities in a building in an optimum manner. They are already being used to handle problems of internal transport, traffic flow and problems of this nature.

Computers should leave time for creative work, the application of judgment. They should make it possible to present the designer with a great many more alternatives than he generally has time to develop; and therefore, give him a better choice. They cannot take the place of creative activity. In consequence, the computer does not really degrade the designer, any more than it really degrades the engineer. If anything, it calls for a higher order of competence on the part of the designer, whether he is an engineer or an architect, because he now no longer does routine drudgery, but has to work at a higher level and with a much higher degree of sophistication.

Progress has already been made in the application of computers to many engineering problems, a good many of which are very close to architecture design. Classically we have had three principal types of languages, three principal means of communication. We have the spoken or written word; we have the graphical means of communication by pictures; and thirdly, we have the language of quantity that is mathematics. We need all three of these in architectural design in order to carry out our function properly. The computer has traditionally been almost exclusively a means of handling mathematical problems. It is basically the mathematical tool. Our problem now is to make the computer useful in the other types of communication.

We saw this morning that a start has been made in the direction of man-machine communication by means of the written word. As the first paper pointed out, we now have a language with which the structural engineer can give commands to the computer, not in mathematical symbols, but by means of verbal or typed-out instructions. These tell the computer to do certain operations and tell it in a language familiar to the engineer who talks in terms of moments of inertia, loads, shears and other things also familiar to the architect. Other languages of this type are being developed, as a first step towards overcoming the gap which is found between the computer neophyte and the mathematician.

This afternoon we will hear about some steps taken in another direction, i.e., graphical communication between the operator and the computer, so that instead of having to use the written word or mathematical input, a graphical input and a graphical output can be achieved. Here we are getting closer to the language with which the architect is most familiar.

Another aspect to be demonstrated is a step in the direction of making the computer a practical tool to the practicing architect. Even the biggest engineering or architectural offices can hardly afford to install a computer because they just wouldn't use it enough. The solution might be to have a central computer with feeder lines from all directions, to be used by people in peripheral offices at any time they wish. This again calls for development in computers and in man-machine communication.

Finally, I must mention, from my own standpoint as a university man, that we have a real responsibility in the education of the new men who are coming along. New designers, both engineers and architects, must be familiar with what the computer can and cannot do. Hopefully, in the future when they enter your offices, they will help you to bring the computer into the picture and make the contribution to you that it is capable of making.

Steven Coons
Computer Aided Design

To many engineers, a "designer" is a draftsman who portrays an engineer's concept of a machine or system in a carefully drawn, carefully dimensioned graphical form; or he may be a "structural designer," which means that he applies analytical, mathematical techniques to the engineer's concept of a machine or structure and makes recommendations of change of physical dimensions so that the device will be strong enough to support he applied loads. There may be other neanings, but in them the notion of innovative activity, of generation of the original concept, of invention, is completely lacking. Engineers tend to like to think that the design process is entirely rational, and they tend to minimize and ignore the creative process as though it were something slightly immoral. Engineers prefer to replace all black arts, necromancy, and art itself with science and scientific method.

On the contrary, many architects, and the archetypical members of their coterie, artists, use the word "design" to mean only the innovative, generative, intuitive acts of conception; to them, the necessities of structural analysis, the mechanics of heat flow, the aerodynamics of wind loading, and other analytical methods for coping with the stringencies of nature and natural law, while recognized as essential processes, are not considered a proper part of design, but only of engineering and construction; subservient functions that must be employed to bring a concept to realization.

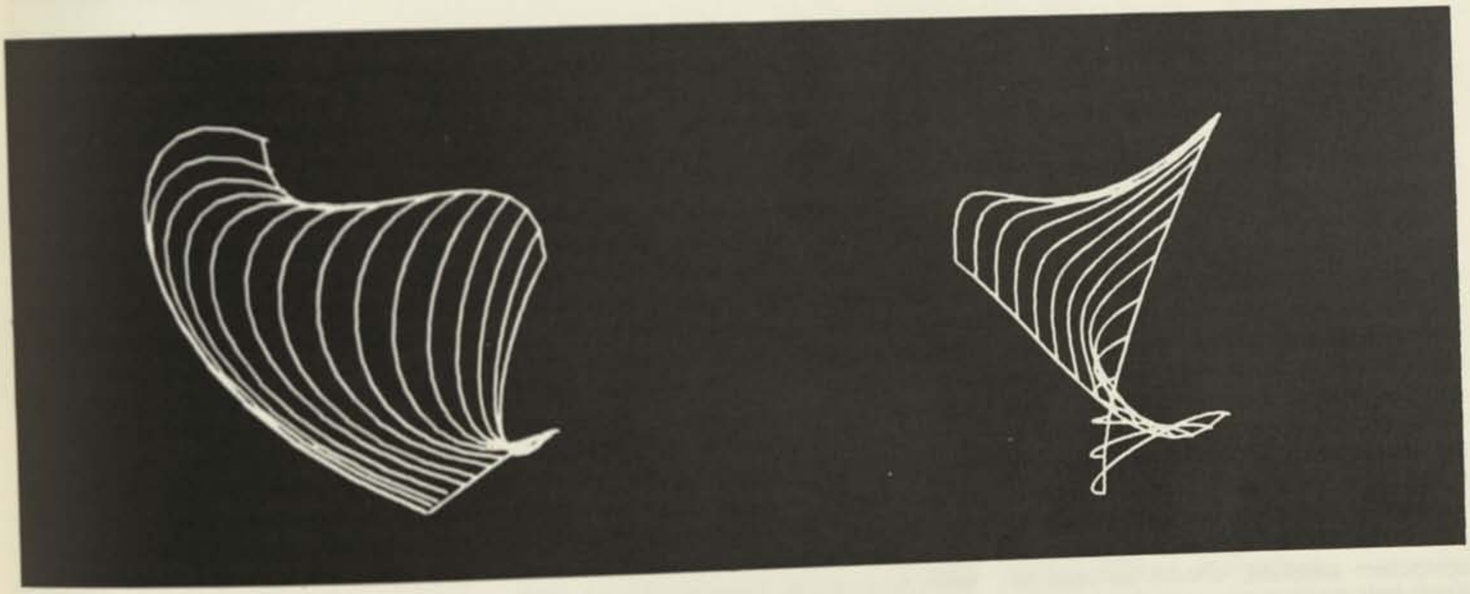
The true and complete process of design, it seems to me, consists of an inextricable mixture of these intiuitive, imaginative cognitive processes together with analytical, mathematical, rational processes. It is the thesis of this article that humans have special skills of a high order when it comes to devising, structuring, comparing, and making penetrating and powerful qualitative judgments, but are remarkably inefficient when it comes to carrying out those rational processes that involve precise attention to intricate mazes of elaborate details. On the contrary, computing machines are extremely efficient and tireless in dealing with analytical processes, no matter how complex, but are completely inept at creative tasks. Since art and analysis are both parts of the design process, it seems only reasonble to combine the human and the computer so that each can perform a proper function.

At MIT this philosophy has been pursued for a number of years, with enough encouraging results to indicate that in some not too distant future, the computer can act as a super-tool, an inanimate but nevertheless benign, efficient and in a certain sense intelligent assistant to people engaged in virtually any creative task, whether it be engineering, science, architecture, or even the arts. There are two research programs in progress directed to this purpose, whose aims and methods overlap and mutually reinforce one another. One is called "Computer-Aided Design" and is sponsored by the Air Force. The other is called "Machine-Aided Cognition" (MAC) and is sponsored by the Advanced Research Projects Agency (ARPA) of the government.

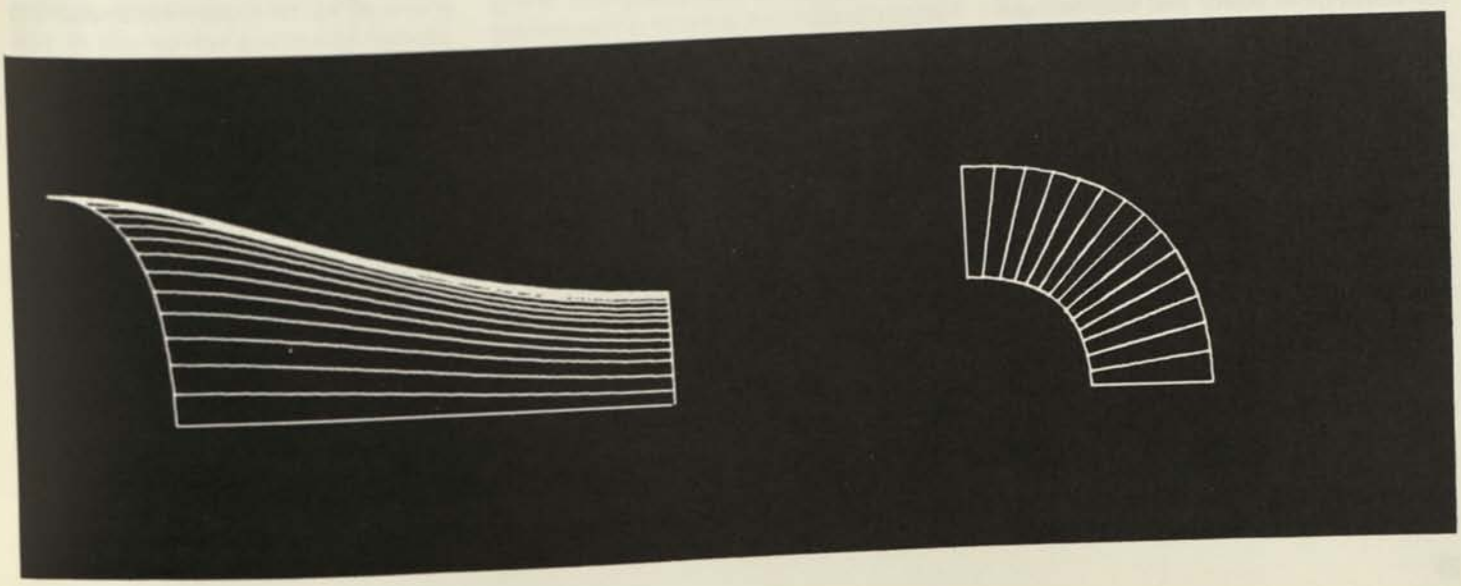
In architecture, as in many fields of engineering, and indeed in some fields of science as well, graphical modes of thought and expression are of primary importance. Two years ago, Dr. Ivan Sutherland developed SKETCHPAD, a computer program that made it possible for the first time to communicate with a computer in graphical terms, by means of drawings. The actural communication is extremely natural, and constitutes an elegant model for future development of other means of communication between man and machine.

Sutherland's SKETCHPAD, together with other more recent developments that have already been achieved, and still more recent ideas that await implementation, will in a few years culminate in the kind of computer system and the kind of man-computer symbiosis we have in mind.

Imagine an architect (or an engineer) seated at a computer console of the future. Before him is a screen very much like the screen of a television set; at his left hand is a small array of push buttons, and on his right is a conventional typewriter keyboard. He begins to sketch on the screen, using a pen very much like a conventional pen in size and shape, except that it is connected to the console by a slender flexible wire. By appropriate manipulations of the pen, together with push-button signals to the computer, he can sketch lines, circles, and even complex free-form surfaces in space. In the sketch, let us assume that certain lines are intended to be horizontal and others vertical. When first drawn, these lines are straight but are not precisely oriented. By a push button signal, the computer interprets the crude sketch and makes appropriate changes to "true up" the drawing. The designer can at any time introduce dimensional information, to any desired degree of precision, simply by pointing to a line on the screen and typing in its desired length. At other times, he can query the computer, and cause it to measure some distance implicit in the configuration he has drawn. If this dimension does not satisfy him, he can modify it by typing on the keyboard; the computer will not only change this dimension, but will "fix up" the rest of the drawing to fit, subject always to certain controlling dimensions. If, as may happen, the constraints on the dimensions are incompatible, the computer will advise the designer of this fact. He then has several options; he can relinquish his requirements on one or more of the constraints, letting the computer calculate the implicit dimensions; or he can readjust the several dimensions until he has achieved some satisfactory arrangement; or he can leave the entire problem of adjustment to the computer, content to accept whatever result it achieves.



Here are two views of two three-dimensional objects, one a free-form shape, and the other a part of an automobile body or airplane fuselage. Each surface is defined by the designer by the four curves bounding the surfaces; the computer does all the rest, in about a tenth of a second. These shapes could be as small as an ash tray or as big as a house. The shapes are known by the computer to a precision of one part in ten million.



The entire process is one of continuous communication between the designer and the machine, but one in which the designer is always in complete control. He is free to accept the implications of what he has done, as shown him by the computer, or to modify his original concept based on these implications.

The designer can call upon the computer to furnish information on certain standards. Bathrooms, car-ports, elevator shafts, theater seating arrangements, are to some extent dimensionally subject to such standards. Bathtubs, automobiles, elevators, and theater seats are items not always under the dimensional control of the architect, yet they have their influence on his work. It is obviously entirely appropriate that the computer, in the role of competent assistant, should be able to keep precise account of all such standards, and should impose their constraints automatically, or at any rate bring them to the designer's attention.

Beyond geometry, the designer needs to apply many other classes of constraints. He needs to know something about the structural requirements of his design, what wind and snow loadings will imply, how sunlight may be expected to warm the buildings in winter and summer, and other problems. These questions are largely a matter of analytical computation, for which the computer is again perfectly suited. The maze of restrictions that must be threaded in architectural design—adherence to building codes, zoning ordinances, population density, traffic flow, compatibility with existing buildings, and aesthetic requirements constitutes a complex, bewildering contour, and the computer can help with such complexities.

At some time after the design is well formed, the designer will be able to look at his design in perspective, to move the picture as though he were seeing it from various angles and various viewpoints, to simulate its relationship to other spaces, in a completely dynamic way. He will literally be able to "walk around" in his plaza or in his building, and to experience what such an architectural form really is like.

Eventually, after the process has produced a detailed description of the design, the computer can prepare, semi-automatically, all the varieties of working drawings and specifications that are required for fabrication—the concrete drawings, the structural steel drawings, the heating, air conditioning and ventilating drawings, plumbing, electrical, and all the other special specifications, each with appropriate attention paid to the conventions and rules of the particular craft. When done, there will be complete assurance that these drawings and specifications will not only adhere strictly to the appropriate codes, but they will be mutually compatible; there will be no possibility that by oversight a water pipe and a ventilating duct interfere with one another.

It is of course true that a computer system with sufficient power to accomplish the tasks outlined here would be far too expensive for even the largest corporation to operate, if it were not for the new technique of time-sharing now being developed by Project MAC, at MIT. A computer is expensive only if it is idle. If it is busy at productive work it is remarkably cheap to operate when one considers work accomplished with respect to time spent. For example, a computer can calculate the lines of an airplane fuselage, so as to describe such a shape with an engineering accuracy of one part in ten million, in considerably less than a second. By conventional methods such a task requires several man-weeks to accomplish. At the relative pay scales of people and computers, it turns out that computers are extremely cheap help, provided they are always busy. A designer often likes to ponder his problem, to sit for long periods simply gazing into space, meditating on various aspects of his task, and various means for its accomplishment. At such times, the computer must, if it is to be efficiently and economically used, be busy with some other problem, and not waiting idly by while the man reaches some conclusion. Accordingly, the modern concept is to connect several, indeed many, consoles to a single large computer system, and to make the computer the willing slave of many masters. In this way it can be kept continually occupied, yet no single individual user need be concerned that he is monopolizing in idleness the time of his expensive assistant.

Such a system has other benefits. It will make it possible for specialists and experts to communicate with one another in the solution of a problem. One can imagine the consultant of the future called in to render his services in some difficult situation, and able at his own console, perhaps in a remote city, to see the problem, to work on it with the aid of the computer, and to render his judgments or his solution, in a matter of minutes or hours.

Systems like the one described will be in use in certain large companies like the automotive and aircraft industries within a very short time. Partial systems already exist in two or three cases, and they are beginning to show signs of fulfilling their promise. As time goes on, smaller and smaller companies will be able to avail themselves of the services of computer systems, in a way very much like the public telephone and electric utilities. Eventually the smallest design office will have access to the power of the computer.

As has been suggested, the computer will in the future aid man in the creative process, making it possible for him to generate wealth with very little labor and emancipating him for activities that are commensurate with his humanity and his spirit. There are those who are quick to point out that the computer can also augment man's power to do trivial things, to compound the banal and the vulgar. These critics are of course misanthropes, and it is improper to attribute to the machine the blame for their dim view of human kind.

Welden E. Clark and James J. Souder
Man and Computer in the Planning Process

Dietz:
Our second presentation this afternoon is going to be an interesting one in that Welden E. Clark and James J. Souder, both from Bolt, Beranek & Newman, Los Angeles, are going to present simultaneously on man and computer in the planning process.

Souder:
Five years ago, the two of us and several colleagues had the opportunity to undertake a research program sponsored by the American Institute of Architects and the American Hospital Association. We didn't have much in the way of guide lines; we were asked to do something that would interest us in the way of research toward improvement of hospital planning. We queried quite a few other architects about things that worried them in hospital planning, and we found some areas of universal agreement. One was that the primary consideration for an architect is to gain a clear understanding of the program he is attacking (this may seem to elementary to need mention, but it was emphasized repeatedly); second, to find means of a clear statement of programs, and third, a method of seeing all the pieces of problems interacting simultaneously: in other words, an overall view of the problem—as one might view the world whirling through space.

After initial efforts to find anything in the literature, the next thing we did was again to question architects about their methods of attacking the planning problem. They all agreed on the need to find a better understanding of function; and secondarily, that this understanding leads to design of the circulation system. Since we couldn't attack the total spectrum but had to have a subject that was manageable within our time-availability and money-availability, we selected circulation planning as a subject for our work.

Looking at the way architects work, we found that their approach over the years had been pretty much the same. Its intensity varies from man to man, but the basic approach is one of determining goals, then finding the functions associated with those goals and finding the resources available to meet the goals, and finding some measures to evaluate the results of what they propose. Our approach now is simply to use some new tools in this old process, which is closely akin to the thing that our friendly engineering colleagues call systems analysis, or operations research. I would maintain that this attack on problems originated in architecture.

The approach we used is a rather elementary one. It simply maintains that any social process is an organized one that may be regarded as a system; that it has inputs—raw material if you like—and the means of applying some resources to the inputs in order to achieve a product. After looking at some data, we came to the conclusion that the hospital can indeed be described as a system, which has raw material (sick people) and resources (personnel equipment and supplies) and finally, a product (well people and a certain number of rejects, which either get reprocessed or discarded). Within this system, of course, are a number of subsystems. These are the major components that go into converting sick people to well people: medical care, nursing care, administration, and then the logistics mechanism by which patients and all the things that are needed to convert them to un-patients are brought together. After several seminars, the most innocuous word we could find to describe this subsystem was "commerce." Now, along with sub-systems, we have the idea of process, and I think I'll let my friend speak of this one.

Clark:
I think the fundamental concept is that we are designing for some sort of a dynamic organism, some process that takes place that is part of our culture. Indeed, the design work, the planning work, the construction of this building is in itself a process. It's something that goes on, not a static thing, but ever changing.

The other concept that seemed important to us at the outset was concerned with things that were measurable and with the concept of measurement itself. Here we can talk of different kinds of measures: some are objective measures, of things that we can measure in terms of length, or area, or dollar cost. Other things aren't quite that simple, but we can get at them with subjective scaling, by judgment that tends to be replicated by different people on such things as ranges of comfort, allowable brightness contrasts, or ac ceptable noise levels. For an area of tl environment that can't be measured rectly in feet, inches or dollars, we can least get *some* quantitative means of evaluating different alternatives.

Along with this, we suggest that there must be a spectrum of properties for a piece of architecture or architecture as a whole, ranging from those things that are easily describable in objective terms, to those things that are quite intangible and difficult to define. We suggest that at one end, one can define an area that would be labelled *utility* that is concerned with function in the narrow sense. The middle of the spectrum we might label *amenity*—concerned with comfort, and with the individual who experiences this, apart from the performance of his task. Finally, at the other end, the properties might be labelled as *expression* relating to the goal of making this an appropriate piece in an appropriate setting, which includes what we talk about as aesthetics.

So we're talking then about kinds of measurement, things that can be measured in one way or another, and a possible scale for properties of architecture. Now in implementing this talk we immediately have to back off because subjective things are difficult to get at. There have been some stabs at what we've called the area of amenity, but there's not a great deal available. And those properties that are elements of *expression* we all know are very difficult. So as a first step, we've concentrated on things that are mainly part of what I've called the *utility* properties. The example we've chosen to describe here is the study of quantifiable aspects of the commerce *sub-system* in the *system* that is the hospital.

Souder:

If you are studying a system and, of course, the aim here is to structure a system that can be studied, you must look at its content. As we begin to structure the planning process, we can divide it into identifiable elements that really represent what goes on in everyday architectural life. The first is assembling of facts; the second, the beginning synthesis of answers, and then of course, evaluation of the answers that we have arrived at. This is a highly interrelated process. The beginning of synthesis may well demand more information, or the evaluation may send us back for more synthesis, or even more information. So, this is more or less a continuous trial and error process in which all three factors are closely related to each other and influence each other.

One of the reasons for this complexity is the very complexity of the information that one encounters in looking at a human systematic process. The kinds of commerce that occur in a hospital—the volume loads of various facets of movement required to bring things into juxtaposition with patients such as wheelchairs or physicians, or of any number of things that might be meaningful to the design of a system such as corridors, communication facilities, or elevators—vary tremendously through the normal daily life span of operation. What we really want to know, if we see all of this operating at the same time, is what kinds of people are active, what their pathways are, where they coincide, where they don't, what their purposes are, and, most important if one is to gain some qualitative insight, what sort of items they demand, or take with them, and when these things occur in time.

To get at this kind of thing, we have to acquire a great deal of information. We used a log sheet that indicates a simple way of observing information and recording seven or eight of its characteristics, such as time, kind of person, origin, destination, means of travel, purpose, items involved in the trip and so forth. This is where the computer becomes a useful tool, because it can digest this information, and it can begin to answer questions that are put to it.

Clark:

The log sheet information is converted to punched paper tapes, for storage in a computer. This information has been coded in a kind of near English form, rather than as a series of numbers, which increases the immediate usefulness in interpretation. We've tried to use simple three letter codes such as *xry* for the X-Ray department, and *nur* for a nursing unit which is about as simple for the computer as dealing with numbers, and makes communication much faster and much easier for people. As an illustration of some immediate output from a sorting process, the question of the origin and destination of each trip was asked to develop an origin/destination matrix. Which applies to the whole pattern of movement, the whole complex of commerce in the particular setting.

Souder:

I think you ought to add some discussion of the possibility of extrapolation and other kinds of presentation, such as time series, and sorts by purpose, and so forth.

Clark:

One can ask questions about the time of occurrence of trips and then create time distributions from the data to show the coincidences between trips by visitors, trips by patients, trips by doctors, etc., so that one can begin to see where this complex of traffic movements gets congested.

Souder:

This gets to be kind of a reiterating cycle where you continually sort data, observe the sorts, and are stimulated to seek new kinds of sorts, and find patterns in them, and then measure pattern effectiveness and seek new sorts again. It's a cycle of investigation, synthesis, and evaluation that is very fast because all of the information is available as quickly as you ask questions.

Clark:

There's no need to show information as tables and numbers. It's a lot more useful to most of us in graphic form. The face of a computer oscilloscope can show bar-graphs of the percentage of movement for different tasks, such as patient movements, medical purposes, supply purposes, etc.

The important thing about having information available in computer storage and having the ability to display graphs is that this gives us a quick way to modify the graphs and thus the data, to extrapolate to some new, some hypothetical situation. If we want to add facilities, or change organization or operational pattern, perhaps add an evening shift, we make a new data pattern by modifying the graph. The important thing here is the close interaction between men and computer that we are all aiming at. With this capability for generating information on traffic and for modifying existing data to project to new situations, we can in addition apply some stochastic processes by knowing something about the fine structure of trips—the ways they occur during the day, and the mathematical laws of randomness to which they are approximated. We can generate hypothetical data for further processing, which look to the computer just like the observed data put in in the first place. So, we now can use either real observed data of past situations, or hypothetical information, and the important thing is the quick ability to change, to try another generation of a new hypothetical pattern.

Now we need to store in computer memory something about the physical arrangement in which traffic moves. One possible way of describing building arrangements to the computer is by sketching in the information on the face of the scope with a light pen. An alternative way of describing this graphic information to the computer, something developed more recently because of needs that the light pen cannot accommodate, is a device to trace the diagram and store the data directly. Essentially, as the man moves the pen of the tracing arm over the plan sketches voltages are read off potentiometers on this arm, these are converted to digital information, stored, and then the computer starts processing that data. With plan sketches now in storage, we can use the plans and the traffic data from the graphs for some analysis.

Souder:

Now we can begin playing block planning games, large scale planning games around partis. We might try three solutions for one problem providing a total number of beds and a total volume of treatment spaces in three different patterns. First, a sort of 1950 standard, vertical hospital arrangement with all the bed units stacked up straight into the air and all of the supply and treatment services stratified at the lower levels. The next scheme groups quite a few bed units on one floor, reducing the height substantially, but still keeps the supply and treatment facilities down below. And there is another scheme that again puts a number of bed units on the same stratum through the superstructure, but also distributes along with them all of the diagnostic and treatment facilities (surgery, x-rays and labs) related to the kinds of beds as well as food service for the patients and personnel, supply services, and distribution services. Now, when we make this physical configuration, we begin to take the data we have on how many people go where, to do what, at what time, and rationalize what the differences in consumption of manpower are between these three kinds of very quick partis.

The computer sort demonstrates that the second scheme reduces the man-hours devoted to all these tasks a little over 30% below the first scheme, and the third scheme reduces them by about 60%. This is not the kind of demonstration that is going to convince the architect on the selection of a parti, but it begins to point out some variables that do indeed affect operating patterns and make it worthwhile for him to examine them in relation to the human elements that have been described before.

Clark:

One application of this kind of device that seems to make sense is the inventory of spaces in existing buildings, again let's say hospitals. Suppose that we have hospitals that date from the 1900's to the 1960's on the same site and include buildings from 2 stories to 20 stories. The same functions are performed in lots of different spaces, and are spread out through facilities blocks apart, and many years apart in age. It's a staggering task to begin to put together a complete documentation of such hospitals to provide just the bare inventory from which to do a master planning effort.

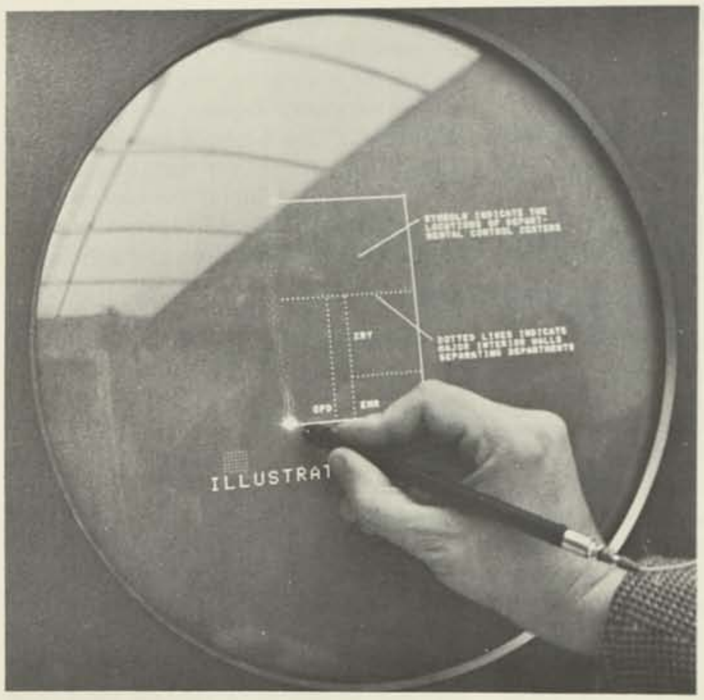
A technique using the graphic input device gives us a chance to quickly sketch in from available drawings all of the spaces, and then essentially build a set of plans of the building in computer storage. Then one can apply some manipulation, some sorting methods, some calculations, and come up with areas for all those spaces, and with outputs on demand, sorting by floor level or building or function, or by combination of these things.

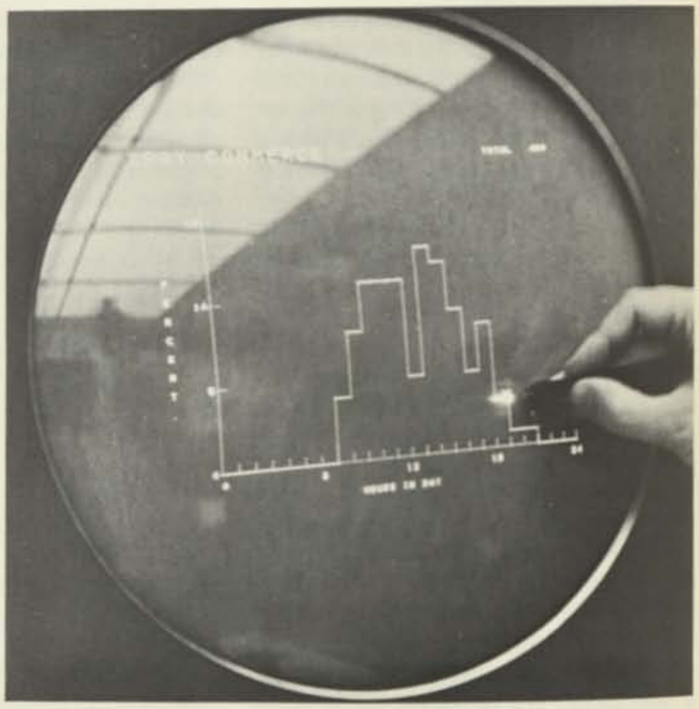
The graphic input tracing device when used with a transparent overlay template is practically self-sufficient during the input process. Some peripheral areas on the left and across the bottom of the template assume control functions, so that one can move the pen to start drawing a figure, trace it in, save it, or close it. One can straighten the figures out according to rectilinear bias so that one can draw not quite square figures and get them squared up. One can add labels, 3 character labels like *xry* for the x-ray department, simply by pointing at those symbols at the periphery of this overlay. We still have some of the handling characteristics that we've grown accustomed to with a pencil and some of the filtering, screening, second-look characteristics that we can only gain with a computer.

Souder:

A real advantage in this kind of thing is that the take-offs are not only made approximately as fast as usual on a simple rectilinear plan (considerably faster than the draftsman can make them on a complex plan), but odd shapes are easily assimilated. Best of all, the calculations are accurate and always available, and you don't have to sum them. If you want to resort them in different ways, you don't have to go through stacks of figures on tablets lost in the piles to find answers.

I think another most important application for this kind of thing is in urban and regional planning, where it is necessary to relate demographic data to geographic entities. Data that come from different sources, such as census data based on census tracts, welfare districts, crime and police districts, school population, and so forth can be reduced to a common geographic base. Indeed, one can set arbitrary boundaries and study an area within a certain radius of a certain point and then get all of the data reduced in such a way that he can see what the sociological patterns are. We can even go farther and talk about economic bases and the traffic flows, and so forth, that accrue to different kinds of land use that we find in these existing patterns, and then we can begin to play games with the patterns. We can pick a piece of residential area here, and replace it with light industry, redistribute the residential usage to another place,





1. Sketching with a light pen on a computer oscilloscope screen to introduce a schematic plan into computer memory.[2]

3. Entering a site plan into computer memory by tracing with a graphic input device.[3] The plan is displayed on the counter oscilloscope as drawn, and labels are added by typewriter.[4]

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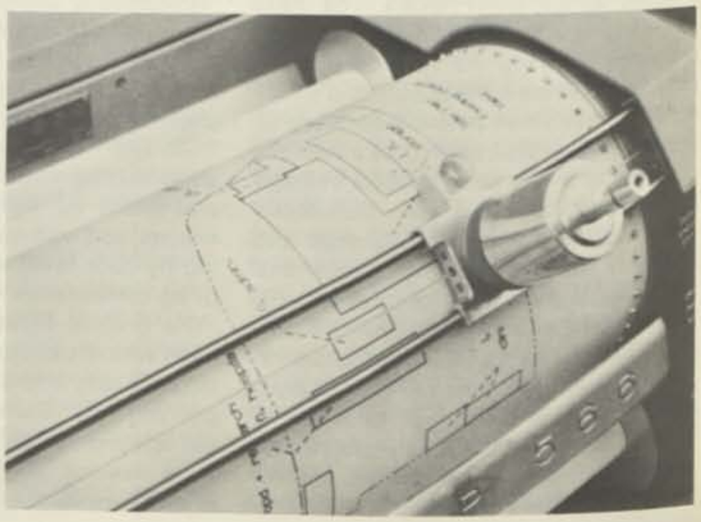
2. Light pen modification of a computer-displayed graph which has been generated by sorting of hospital movement data.[2]

4. Plotted output,[5] as a reproducible ink line drawing, of data for a site plan stored in computer memory.



and see what happens to land values, to time distances for people who work, to the traffic circulation in the community, and we can really begin to play modeling games.

Of course, we can play more intimate modeling games with buildings. I imagine many of you saw the story in *Business Week* not long ago about a program done to determine the need for teaching spaces of different kinds demanded at any one time by a junior college curriculum. The result produced a much higher utilization rate for the rooms that had been proposed, and resulted in a program reduction of some fantastic percentage, perhaps 15% of the programmed space of the college.

Now we can make models, such as a hospital model, which would represent the flow of a typical patient census, i.e., a census with the range of diseases or the array of diagnoses usually found in that institution, and we could process this through the treatment regime normally prescribed by that group of physicians. We could have blocks representing the admitting office, blocks representing the kinds of beds available, the X-ray department, the surgical department, and so forth, and we could in effect run these patients through this mill until it fills up in blocks for lack of some kind of facility. Whether the lack is an appropriate bed for a lady who has small pox, or not enough technicians in the X-ray department, would be indicated, and then we could substitute. We could change the array of beds, or we could enlarge the X-ray department, or indeed, we could change the hospital policy on the kind of patients it admits. We might very well elect to refuse small pox patients, but it's sort of a real-life playing with an organization.

Clark:

I would like to mention the kinds of problems I see in implementation. There are several kinds of costs that are important here, and this is particularly true in the urban planning area, I think. Many kinds of data need to be made available, and it's time-consuming and costly to acquire these data. One has to know something about how good they are or how reliable they are. There are some kinds of data available that have probably not gotten the use they could have gotten, were the manipulating easier. These include information on census, on space-use experiences in large complexes, on traffic movements, both in buildings and in communities, and so forth. Another major problem is the programming time necessary to do computer analyses, and particularly to do things that involve close interactions between people and computers. Programming costs and effort are still kind of staggering. We heard earlier today of efforts in the direction of simplified computer languages and of better communication. We have some other problems to face in terms of the choice between many remote users of large time-share computers, in the direction of Project Mac, and the more intimate use of smaller computers.

Souder:

There are some architects using computing equipment in their own offices today. I know a few of them: Skidmore in Chicago has equipment, and D.M.J.M. in Los Angeles has equipment and they use it constantly and for some planning functions that are by no means routine. I think the average office is such that the time-sharing thing is going to be very important. I think for quite a long time architects are going to be heavily dependent on consultation. I say a long time—a matter of a few years probably—until we educate ourselves to use this new kind of tool and until, indeed, some of the attributes of the tools are simplified.

Welden talks about English language simple enough that secretaries and clerks with no technical education—let alone a mathematical education—can operate the programs. They don't have the judgement obviously to select the programs that they should use and it's going to be a while before most practicing architects have that capability; but once that capability is gained in the profession, the consultant's role will shift from the problems that have become routine to the problems that are a little more esoteric. If it's any reassurance to you, we are using these tools in our own practice now. We use them clumsily perhaps, but they are indeed effective and give us better understanding of the kinds of problems that really exist below the surface of complex situations. Thank you.

1. The computer is a PDP-1 with display and light pen, manufactured by Digital Equipment Corporation, Maynard, Massachusetts.

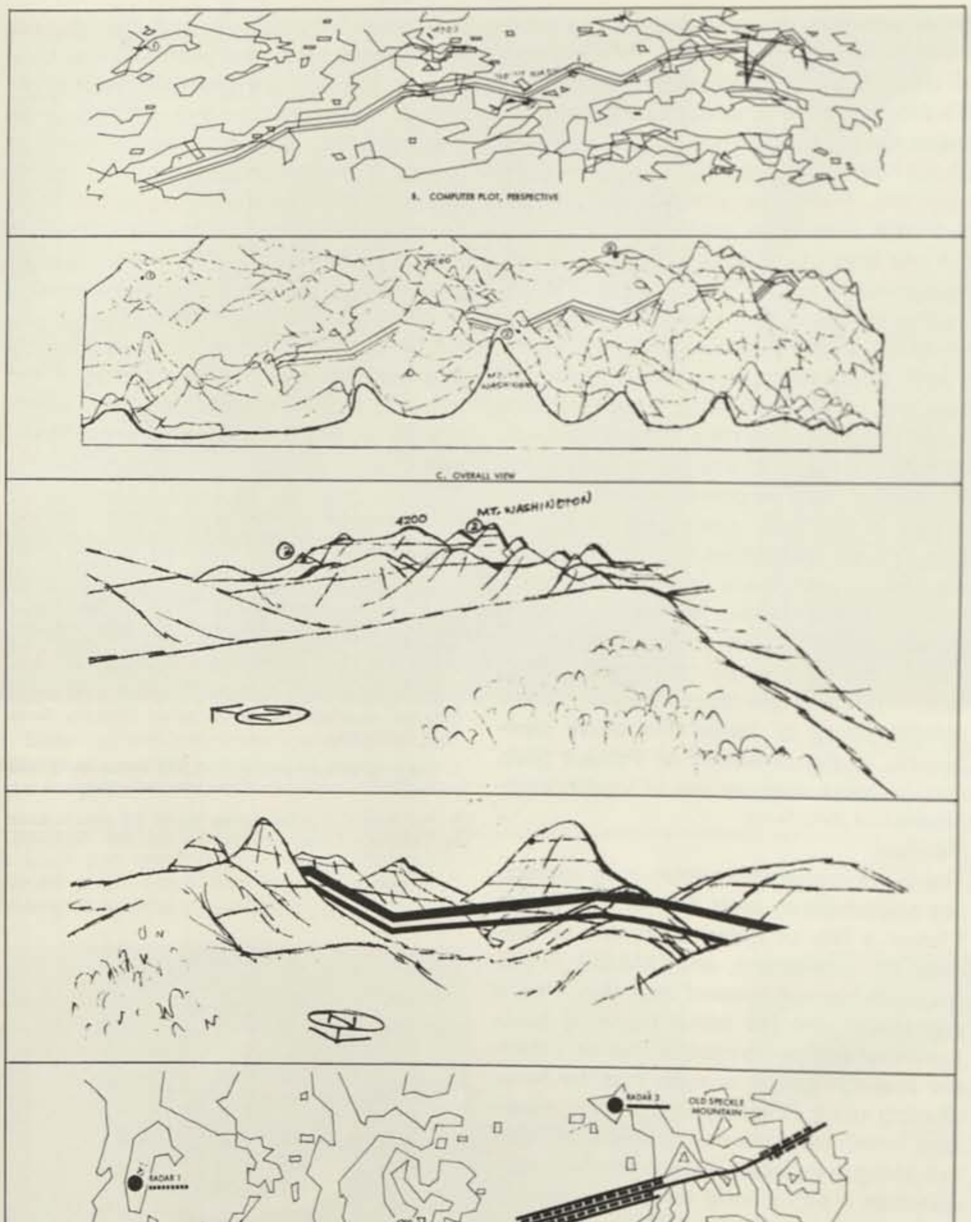
2. The programs are part of the COPLANNER system developed in USPHS Project W-59 and reported in *Planning for Hospitals: A System Approach Using Computer-Aided Techniques*, Souder, Clark, Elkind and Brown, Am. Hospital Association, Chicago, 1964.

3. The graphic input device is a GRAFACON Model 8500 manufactured by Data Equipment Company, Santa Ana, California.

4. The programs are part of the LEAP system developed in the BBN Los Angeles Computer Laboratory.

5. The plotter is a Calmcomp Model 556 manufactured by California Computer Products, Anaheim, California.

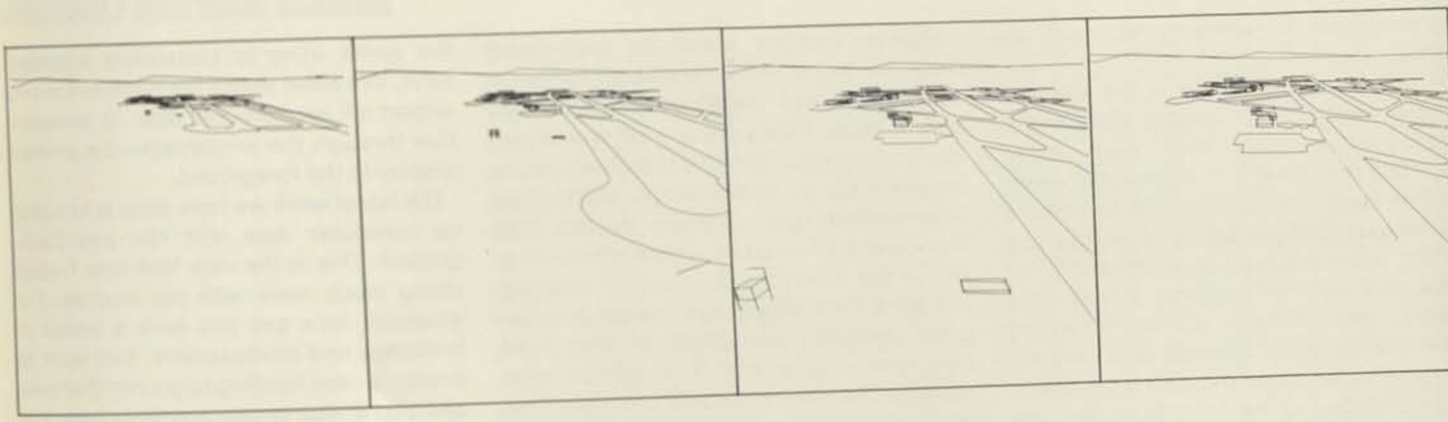
W. A. Fetter
Computer Graphics



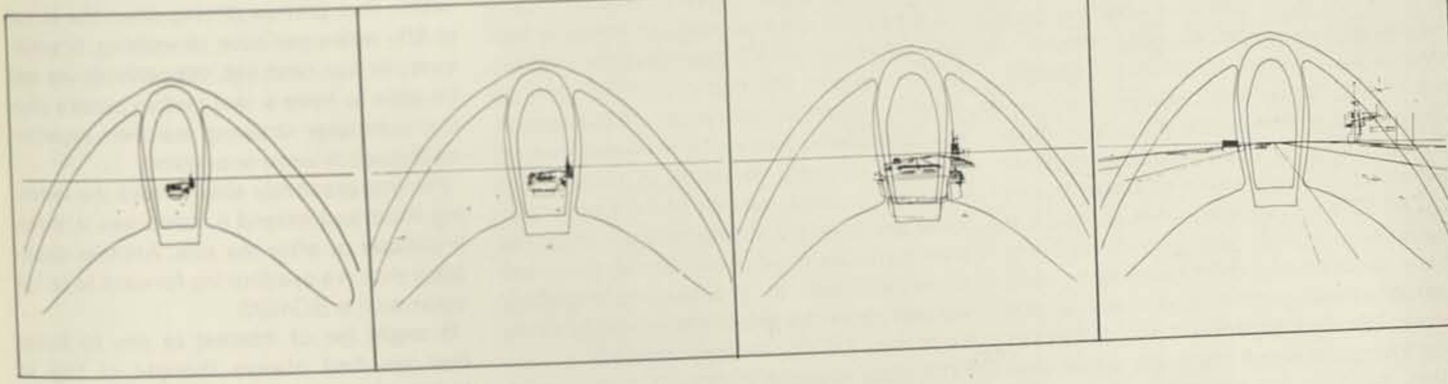
Flight path selection by three-dimensionalizing topographical maps.

The name of our organization is Computer Graphics, and the whole purpose is to make data understandable to the human eye, and to do this with all the speed and economy that we can muster from a computer. The first true perspective drawing that we did was in 1960 and I'd like to show you the process we go through using available equipment within Boeing. The first step that we take is communication design, which can be very simple, or it can be very complex. In fact, all of our computing is based around the communication message. The next step is data taking in which the draftsman or designer selects the amount of points that he wants to use for a certain effect. This information can be coded on punch cards for use in the computer. Now another method of getting data is by the master dimensions process which is a totally different organization. This very carefully tailors a numerical definition of the surface which we can use in our computer graphic routines to make them quite visible. The next stage is the computing and computer programming. We use an IBM 7094 and it produces a tape from the data cards on the particular subject involved and the tape then operates one of several types of output devices. One is an SC 4020 which produces a cathode ray tube image which is then immediately photographed on a 35 mm. film. Then the last stage is final rendering, and includes anything that must be done to the end product to put it into communications form.

The very first true perspective drawing we made was produced back in early 1960. I think you can realize that there is a certain advantage to storing data once and then being able to produce any kind of projection once this data is stored. Sometimes the ease of understanding is far more important and is almost a reverse value in this kind of a chart, because the perspective is just the way the eye sees an object. And by the time you add shading, color and motion, it can become a



Aircraft visibility motion pictures.



dynamic tool for showing technical objects.

A proven application is in the example of body studies for aircraft design, designed for an aircraft carrier. We repeated the data and drew it from several views. In this case, it was important to make a quick definitive rendering of an airplane which we wanted to make sure did not look like another airplane. It was also being constructed at that time. The weight relationship of this airplane was very important, so we made the computer graphics drawings and the artist then used one drawing for the rendering. We could assure the engineer that this was precisely the size and weight relationship wanted.

We've also done 3-dimensional graphs, which are rather descriptive of air dynamic data and acoustic data. We make several views for documentation to show just exactly where some of these deeps are. About two years ago, we shared our computer graphics routines with the Aerospace division and they have also made 3-dimensional graphs and aero space forms. We've also done a large number of drawings in which there are a few variables, such as the amount and direction of energy in the air after an airplane has passed.

One thing that pleases me a great deal is that on some of our latest work, our drawings are actually becoming a part of the design process—not because of accuracy alone, but because the manner of presentation allows the prediction of the way things will feel as well as the way they are. An operations analysis study that we did involved taking a map with a flight path and determining just how vulnerable the plane would be at low level altitudes to 3 radar stations. We gave very simple data to the computer and asked for a view of this from 20,000 ft. in the air and 6 miles from the center. What we got was a confused drawing. Then some art work was added to this and we got a better drawing, and using this method of the computer and the artist, we took looks from all three radar stations. In some cases, little was visible of the flight path and in other cases quite a bit was seen. Having it in visual form, rather than simply tabular data or mathematics, allowed an experienced radar person to see that there were other areas where rebounding would cut down the amount of visibility. We were then able to summarize in a diagram precisely how much of that flight path was visible, and from which radar stations the airplane would be seen. This small study was taken back to the Navy and led to a larger research effort.

A lot of our work as you can imagine has been involved with human factors, primarily in cockpits. We can give a 360 degree view in which at the center of the screen you are looking straight forward, seeing into the cockpit. In addition to taking a single eye point, we can show a binocular view and then we show the view when the pilot turns his head about during a combat situation. Then, as in a taxi-ing situation, we can show the increased visibility when he moves his upper body around.

We also prepare materials that can be used right at the engineer's desk. We make a computer plot of a particular airplane designed to land on a carrier, plus separate plots of the carrier, and the engineer can actually adjust these after figuring out certain load and speed ranges and determining just what effects they have on visibility. In some cases, these plots are rendered fully for documents and slides.

The last approach was to use orthomath plots directly on 35 mm. film which was put through studio processing and combined with some art background. So we have a number of different methods of combining it in film. Dealing with simulated landings of the supersonic transport at the Seattle-Tacoma airport, all the background drawings were computed and then illustrated. We have done studies of different methods of using film to show the same thing in completely animated form. We have drawn the Seattle-Tacoma airport all in computer data, in perspective through the windshield—the cockpit display in the foreground.

The latest work we have done is to match up computer data with real live background. This is the very first step toward doing much more with this medium. For example, let's say you have a series of buildings and environments. You want to design a new building to go into that area and you'd like to see precisely how it is going to fit, and how it is going to look within that picture driving down the street at fifty miles per hour, or walking, or whatever. In our next set, conceivably we will be able to have a real motion picture plus the computer drawing matched together as though it were in position.

We are presently able to take the lettering form and extend it, compress it, make it oblique or alter the size. Another capability that we are looking forward to is full color on the SC4020.

It might be of interest to you to know that we had always thought of this in terms of estimating something in the future. There was one application in which a missile actually was shot off, and after it got to a certain point in its path, it began to tumble. The engineers had all of the data that they needed in the form of rolls and rolls of telemetered data. They had data as to roll, speed, altitude, and so forth, but they had difficulty in interpreting it, because there was so much of it. A film was made in which the shape of the space vehicle or missile, or whatever it was, was defined very carefully; and it was shown as it was turning and tumbling and they discovered what the problem was. In a sense you fly along with the object and sit on a kitchen chair with it and watch it. This turned out to be very useful, and what interested me was that this was not a prediction, but was studying something current that was otherwise not observable at the time.

Questions / Afternoon Session

Question:
I wonder if at this time you could find any way to use the computer to define relationships before the designer or the planner makes arrangements? Can you use it only as a tool for analysis, or can you use it to indicate relationships before?

Souder:
The question as I understand it is whether one can use data analyses before planning to understand relationships and predict hospital planning approaches as well as using it later to analyze preliminary planning after it is done. The answer is "Yes"—the information sorts give you clues to the existing organization and existing physical patterns, if it is an existing building. If not, it would be clues to existing organization concepts in the way of important relationships between kinds of people and purposes, etc. In our view, it precedes planning.

Question:
What information can now be related to the visual image?

Coons:
I think you mean by that, can you relate information such as the nature of a structural member, its size, its material, to the visual image, or if what you have drawn is not geometric, but is a representation perhaps of an electronic circuit, then can you relate the various elements of that circuit—distances—inductances—capacities, etc. The answer is "eventually, yes—not right now." We can draw a schema which might represent many different things and we are just learning how to associate with that diagram, with that graph, whatever meaning we intend to apply to it.

Question:
I am interested in the relative merits of producing models vs. some of these computer-produced images here. Can you comment?

Fetter:
You also mention something about costs being not too great a problem, and I want to point out that they are a considerable problem. We have to work on a very tight budget. All of this work has been done on Boeing funds and has to be watched very carefully. In fact, this is one of the strongest parameters of what we are working on. To give you an example of costs, the 84B F4B film which you saw a part of, cost $6,692.54 and took one month and three days and everyone involved with it felt it was a very good trade. I don't look at the computer-produced image as a replacement of other modes. I look at it as one of the many elements you can use if you know what kind of situation to use it in. However, this does not replace the mock-up—it simply means that designers could get a good feel for what visibility would be like very early in the design process. They wouldn't have to wait until they could do a mock-up.

Question:
How should we begin to educate architectural students now for the computer oriented practice of tomorrow in view of the rapidity of change in computer language and techniques?

Coons:
Some people think that we should educate people in programming computers. I tend to think not in the case of architects, because I believe that my greatest efforts and many other efforts that are now going forward in this world will make it possible for people to use computers directly. However, I think it is important to make students aware of the existence of the computers and in some sense, which I am not prepared to describe in details, prepare them for the coming of the computer age.

Question:
What is the time factor in the development

of the light pans and the light tables for 1) practical application by the architects, and 2) teaching in schools of architecture?

Coons:
I hope it will be very soon, for I want to be able to teach students in a classroom with perhaps 10 to 20 consoles at which the students can work, and we can even communicate. The acceleration of education by virtue of the computer and the intimate interchange between man and the computer, and through the computer between man and man, is almost magical. I have learned more about complex geometry recently than I could possibly learn by years of tedious efforts otherwise. Specifically, I hope that within two years such facilities will begin to be available. Right now, at M.I.T., facilities of this kind — but somewhat limited in scope — are already in use. We will have practical applications by architects hopefully in five years. The problem here is one of making available to relatively small architectural groups the facilities of a very large, fairly complex system — not necessarily one large central computer, but possibly one large central computer, with peripheral smaller computers — that can do routine tasks and can also call on the more powerful cerebral cortex when they cannot handle problems. I can envision a large nervous system made of computer machinery, and hopefully, this will be within five years and economically feasible even to the single architect.

Question:
Are the forms which you produce by means of the computer the results of all possible equations from calculus?

Coons:
No, for one reason it is virtually impossible to imbed in any machine all the possible equations of calculus; in fact, some of the possible equations of mathematics have not even been discovered yet. Instead what is in the computer, as far as has been developed today, is a very general and powerful quasi intelligence. I had a receptive, intelligent, or quasi intelligent being to communicate with, and I taught it to do things. Similarly, on an architect's scale it will be possible in the near future — perhaps 5 or 10 years from now — to use the computer to learn (and I used that expression before), to learn how to satisfy human wants, or how to solve problems, where the computer and the man are mutually engaged in the learning creative process — the man as the general of ideas, and the computer as the appropriate slave.

Evening Panel Discussion / Computers and Creativity

Phokion Karas

Walter Gropius
Computers for Architectural Design

READ BY HENRY A. MILLON

When I dare to venture a few words on the potentialities of using computers for architectural design, I must emphasize that I am still a complete layman in this field and that my remarks are therefore of a mere speculative nature.

Is it at all imaginable that the phenomenal achievements of mechanical computers can be of influence to the creative process of architects and designers? Some people scorn violently the idea that lifeless machines could be of any advantage to inventive thinking. They feel that their intuitive power will be only disturbed by the forces of mechanization, that the willful and unique spark of a creative individual may be drowned in the attempt of mechanical fact finding.

I believe that by this attitude the baby is cast away with the wash.

In his remarkable book, *Mechanization Takes Command*, Siegfried Giedion says:

> Mechanization is an agent, like water, fire, light. It is blind and without direction of its own. It must be canalized. Like the powers of nature, mechanization depends on man's capacity to make use of it and to protect himself against its inherent perils. Because mechanization sprang entirely from the mind of man, it is the more dangerous to him. Being less easily controlled than natural forces, mechanization reacts on the senses and on the mind of its creator.
>
> To control mechanization demands on unprecedented superiority over the instruments of production. It requires that everything be subordinated to human needs.

We seem to be always wrong when we close the door too early to suggested new potentialities, being often misled by our natural inertia and aversion to the necessity of transforming our thoughts. Being not at home in the vast new field of computer systems, I want to be cautious. Still I believe, if we look at those machines as potential tools to shorten our working processes, they might help us to free our creative power.

Some time ago I was visiting the headquarters of I.B.M. in New York when I was told by one of their engineers that they are now able to have the computer deliver a large variety of graphic pictures of different bay systems for a building, showing at one glance *the changing proportions* of potential bays and their comparative cost. This is only one example of how the computer can help us to make sound and quick design decisions of an aesthetic consequence. One can think of an infinite number of major and minor details for which the quick delivery of a variety of potential solutions would help us to clarify our conception of a design, offering us valuable short cuts.

What I cannot envisage yet is a practicable method for the average architect or designer to use these tools at the moment when they are needed. The emphasis will certainly be on the intelligent formulation of the questions to be answered by the computer. Will it then be necessary to educate a new profession of architectural assistants for the purpose of articulating the problems to be solved into the proper language of the computer? Furthermore, will it be feasible economically to construct individual computers in the future for ordinary office use right at hand, or must the answers to ensuing questions be received from specific computer centers where computing time must be rented according to one's demand? These questions can, of course, be answered only by computer experts.

Meanwhile I wish we architects would keep an open mind towards these new possibilities offered to us by science. The increasing comprehensiveness of our new tasks in architecture and in urban developments need new elaborate tools for their realization. It will certainly be up to us architects to make use of them intelligently as means of superior mechanical control which might provide us with ever-greater freedom for the creative process of design.

Panel Discussion/Henry A. Millon, moderator

We have already seen how automatic data processing may in several ways lessen the burden of rote calculation of the architect, planner, engineer and builder as well as enable him to analyze problems of a more complex nature than heretofore possible. It seems likely that machines, in the future, may be programmed to produce errorless working and detail drawings (pointing out in the process points of conflict and contradictory bits of data) as well as provide new methods of visual analysis (video tape simulating what may be seen by pedestrian or vehicular circulation through a proposed complex, etc.). New automatic data processing equipment may provide additional means of testing a solution from a structural, functional, or even formal point of view. If adequate mathematical models can be constructed it may become possible for the planner to test the social structure of certain aspects of a proposed scheme. In addition, the ecologist may well find himself able by projection to cope with present and projected future environmental problems. He may be able to suggest ways to construct an environmental system that would enable industry to both exploit and replenish the earth's resources.

Acceptance and exploitation of these new analytical tools can provide us with additional relevant information upon which we may base decisions. Our decisions may then enable us more easily to approximate or obtain our objectives. Automatic data processing operations will not, however, tell us *what* is relevant. It may help us find out what is relevant. Relevancy must be decided by one of us. Decisions cannot be made by the equipment. The solution offered by the equipment may indicate the "best" choice given the data it has processed. But it is up to us to weigh the evidence, examine the "best" solution offered and decide if the "best" solution is indeed in the best interest of those concerned. We cannot hide behind the "solution" of the equipment. Solutions offered by the computer are based on the data (always no more than partial) given it. Evaluating the solution within the wider importance of the problem and with respect to factors not fed the equipment may indeed suggest that a path of greater human or monetary expenditure would be more beneficial to ultimate objectives. The equipment might, in such cases, suggest possible consequences of alternative solutions, but ultimate judgment of the applicability of the offered solutions rests on us. It is we who must define the objectives, we who must evaluate proposed actions with respect to desired objectives. Most of our actions result ultimately from an ethical choice, be they political, economic or social. We cannot shirk the responsibility of such a choice.

A. Equipment tasks:
Automatic data processing equipment can be designed to perform selected analytical tasks. What aspects of planning, architecture or architectural design can you cite that might lend themselves fruitfully to analytical techniques?

B. Inspiration:
Inspiration is a special moment in a rational process. The two are inseparable and complementary (Chermayeff). What is the relationship between the computer and the rational process? Between the computer and "inspiration?"

C. Objectives:
"Instead of exploring distant social aims . . . young men (architects), seek answers to immediate and limited situations" (Kallmann). In a period when young designers shy away from moral or social philosophy and theoretical statements of objectives while seeking only solutions to "immediate and limited situations," will the computer as an objective analytical technique divorced from social objectives and ethical concerns play an increasingly greater role?

D. Decisions:
In science decisions must always be made between scientific theories; therefore science includes value judgments (Lindsay). Are decisions made by the architect similar to those made by the scientist? Is the architect called upon to make both factual and ethical decisions? How can ADP equipment help him recognize the difference?

E. Relevance of Information:
"We take the step from description to criterion too easily, so that what is at first a useful tool becomes a bigoted preoccupation" (Alexander). Who is to decide what is relevant to a particular problem? How is the relevancy to be decided? How can the computer aid in evaluation?

F. Will the architect's time honored role as "image maker of a new society" be affected by new analytical techniques?

G. If many of the major tasks of the architectural firm are to be taken over by ADP (working drawings, specifications, etc.) will the office structure change? Will the architect alter his traditional role and depend less on drafting board techniques?

H. Do ADP techniques affect intuition, inspiration, or creativity? As ADP techniques develop will the areas in which these three may operate be more clearly defined or more sharply limited?

I. In order to utilize ADP techniques the architect may well be forced to reformulate problems drastically. If he does so will he also be forced to change his traditional role?

J. If ADP techniques are to become commonplace in the planning and architectural profession will the education of architects have to be altered? If so, in what way?

I think now that these few remarks of Mr. Gropius suggest possible re-evaluations of the architect as a professional, of the education of architects, and of the uses to which computers may be put. Tonight, we are going to discuss some of the issues that have been brought up here, after which we would like to throw the whole meeting open to questions from the floor which may be directed to any of the panelists or any of the morning or afternoon speakers who happen to be here.

I would like to start by addressing a question to our panelists. This question deals with problems of the design of computers themselves. At the moment they solve certain analytical problems extremely well, and they have been designed to solve these problems. Architectural planning will certainly require different kinds of equipment and it may be that the architects should suggest the kinds of problems that computers might be designed to solve.

Question:
I should like Prof. vonMoltke to think about and suggest some possible avenues of computer research that might have definite effects on computers and architecture.

Prof. vonMoltke:
I have quite an interesting design problem which would have been greatly helped by the use of computer graphics, the use and potentialities of which we have seen a very fine demonstration of this afternoon. For the last three years, I have been in Venezuela designing a new city with a team of the Joint Center for Urban Studies of Harvard and M.I.T. I was responsible for the urban design aspects, and the situation was as follows:

This city is located on the Orinoco River in an area where 65,000 people already are living. There is a steel mill at one end and a small Spanish colonial town at the other end of the future city site, and these two elements are separated by 17 miles. In between, there is an airport, some waterfalls, a bridge, a hydroelectric dam, two ore loading ports, and a general purpose port. This city is planned for 650,000 people and one of the basic design policies is to try to unify all the scattered elements to create visual continuity, visual unity. To complicate things even more, there are two major physical barriers: a ridge and a slight elevation in the western plateau.

The only way we could see of creating visual continuity, even at an early stage, was to develop a lineal city with nodes. Now, the location of these nodes was not only tested from the point of view of meeting functional needs, but also from a visual point of view. We tried to find out which were visually the best locations for the nodes. We used models and maps for the first approximation and finally drew from certain points radial cross-sections at frequent intervals to establish what we called the "visual unit," of which the point tested is the focus. Thus we established the area of intervisibility in relation to this point.

This is, of course, a most primitive method and computer graphics would have enabled us to test various locations from this visual point of view. Extensive testing was impossible because of lack of drafting help and because we had a limited time for this analysis, and it might have taken a year for two or three draftsmen to analyze the terrain thoroughly. Furthermore, we would have been able with computer graphics to get a very accurate impression of what you can see from each point once the line was established, and it is very important where you place your buildings—what you do with your landscaping—and how to move earth—and so on. I think this is a good example for the use of computer graphics in design. Thank you.

Question:
I would like to ask Professor Landau to speak on the same issue with relevance to the design issue itself.

Professor Landau:
I wonder if I could raise just one other point before I mention that. I want to talk about one particular instance of analysis that has been taking place in England over the past few years, and particularly, work done by Donald Gibson who is number one official architect, on a system which includes a lot of controlling, and particularly, cost controlling. Now, we have worked in various official capacities with programs that include standard architectural components which are at fixed prices, and these fixed prices have been agreed competitively by contract for a particular program. A building will be constructed under such a program with first a set of standard component drawings for this whole program, which would, of course, include anything up to 20 or 30 buildings and shop assembly drawings. Because of this degree of organization,

the working drawings themselves are organized so that some form of cost control can be implemented, and within a matter of moments one could just change any component with any other component and come up with the exact cost of the building, which makes a lot of sense within a certain context. There is a lot one could say about that, and about some of the work that Donald Gibson has done. He was also, for example, responsible for the instigation of the Clasp program, which many of you have heard of, and much of this work has been systemized in such a way that computerization is just the easiest thing in the world.

But the main subject I want to come on to is the design process itself, which is not exactly an easy thing to discuss, and can the design process be computerized? Of course, one immediately is put onto the sort of work that has been done by people like Christopher Alexander and J. Christopher Jones. To start on a program of this sort, one has to design a strategy or heuristic to account for this operation of design. Christopher Alexander has chosen to produce a heuristic which might be described as a configurational approach. There are certain complications in this. If a problem is to be described configurationally, there are possibilities that it will be very difficult to describe. Because there are so many factors to be taken into account, and if a situation which one might call a situational infinite regress (which means going back and asking question after question after question) is encountered, one must make a commitment towards, or one must introduce, value judgments along the line. This means that the total configuration must be as close an approximation to the problem as one is able to arrive at, bearing in mind that one cannot describe everything. When the configuration is complete, you have a model. You have a model of tri-particularization and low universality, but it is a model and the question is what is the role of the model in design of a building?

I think the model seems to be suggested in some quarters as being the answer itself, and there is a big point that has to be faced here. How does one arrive at the building from the model? This is an old philosophical problem which has a very long tradition—the problem of induction—which says a universal statement can be arrived at from a particular set of facts. It probably cannot, and this is the reason why scientific processes come into being not as a universal statement, but as some form of approximation. So, a building becomes an approximation related to a model. What role then does the model play? I would suggest that within the context of the methodology of architectural design, the model plays the role of a test situation against which one measures the efficacy of the design itself. I don't know whether there is a way of arriving at the design itself from the model. I am assured by Dr. Minsky that there are some very sophisticated methods of inductive organization—sometimes a sort of random organization—so that you can arrive at an answer the way a human being will arrive at an answer. But I think that the position, as I see it at the moment, is that one *can* use the model; in fact, one MUST use the model. The model is of the utmost significance in design, but the model is to be used first for the formulation of what the real problem is about, and for the testing of the solution once you have arrived at it. Thank you.

Question:
Millon: Professor Chermayeff would you care to comment about the design aspect before we leave this point?

Chermayeff:
You see if I understand what has just been said, it is that configuration, a way of setting up problems in a visible way, a comprehensible way, really amounts to an expression of cultural experience. You can only make images if you presuppose that the image is comprehensible to others. Then the model technically speaking is simply the old friend, hypothesis. But, actually what bothers me most is that one tends in this discussion to always come back to building. I happen to think of building as the least of it. To me, building an enclosure is simply a component of environment and, in fact, what I am mostly concerned with is the design of places—namely, something which is used and inhabited. It could be a space between, it could be as a matter of fact a conservation area of a nature-starved urban decay. Whatever it may be, it is a place. It is not a building. It is a situation, an event in human affairs. I suggest, therefore, that everything we have in the way of complexity of resolution must take into account the measure which is man and not be so very much attached to this dead thing, this obsolescent thing which we are writing off at the rate of 20 years, 15 years, 12 years. I prefer places we can write off in 5 years, and nobody gives a damn. Thank you.

Question:
Millon to Minsky: The utilization of ADP techniques may force the architect to reformulate his problems drastically. If he does so, does this alter the traditional role in which he has conceived himself?

Minsky:
I can answer that in two ways depending on what's going to happen in the next two decades. Even if you take a conservative view, we can see computers being helpful on a very large scale; in ten years computer graphics installations will be available in the office. Of course, for this to happen, there's got to be a demand for them. But, at a reasonable rate of effort, by that time one ought to have these machines take your plan, show views of the building—if architects are still interested in that sort of thing—turn knobs to see

things from other points of view and even, in effect, have yourself walk inside the building, look outside and see what the neighborhood looks like.

All these things could be done next year if there were a tremendous energetic effort to do so. As you know from some of the presentations, the ingredients for that sort of thing are available now. When SKETCHPAD was first developed, it was using up a computer worth perhaps three million dollars. Currently, in the M.I.T. Project MAC installation, when the graphic console is being used, it represents a capital of $300,000 being used. For a new system built now, it should be $30,000. By 1970, the use of such a console will represent about the same capital investment as an automobile. I'm still talking about the conservative view.

As this complicated technique becomes practical, one has to face the same kind of question that the medical profession now has to face. So much is now known from other aspects of science that bear on the way in which the human body fails to repair itself that one hears serious proposals that there be two kinds of medical training: one, for medical research where you train scientists, and another, where you train practitioners of a very sophisticated sort of nursing.

Do we need this in architecture? In the short range, and by that I mean by 1970, there will be very powerful facilities in the computer area. There will be straightforward things like computer graphics that can sketch things, manipulate plans, or produce renderings. But there will also be more sophisticated programs of the sort that Alexander discusses, where one tells the computer—possibly in English—what the facts are about a situation, including value judgments, and it will make decisions for you if you want it to. At that point, there will be some people who know how the thing works and know its limitations and its complicated prejudices. There will also be people who use it but who don't understand these things. Can education make one know both of these things or will we need two kinds of training?

From the longer-term point of view, I am inclined to say: let's not worry about these short term affairs, about how computers are going to help us in small things. For in no more than 30 years, computers may be as intelligent, or more intelligent, than people. The machine may be able to handle not only the planning but the complete mechanical assembly of things as well. Some computers now have scanners attached to them so they can see drawings; eventually computers will have hands, vision and the programs that will make them able to assemble buildings, make things at a very high rate of speed, economically. Contractors will have to face automation in construction just as the architects will have to face automation of design. Eventually, I believe computers will evolve formidable creative capacity.

So you have your choice between these two views. You can look ahead from one year to the next and predict normal progress. On the other hand, if you look back ten years, computers couldn't do anything intelligent; now they solve quite difficult design problems. If you look ahead two or three more intervals of ten years, you can imagine the face of the world as entirely different with machines competing in creativity and intelligence with me. It depends on how far you look ahead.

Millon:
Professor Minsky's views represent a different and much expanded viewpoint from the morning and afternoon sessions. I'd like to direct further examination of this particular aspect in relation to what Professor Chermayeff was speaking of a moment ago: the role of the architect and what he would like to call total architecture, including its political, social and economic implications. In connection with a highly developed computer technique, it may be possible to see architecture as perhaps the most inclusive of all the disciplines. We had a rather energetic disagreement about this before dinner, and Aaron Fleisher took the strong viewpoint that the architect exaggerated his own importance a great deal more than most architects thought they did.

Question:
I'd like him to address himself to the question of the architect who conceives himself as the total image maker.

Fleisher:
I don't know how the architect would describe himself, and I should have guessed that he could get on with the problem of the uses of computers in architecture without locating the limits of his domain precisely. However, the question appears to touch large sensitivities and since it has been raised, let me say what I think.

I appreciate that the architect considers his job more than the design of buildings. But I don't know what is meant by "total architecture." Architecture certainly has political, economic and social implications. The architect is hardly, therefore, either an economist, or a sociologist, or a political scientist—anymore than parents are experts on genetic coding. Such competences are not automatically absorbed. It is not even clear that they would make him a better architect.

I would argue, in a similar manner, that the architect is neither a philosopher nor a moralist—although, in the discharge of his purposes he juggles problems of value, and of being and knowing. The architect is an artist, not however in the sense of the poet and sculptor, but rather in the manner of the chemist, for his creativity must submit to the same constraints of validation.

Let me say again that I do not mean at all that the architect cannot be a person of cosmic capabilities. He rarely is. That is not a limitation of architecture, but of people. It is precisely in this respect that the computer is important for it promises to relieve some of these limitations. I doubt that it will produce the cosmic man. But that isn't important now. We can use a lot of relief locally. What is important is a sense of the most profitable problems to work on. I should like to hear Dr. Minsky's opinion.

Minsky:

I think graphics is the most important immediate application of computers, if by graphics one means not just the manipulation of visible forms but this along with the simultaneous computations of things like costs and stresses. I recommend that everyone become familiar with the type of structure used in the operation of SKETCHPAD. SKETCHPAD has two aspects: on the surface it helps you keep your lines neat while drafting, but it can also, by the nature of its constraint-satisfying structure, do computation concerning stresses. Just as easily it can allocate other resources, such as costs, and eventually it could incorporate aesthetic constraints.

One must be suspicious of the alleged rigidity of programs and computers. It's true that any particular program may take into account some factors and not others, and one likes to think that therefore programs can't have the balanced judgment that man does. But, if you look at the differences between humans, the nature of this ideal we talk about is quite uneven. People disagree, too, in the ways that they assign different factors. A complete program, to help in a complicated problem, does not work at first; one makes it evolve. If it has "bugs" and does bad things, then one has to adjust it. A large program can become so complex that noone understands the whole thing, but if it is properly laid out, one may still find ways of getting in and fixing it and changing it, so that it gets better at things. I'm not sure that answers your questions.

Fleisher:

Let me make the question that I asked a little more pointed. If you are going to use a computer in design in one way or another, then what you must be able to do, I think, is to program criticism and in particular to program criticism of visual design. Perhaps it is easier to program criticism of functional design where you have a measure of how well the function is performed. How to criticize design on the grounds of looks is more vague. But if you can do it, then you are working on the possibility of synthesizing a theory of aesthetics. I'm particularly interested in that, because I regard the absence of a theory of aesthetics in our civilization as a curious phenomenon. It's quite interesting that despite the number of years different people have devoted themselves to aesthetic criticism, there is no such cogent theory. This a most singular failure I think in the history of Western civilization, perhaps next to the failure to prove the existence of God.

Question:

Millon: Now, if one addressed himself to the design of a theory of criticism of which architectural criticism would be a part, how should one go about doing this?

Minsky:

I can think of a couple of reasons why good theories of aesthetics are few and far between. One is that it is a very difficult subject; another is that people laugh at you if you work at it. The attitude towards a theory of aesthetics among both scientists and artists has been very negative. One notable attempt at a theory of aesthetic measure was made by George Birkoff, a great American mathematician: he proposed some linear decision methods based on measuring and weighting many features. It received very little attention. If you followed the reception of this theory, you would be reluctant to announce one of your own. I think the existence of computers will change this, because now if you have a synthetic theory of how to write a pleasing piece of music, or make attractive line drawings, you can implement this and see objectively what the theory does for us.

Some of you have seen the more or less random designs of exhibits produced by the computer. While currently there is a great deal of human intervention in the selection of those pictures, I feel they do show the kind of aesthetic production one could get machines to do on their own. The pictures by Libman and Price are an attempt at a conscious aesthetic selection from the hours and hours of rapidly changing displays that come out of the computer. The variety is incredible and what one thinks of while watching these is quite incredible too.

As far as immediate application to design is concerned, graphics should have a liberating, rather than constraining influence. If you understand how the SKETCHPAD structure works, for example, if you sketch the building and put windows in all over, you have a choice of paying individual attention to the windows or making them all replications of the prescribed prototype pattern. If you want to change all the windows at once in some horribly elaborate way, you can do that by pressing a few buttons and making a quick rough sketch and watch all the windows change. That's a simple example. Without this machine, if you have designed a building and made all the drawings, and now would like to change the windows, you might not bother. You might draw a certain section and see what two or three look like. But, there's a point at which you and your draftsman and your time and patience give out. With the implicitly defined graphic production of the computer, you are free to define very complicated instructions where you give a general rule for hundreds of components and then watch them quickly settle down into the new position.

One way to regard a computer is as an

equivalent to a million clerks doing vast amounts of work for you, provided the task is very simple—we often say "clerical." Another view, more significant I believe, is that the computer has just the opposite role. We can use a computer to execute a procedure that is not just more tedious, but more *complicated* than anything we can ask humans, including ourselves, to do. In SKETCHPAD, in principle at least, you can ask the computer to produce an object which satisfies several hundreds of complicated constraints. You can't ask a person to do that, nor a million clerks. That's the other direction in which the computer applications are moving, and even in the short range there are complexity barriers as well as the clerical barriers.

Question:

Millon: But the value judgment is still up to the person who puts in the data into the machine, is not that true?

Minsky:

At the moment it is because machines don't hold large amounts of experience. But in a few years we can imagine that a computer's memory could hold a lifetime of experience. Of course, now you have to tell it everything it is going to use, taking into account only a few aspects of the problem. Naturally the thing becomes monomaniacal about one aspect or another. Eventually we will have programs able to draw on a large body of experience, the value judgments of a large number of people who have contributed to its memory.

Millon:

I'd like to interject a new point here. The final one that Mr. Gropius raised—that of the education of the architect. If in five years we are going to have a walkie-talkie computer going around with us on client contacts, then perhaps the education of the student-architect should radically alter.

Question:

I would like to ask Professor Vigier if he would comment on what alterations he sees as essential in the education of the architect in the light of these new methods discussed today.

Vigier:

Let me first answer first, not in terms of the education of architects, but of the education of planners. In my own use of computers in planning decisions, I found that one of the great benefits was that I was forced to start articulating the problems I was asking the computer to solve. To articulate these problems at a level of detail which most of us, I think, are too sloppy to do usually.

This year at Harvard, we introduced for the first time the use of computers in our planning curriculum. In the spring we are going to use them for mapping purposes, and this term we are running a seminar on planning models and the simulation of planning decisions, using computer programming as a way of structuring the problems at hand. One shattering experience which we had in teaching this new course was to find that people who were supposedly selected on the basis of a relatively high intellectual ability, were in fact extremely sloppy intellectually. When asked to articulate a planning problem, in order to attempt to simulate a planning situation, using a computer, they were in most cases totally incapable of so doing.

It seems to me that perhaps the use of computer techniques in the school would be a rather good didactic way of forcing students to think in a more logical manner. I suspect that, in many of our architectural schools, the emphasis on the design ability of the student may up to a point stifle whatever native logical ability he may have, and perhaps, if he is forced to articulate his problems in a very detailed and specific way, the use of computers might help him to develop logically as well as in terms of his creative ability.

In a way, I'm rather distressed by the examples of the use of the computer which we have seen today. I wonder, for example, whether to turn a computer into a drafting machine is really the best use of the animal. I wonder whether to ask the computer to solve standardized structural problems by remote control, by putting questions to the computer on a typewriter and then having computers type back the answer, is also the best use of the machine. Similarly, I wonder whether the very exciting presentation that Professor Coons made of the use of the computer as a sketch pad is the best use of the computer. Whether, in fact, to give the architect or the planner or any type of designer a tool which will just enable him to sketch faster and alter his sketches faster may not help him to move away from a rational process rather than guide him into a more rational sequence. It seems to me, because of the lack of rationality which seems almost inherent in the architectural profession that we may ask whether the type of problem which we have to solve in architecture is the type of problem which lends itself to a more creative use of the computer? I don't really know the answer to that.

I can see that a computer might start to be used, if you like, in a review function. I doubt whether it is worth the effort to attempt to program an aesthetic system into the computer, or an aesthetic theory which would tell us whether the building is a good building or a bad building. I would rather see, for example, in the case of low-cost housing, a program which would feed into the computer a number of social and economic parameters so that a solution which is offered by the architect could be judged in great part, if not entirely, on the basis of whether it satisfies those particular parameters.

Chermayeff to Fleisher:

It's a sort of an oblique question and I really want to bounce off to the left in order to get to the right. This is not normal today, but it happens to be the order of the table. I have a sort of sneaking suspicion that the discussion is taking the usual turn, namely, what does a playboy of the western world do with a new toy? I really think that Mr. Vigier has actually put his finger on the thing. It is not in the least interesting to put this marvelous machinery to use in order to find out how to do things. It is infinitely more significant to find out why we should do anything at all. It seems to me that the computer is such an expensive tool that it presupposes the public sector, because that is where quantity lies.

Question:
Do you see the attrition of the private practioner and the growth of the public sector of technical environmental design?

Fleisher:
I presume your question is whether because the machine is so large, and therefore so expensive, is it a device that the individual can manipulate freely or is it justified only if the problems towards which it is directed have a sufficiently large field over which their cost and their effectiveness might be spread? The answer is: no, of course not. If you attempted to build an automobile in 1820, you would have had to be very rich to have the resources to do so. Automobiles now are rather cheap. I think the computer is rather cheap now, too. If I accept Professor Minsky's rough estimate of the decrease in the cost of SKETCHPAD, for example, as being symptomatic of how costs might decrease in the future, then perhaps time-sharing may no longer be necessary. But whether you buy the machine for yourself or you share it with someone else is not a critical issue. We don't find it objectionable to share a taxi with the last fellow who used it. I see no reason why we should find it culturally objectionable to share the machine that someone used on a different problem. It's not quite the same as a toothbrush, you know. I do not think, Professor Chermayeff, that the complexity of the machine in any way makes it impossible for it to be a matter for individual play, and perhaps one of the ways we will use the machine to play with in our increased leisure will be on problems that we might not have considered when we were occupied.

As far as the emphasis that Professor Vigier put on the kind of problem, I don't know which is the more important. Perhaps social problems are truly the more important. I think you will find a large number of people who agree. Is there any reason for saying that's the only kind you must work on? You can work on many things at the same time; that's one of the great advantages of the machine. Why limit yourself to one kind of problem, rather than another? Why not try them all? Multiplicity of uses, the multiplicity of activities are particularly characteristic of our civilization. When the device is available to you at no added penalty would you deliberately turn your back on its possibilities merely because some of the uses are relatively frivolous? Perhaps we will reach the stage of affluence when we no longer have to decide which problems are more important; we can work on all of them.

Chermayeff:
I have a feeling that what you have just described is the situation we are faced with where everything is possible, therefore nothing is possible, which is the first stage of idiocy compounded. But in the final analysis your freedom notion and logic is impeccable. What I'm really afraid of is that too many people would pick this up as a truck for the most contemptible purposes, and we shall then have to overcome this problem. This is the only thing that I am frightened of and we are all in a hurry. You know cities are getting congested; our children (getting neurotic and paranoid) are proliferating. So how much freedom can we take?

Fleisher:
Professor Chermayeff, if that's what's going to happen, then let's stop right now. That slides the issue to the question: is that what's going to happen? I don't know. Are you interested in painting catastrophic pictures? It's easy. Are you interested in painting optimistic pictures? That's easy, too. Perhaps what separates the philosophers from ordinary men is the ability to control circumstances so that they get what they want. However, the choice is yours. This thing that is called a computer has, at this point of the game, no influence on the outcome. For myself, I would like to go a little further before I decide to call it quits. I don't know how you feel about it.

Question:
Professor vonMoltke to Minsky: What then is our role?

Minsky:
I am glad to be in a position of authority on that. The question is I think, what will man find to keep him occupied? Can we keep things the same as they are so that we will have a known place? Suppose we were all out of jobs, and had to find some way to use our leisure? This is often considered to be an acute problem. One answer to that is that computers are getting cheaper. The amount of computation you get per dollar is now such that we're just on the threshold of being able to use them for entertainment.

Chermayeff:
Can I just join in at that point? One had this thought from Herman Fleisher that really the role of the architect demands that he concentrate his energy at a low level and also that he concentrates a lot of his energies on things like a theory of aesthetics, conceivably a theory of aesthetics for small buildings. Now, if I could introduce a notion that Buckminster Fuller once voiced which was that specialization leads to obsolescence and that the com-

puter is just about to make man obsolete as a specialist. I think we might see our role even encroaching mildly into Fleisher land and I think that this is the sort of thing that most people are feeling today in the architectural profession. The schools are not orienting themselves to highly specialized problems, but to viewing whole configurations of architecture, planning, quality, etc., and all these things as they relate back to architecture. What I am suggesting is that our role, with the aid of the computer, is possibly a much larger one.

Fleisher:
I didn't advocate that the architect confine his activities. I think I was describing their extent; there is a difference. If I say their extent is smaller than perhaps has been claimed, I don't therefore say that he must design the small buildings; he can design big ones too. He can take anything that he wants to take for his domain of reference and work. It doesn't make any difference to me. I tried only to describe what his realm of activity is and if I made a mistake, please forgive me, but I don't think I have.

Question:
Millon: (Lengthy question to Minsky not repeated. Apparently from the floor.) About the computer and music composition.

Minsky:
We can give you what you want; the trouble is you can't afford it. I could give you in six months a system where a score appears on a scope; you could alter it and you could type in statements about the tone quality. It needs effort and ingenious programming, but it also needs a computer in the $300,000 or $400,000 price range today. If you're willing to accept a delay, then people are doing that sort of thing already both at M.I.T. and at Bell Labs, but the composers who have used such systems have found it unsatisfactory to program a change in tone quality and wait until the next day to hear it. If you are holding an instrument or playing one you may try a couple of hundred small adjustments inside of two minutes, whereas if each one takes you two days then a year may go by before you've got the thing phrased right and that's what the two composers I know of have run into. If he had his own computer, we could give a composer a laboratory within six months, and a very good one in a year I should think. There are no unanticipated problems in this that I can see.

Question:
The figure quoted could not conceivably have to do with time-sharing, and why not?

Minsky:
I was going to have the computer make the music in real time, and in order to produce acceptable music, you have to produce about 5 kilocycles for the average person, but it takes a fast computer and if the computer is producing the actual wave forms in time-sharing. At present it is not suited for that. The multiprocesses time-sharing computer could do it, and we won't have one for a couple of years that could do that.

Question:
Question from floor regarding sharing of programs.

Minsky:
I think this is a good challenge. It seems to me that out of a conference of this sort could come the possibility of establishing some form of central office which could be a nominal depository for the sorts of programs which are used by all these inter-related building disciplines. It could house programs in such a way that they would be available for everyone. The Boston Architectural Center has done a valuable job in organizing this computer conference, and it could conceivably follow this up by addressing itself to the problem of a central place where computer programs could be shared among all the various trades and all the various disciplines concerned with architecture. Normally computer programs were not shared, there was not the opportunity for it, but maybe this could be engineered.

Chermayeff:
I would like to comment on this because it was implicit in the question which I addressed to Professor Fleisher. He fielded it rather neatly, don't you think, by saying nothing is closed, everything is out, but I think implicit in the whole business we have been discussing all day is the redeployment of functionaries for purposes which are now roughly described as architecture or city planning or as engineering. Everything is still in this rough and ready empiric kind of nineteenth century technology, but I think we are really entering an entirely new era in which our task will be much more comprehensive and therefore the functionaries will be redeployed in accordance with the demands of the task, and not the notions of professional associations or anything else which exists today. In fact, I think the whole damn lot is obsolete. I suspect that the answer is that we shall re-deploy in accordance with patterns not yet revealed, but the pressure of which will make us do that which we must.

Question:
Question from floor about culture being depleted or diluted by too much machine-aided art, planning, etc. Would people revolt against this?

Minsky:
Your question really has two aspects. First is the implicit assumption that the music and the philosophy produced by the machines would be very bad. There is a possibility of that, but in that case I fear that your revolution won't come off be-

cause 99% of people prefer bad music and 99.999 prefer bad philosophy.

I'd like to jump back to the other question of the group practice. If it's like any other field in the last decade or two where a new technological thing has come in, firms will appear who specialize and bring together people who know how to do these things. Firms will appear and for a time they will be profitable and prominent.

The question of whether individual architects will have to gather together in groups to share the new equipment is not easy to answer. The use of computers by individuals is now within reach and it soon won't be necessary for people to buy their own machines, because time-sharing is clearly successful and clearly economical. I expect that in just three years, most of the large machines sold will be equipped for time-sharing. When a firm buys a computer three years from now, usually they will ask for time-sharing on it, since it may not cost much more. This means that an individual will be able to rent access on a commercial time-sharing system, presumably with access to programs that are distributed by some organization which very definitely should be formed. It will not be necessary to get together to buy a computer.

Even so, the use of computer graphics does suggest group practice. Today it is uneconomical to pipe even television-quality pictures great distances by telephone. There ought to be distinct progress in this area pretty soon, but I don't expect an economical rate for this soon. For good computer graphics, if you want to get practical use for the next two or three or four years one will need a large computer time-shared with 20 or 30 deluxe television displays, all located near the machine. When the long distance display problem is solved, then this kind of center can die.

Question:

Landau: Professor Minsky, would you comment as to whether or not the computer can handle questions that are in essence ethical questions or is this actually the role of the human being . . .?

Minsky:

How can you leave value judgments to humans when you don't agree with most of them? If there were another entity which also makes value judgments, you may disagree with it, too. You can have rules against computers, but this is bad philosophy. What is a good ethical judgment? A person has an opinion; if he is a friend of yours, he has knowledge. If he is somebody you don't respect, he has prejudices. We can program "inductive" procedures. Given a bunch of facts and a bunch of statements about what you want, we can compute the answers. Different people will disagree, and different computer programs will disagree, and in many respects it will depend on who worked on the program.

Question:

Landau to Minsky: Do programs come all that easily? I gather that a breakthrough program is quite a challenging thing which takes a great deal of time and a great deal of skill to arrive at. Is this so?

One can't measure it easily. It seems to take perhaps three years to implement a major new idea in programming—with perhaps only one year of written work, the rest thinking. This has been my experience with graduate students working pretty much on their own.

Question:

Question addressed to Vigier: What is the architect's, or the man's role within the next few years?

Vigier:

Let me go back to the one point that I was making before. In thinking it over it may be a matter of emphasis. I'm not attempting to deny the usefulness of computers to solve graphic problems, structural problems, programming problems or what have you. I think they are very, very handy tools. What I would like to see, however, is a more creative use of computers. For example, in architecture, in planning, we create an environment for other people, and I suspect that most of the time we really have very little knowledge about how well the environment will fulfill the needs of those people. An example of that would be Festinger's study of the temporary housing for married students which was put up at M.I.T. after the war. Those of you who read it will remember that through a series of very extensive interviews, he managed to demonstrate that the shape of the series of row houses grouped around courts had a very great influence on the friendship patterns of the inhabitants. The juxtaposition of housing units and the circulation pattern which this juxtaposition caused had an effect on the number of people one would tend to encounter and, therefore, the number of friendship patterns one might create. It seems to me that this type of exploration would be a very creative use of the computer, in the sense that it would start to give designers, be it the architect or the city planner, a format within which to operate.

I think a similar case could be made in the case of urban design. We put up schemes which supposedly are one of the means we have to inform people what certain parts of the urban environment are all about. How do we know how people react in a particular situation? Do we know whether what we think they believe is actually what they perceive and understand? I think there is a great danger that we as professionals have an atypical vision of the environment around us, and a biased understanding of it.

To me the computer, like any other new technique of research, is only as exciting as the use to which it is put and I would really hate to see an expensive and sophisticated machine, one which will continue to be developed and to be improved upon, used for what are essentially menial tasks. It can do them too, and it should, but this is not all it should do.

Chermayeff:

This has recalled, and I am very grateful, my sense of discomfort at the end of the afternoon session. It is not only that we are using this fantastic extension of man for menial tasks, by implication, by the use of it as a technical device, as mechanics. We saw also examples, I would guess, of the technology under discussion for purposes which bring very little return. I was deeply impressed with everything except the presentation of infinite ingenuity for the purpose of making supersonic planes, mostly war planes, perhaps none of which we need because they obsolesce so fast. We have at this moment absolutely no research money available for the purposes which we absolutely need, namely, urban renewal, public transportation, and all the things our civilization needs and without which we could perish. We shall have all the planes in the air and we shall be dead on the ground. We need new priorities.

Fleisher:

I just want to underline what Professor Chermayeff said. I mentioned it to Professor Minsky and he said of course I have a professional prejudice since I'm a human, but all night we have not really defined our goals. I consider the human need a very important goal, and we should not be seduced by the possibilities of this wonderful tool to use it for purposes which are really not in conformity with our goals. After all, we have a certain limited amount of ingenuity, and I agree with Professor Chermayeff that we saw demonstrations where it has been used for inappropriate ends and that the question is not what we can do, but it is a question of survival.

Minsky:

Well, I don't agree. I agree with Professor Chermayeff that we should go around at all times with a prayer for peace on our lips, but let's not confuse it with the issue. And if you attended to what the last couple of speakers have said, which was let us not use these expensive machines to do the dull repetitive trivial tasks that people are so good at, surely you don't want to swallow that along with the peace prayer? It's a strange aversion, isn't it? I went into a tool store to buy a micrometer and I bought one of the nice new fancy ones, which has a little window where you can see the first digit instead of having to count the lines, and there were machinists in the place who looked at me and must have thought I was a dangerous communist or something. It doesn't seem to me one should get upset about the use of a great new tool for the things we can do today, while other people are thinking about the things we don't know how to do yet.

Millon:

In terminating this evening's panel and the the sessions of the entire day, we of the panel would like to commend the Boston Architectural Center for its foresight in initiating this kind of a conference. In the name of the Boston Architectural Center, I would like to thank you for coming and invite you to visit the Center in its present state, and to visit it again when the new building is completed. I want also to invite you to the second conference when it occurs.

Christopher Alexander
A Much Asked Question about Computers and Design

Since I use computers to solve both practical and theoretical problems in design, I have received a large number of enquiries from people who are interested in "The Application of Computers to Design." The most recent enquiry of this kind has come from the magazine *Landscape*, which is now kind enough to publish this reply:

In my opinion the question all these questioners ask, namely, "How can the computer be applied to architectural design?" is misguided, dangerous, and foolish.

We do not spend time writing letters to one another and talking about the question, "How can the slide rule be applied to architectural design?" We do not wander about our houses, hammer and saw in hand, wondering where we can apply them. In short, adults use tools to solve problems that they cannot solve without help. Only a child, to whom the world of tools is more exciting than the world in which those tools can be applied, wanders about wondering how to make use of his tools.

This would, of course, not be worth saying if there were hundreds of significant problems which the computer could help us solve. But there are not.

A digital computer is, essentially, the same as a huge army of clerks, equipped with rule books, pencil and paper, all stupid and entirely without initiative, but able to follow exactly millions of precisely defined operations. There is nothing a computer can do which such an army of clerks could not do, if given time.

Since the IBM 7090 takes $10^{-5}\left(\frac{1}{100{,}000}\right)$ seconds to do an elementary operation that might take a clerk about 10 seconds, it works about a million times as fast as a single clerk. One hour's operation on the computer (costing only a few hundred dollars) can therefore achieve the same as an army of a thousand clerks could achieve in a thousand hours, or five months of working days.

In asking how the computer might be applied to architectural design, we must, therefore, ask ourselves what problems we know of in design that could be solved by such an army of clerks, if we could afford to pay them.

At the moment, there are very few such problems. Although we speak a great deal about the complexity of problems, the complexity of architecture, and the complexity of the environment, this talk, so far, is rarely more than hand waving. In the present state of architectural and environmental design, almost no problem has yet been made to exhibit complexity in such a well defined way, that it actually *requires* the use of a computer.

Until we have thought these problems through so far at the conceptual level that we encounter unanswerable complexities in them, and until we have managed to describe these complexities so precisely that an army of clerks could help us unravel them, there is no sense in trying to use a computer.

Indeed, until then, efforts to apply the computer to design represent only the desire to be up-to-date, and the wish to believe that we have already reached this level of complexity in our understanding. If you use a computer to solve an equation that you can solve in your head, or that you really didn't need to solve in the first place, you are only kidding yourself, or trying to kid someone else.

But there is a danger in the currently fashionable preoccupation with computing machinery which goes far beyond irrelevancy. The effort to state a problem in such a way that a computer can be used to solve it, will distort your view of the problem. It will allow you to consider only those aspects of the problem which can be encoded—and in many cases these are the most trivial and the least relevant aspects.

Do not regard this as an empty possibility. Experimental psychology, obsessed by the idea of rigorous mathematization and hypothesis testing, has for the last forty years, by-passed the significant problems of human behaviour, and dealt only with those trivial aspects that happen to be the easiest to make precise. I am not saying that we should not wish to be accurate. That is the aim of all scientific or creative work. But if the love for precision outweighs our ability to pick significant problems, and our ability to distinguish the relevant from the irrelevant, then we must admit that this compulsion to be precise has made us bankrupt.

This is just what happens when a designer puts his desire to use the computer first, and his desire to understand form and function second. It will happen whenever someone sets out to *apply* the computer to design. We may see it, for example, in a recent study of computer aided planning in hospital design.*

In this study the computer was used to compare different plan arrangements, from the point of view of the total amount of walking done by patients, nurses, suppliers, and visitors. To do this, the authors defined a series of possible room types in a hospital, and gave ways of estimating the amount of traffic between rooms of different types, so that they could compute the relative amounts of patient, nurse, supplier, and visitor traffic for any given layout. There is no doubt about the technical ingenuity of the simulation. But it is not informative or relevant. First of all, the fact that the computer had to be used, forced the authors to deal with phenomena which could be measured and encoded. That is why they analyzed walking distance and volume, instead of the well-being of the patients, the effects of the sharp differences between home life and hospital life, the effects of patients on one another, the rapidity of cure, the problem of preventative medicine, the conditions under which doctors can most easily and successfully diagnose disease, the advantages of out-patient clinics, or any of the hundred other significant problems which cooperate to make the hospital a complex form.

Secondly, even if we take the traffic problem seriously, we find that the helpfulness of the computer is only apparent, not real.

Any intelligent designer could examine the various hospital plans examined by the computer, and could tell roughly what relative amounts of different traffic they would generate. The key word here is "roughly." It is unnecessary to know the amounts of walking generated by a plan to the second decimal place, because it is irrelevant—and only has the appearance of accuracy. It is insignificant accuracy. It is like measuring the size of a cooking apple with a micrometer. Yet it is only in the second decimal place that the computer can do better than the designer's experience.

It will be said that the point of using a computer is to examine a much larger range of alternatives than a designer would have the time or patience or insight to examine. In theory this is a reasonable objective. But in practice, although the number of alternatives the computer can examine is large, the range of these alternatives is small, because the computer can, at present, only examine a very restricted type of solution.

Suppose you are looking for a block of wood to put under the wheel of your car, to stop it running away when you change the tire. You may look at a few different bits of wood to find a bit that works. But there is no point in examining a hundred, or a thousand, different bits of wood, each different from the others only by a matter of millimeters. This procedure would give the impression of greater scope. It is in fact spurious. Yet, this is the kind of variation which the apparently great variety of different hospital plans actually have.

It is only worth examining large numbers of alternatives, if the differences between the alternatives are significant, and there is some chance of discovering truly unexpected alternatives among those examined. Our present ability to construct domains of alternatives does not permit this. At the moment, the computer can, in effect, show us only alternatives which we have already thought of. This is not a limitation in the computer. It is a limitation in our own ability to conceive, abstractly, large domains of significant alternatives. Yet, until we overcome this conceptual limitation the use of the computer will remain spurious. Like the hospital results, its results will not be genuinely informative.

Apart from trivial over-precision then, the results of the hospital study did not really require the use of a computer. The investigators' underlying motive was apparently a wish to use the computer, rather than their need for results which they could not get without it. As a result of this motive, the problem itself—the design of hospitals—was absurdly distorted, merely so that the computer could be used to solve it.

The distortion and triviality were not caused by an incompetence on the part of the authors. It is bound to occur whenever people *try to apply* the computer to design, rather than waiting until they *have* to use the computer because they are confronted by a complexity which they cannot resolve without it.

There is no doubt that a hospital is a complex form, which has arisen in response to a complex pattern of needs. Any designer may rightly feel perplexed by this complexity. But if he strips the hospital design problem down to those of its aspects which can be measured or encoded, he will eliminate just that complexity which made the problem seem difficult to begin with.

It is ironic that the very tool which has been invented to unravel complexities imposes such severe restrictions on the de-

*J. J. Souder, W. E. Clark, J. I. Elkind, M. B. Brown; *Planning for Hospitals, A Systems Approach Using Computer-aided Techniques*; American Hospital Association; Chicago, 1964; especially pp. 113-163.

sign problems it can solve that the real source of complexity has to be eliminated before the tool can even get to it. But for the moment that is the situation. Our effort, therefore, must be to learn to see the actual complexities of design so clearly, that we can make use of a machine to help us unravel them. When we have done so, we shall very likely discover that the kind of computer we really need is not like the present digital computers at all.

Meanwhile, any use of the digital computer which does not entail conceptual progress invites only suspicion, not respect.

Lastly, I should distinguish my fear of over-zealous interest in the computer, very sharply from the much more widespread fear which leads designers to exclaim, irrationally, both that the computer threatens intuition and creativity, and that it cannot replace them.

Those that fear the computer itself, are invariably those who regard design as an opportunity for personal expression. The computer is a threat to these people because it draws attention to the fact that most current intuitive design is nothing but an outpouring of personal secrets in plastic form. The computer cannot imitate these outpourings. But serious designers do not want to imitate them anyway.

A form has a definite, substantial, functional structure. As we begin to understand this structure it becomes clear that it is very complex, and that sheer computational speed can be a tremendous help in dealing with it. When the inner relationships which go to make a form are better understood, it is unthinkable that the computer could be anything but helpful. The computer is a tool. It is a wonderful, almost miraculous invention. The more we understand about the complex nature of form and the complex nature of function, the more we shall *have* to seek the help of the computer, when we set out to create form.

But understanding form, and creating form, in this sense, are not well served by those who want to use the computer first, without really having any reason to. In fact these enthusiasts do the same disservice to design, as the ravings of the very expressionists whom they are trying to replace. Both delay our understanding of form and function, and our ability to create deeper theoretical conceptions.

Anybody who asks "How can we apply the computer to architecture?" is dangerous, naive, and foolish. He is foolish, because only a foolish person wants to use a tool before he has a reason for needing it. He is naive, because as the thousand clerks have shown us, there is really very little that a computer can do, if we do not first enlarge our conceptual understanding of form and function. And he is dangerous, because his preoccupation may actually prevent us from reaching that conceptual understanding, and from seeing problems as they really are.

Phokion Karas

List of Exhibits and Demonstrations

1. *Airplane Division of The Boeing Company*
This exhibit of photographs supplements the presentation of Mr. W. A. Fetter in the Afternoon Session. The photographs taken from graphic output from a computer are of a pilot's view as his aircraft approaches an aircraft carrier for landing.

2. *California Computer Products, Inc.*
This demonstration of the Cal-Comp Plotter is arranged by Brogan Associates. It is an example of automatic drafting currently in use. There will be a demonstration concerned with changing the proportions of bays on an architectural elevation of a building.

3. *Cornell University*
Barclay-Jones, Associate Professor in the Department of City and Regional Planning, College of Architecture, Cornell University has been using the computer for city and regional planning. They have carried out analytical studies, and have developed a library of computer programs for this purpose. This display illustrates these achievements.

4. *Digital Equipment Corporation*
On display is Digital's PDP computer and scope. This is the computer Messrs. Clark and Souder of Bolt, Beranek and Newman used in their systems analysis applied to hospital planning. They will make a "live" demonstration of how they used the computer in their work.

5. *Howard Fisher*
Panels describing a technique for processing complex statistical data into meaningful graphic form.

6. *I.B.M.*
I.B.M.'s 7094 computer at M.I.T.'s Project MAC in Technology Square, Cambridge is tied into console and display equipment on exhibit at the Conference. A STRESS (Structural Engineering Systems Solver) demonstration will be made. It is a programming system for solution of structural engineering problems on a digital computer.

7. *LeMessurier and Associates*
A series of five panels illustrating a structural engineer's use of computers for stress analysis and for preparing construction specifications. Three panels show for comparison: an architectual section through a building; the same section as the structural engineer draws it; and the same section as seen by the computer. The remaining panels illustrate the computers specifications output.

8. *M.I.T. Students*
This series of colored and black and white photographs are of man- and computer-made designs. They were taken by students for a studio course for science and engineering students given by Robert O. Preusser, Associate Professor of Visual Design at M.I.T.

9. *Bell Laboratory*
This movie is a computer made movie explaining computer techniques for producing animated films.

10. *M.I.T. Science Reporter*
This is a kinescope of the noteworthy WGBH-TV (Channel 2) program. It describes Lincoln Laboratory's (Bedford, Mass.) and M.I.T.'s progress in computer graphics.

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