Carnegie Review

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Scene: The Annual Carnegie Conference, staged by the Alumni Federation of Carnegie Tech, with the cooperation of faculty and friends.

Personae: Nicholas Johnson, Federal Communications Commissioner, and a participant last year in a prior incarnation as Maritime Commissioner. Mr. Johnson recommends a systems approach to our communications problems (see *Carnegie Review* #11, "Systems, Sub-systems, and Super-systems").

Gordon Bell, associate professor of electrical engineering, who has designed a computer with his bare hands, and has had occasional conversations with it.

William Kobin, vice-president, National Educational Television (N.E.T.), who reviews the startling new prospects for support of educational television, as well as the unprecedented depth reporting which N.E.T. has provided this past year.

Lee Goldman, head of the department of design. Mr. Goldman represents the panel on the arts and communication which took place during the conference: his contribution was obviously most suitable for visual presentation among music, drama, poetry, and the visual arts. In addition, it is of more than ordinary interest in itself.

Carl T. Rowan, newsman, diplomat, author, columnist, former director of the United States Information Agency, who discusses the role of the press, and TV and the movies, in forming the image of America abroad.

Ghost at the banquet: Marshall McLuhan.

Acknowledgements: Special thanks to Bell Telephone for lending us the model of Telstar which we have photographed in more than its natural glory, and to the Carnegie Corporation of New York for permission to use the TV cartoon in connection with Mr. Kobin's article. The cover was created by our photographer, Donald Yenick.—Ed.

Communication, and Computers

C. Gordon Bell

C. Gordon Bell is associate professor of electrical engineering at Carnegie-Mellon University. A graduate of M.I.T., he came to us from his post as Chief Engineer, Large Computer Engineering, of the Digital Equipment Corp.

When Bob McCurdy, your alumni secretary, first discussed this Carnegie Conference with me I didn't get the message. As a medium, he didn't get across until our second meeting. I thought we were trying to decide who would speak on communications. Then I realized he was asking me to discuss the science and technology of the future. This could be anything — the laser, underwater communications, and other media along which information is transmitted.

Since some of my best friends are computers, any laser applications become relevant, particularly in terms of how lasers can help build computers. From a communications standpoint, the laser seems to solve a lot of problems, Or by providing so much capability, to create a lot more. I'll dismiss this aspect by admitting that the laser has the ability to let everyone have a picturephone in every room.

I even watched a few TV programs on the 21st century but found that there wasn't much happening that I, and everyone else wasn't aware of. A lot of the future evolved around computing machines. In our future oriented society, in which we have grown to expect new things, one only gets bored with such discussions. Collecting prognostications can be rather dull. They center around things we've been seeing in the laboratory that no one is interested in marketing. Like Microwave Ovens (which appeared in the 1930's) and Electric Cars (which also may some day be re-invented). On the other hand, they also include discussions by people who don't conserve energy with their contraptions, or who would try to invent a perpetual motion machine, or better still, a money tree. In this regard, the Teleportation System could be discussed: A Teleporter input terminal copies anything attached to it, converts it into information, transmits the information along some media (like a laser beam or simply a wire) and at the destination a receiver terminal makes an exact copy, according to the information transmitted. This allows us to make exact replicas of arbitrary objects, or, when noise enters the system, arbitrary objects with no replicas. We think we have birth control problems now; at least we only have one of everyone. The Teleporter can't be seen in the laboratory. With a little luck, or perhaps lack of it, developers suggest it will be available in 100 years. Based on my observations of technological predictions — today means 2 years; 1 year means 3-5 years; and 5 years may mean 20 years or 2 years; I'm leery of an optimistic technologist who talks of 100 years. Predicted time accuracy varies inversely with the distance of the predictor from his subject matter. Thus, the future technological predictions can be entertaining, though for entertainment the quality of present-day television may be higher.

I'd like to break this trend of technologists talking about the future, and particularly the future of technology which is outside the scope of their own work, and try to not stray too afield of my own work — computers — and discuss the aspects of them, and their relationship to communications. Computer scientists like to talk about computers and society, computers and privacy, or other esoteric topics that they feel that others feel they should feel responsible for. To a computer scientist, or computer engineer, there appears to be a computer or so in everyone's future, and only the less-forward looking disciplines do not admit this. Computer scientists are recognized as that group of people who have at least a one-million-dollar general solution in their hand, busily looking for a problem. If we were to have our machines taken away from us, the world would surely be over-run with missionaries. Thus, since there weren't other places on the conference in which machines were being discussed, I felt a duty to bring them up in relationship to communications. To fellow technologists, and in the idiom of or another and from different perspectives. As an example, frequency management is shared by the FCC and the Director for Telecommunications Management in the Office of Emergency Planning (who also serves as the President's Special Assistant for Telecommunications). The Department of Commerce has the government's major research facility on radio wave propagation and atmospheric conditions. The Federal Aviation Agency (which has become part of the new Department of Transportation) has major responsibility for commercial and private aircraft radio. It may be that the present structure as it has evolved is best suited to meet present and future demands. But it is rather more likely that our present governmental structure should be thoroughly examined in an effort to devise means for encouraging more rational analysis in the formulation of public policy in communications.

The problems I have just talked about are illustrative and in no sense exhaust the subject. They do, however, it seems to me, provide adequate support for the observations with which I will close.

1) In a free society (and shrinking world) the performance of the communications system is extraordinarly important.

2) A useful way of approaching communications problems is to consider them in the context of a total communications system. When talking about *one* problem, we are really talking about the *whole* problem. The range of choices is illustrated by frequency allocations, which are still today being "solved" on far too much of an ad hoc basis.

3) These problems cry out for a great deal more informed, resourceful, and imaginative research and analysis than our nation—you and I—have provided. The Commission has requested money from Congress for communications research for this next year. With it we can, among other things, begin the task of planning our future communications research needs and programs. In other words, we will have, at last, reached a point of beginning.

4) Virtually all academic disciplines have something to contribute to the total conceptualization and resolution of communications problems. Many of you can take a hand at turning our foundations and academic and research institutions to this task. Because these problems are indeed susceptible to an interdisciplinary approach.

Now — one positive proposal:

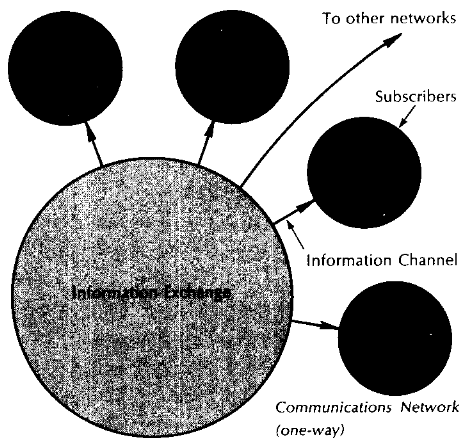
5) A single, national clearinghouse of communications research should be established promptly to keep interested parties informed — to communicate about our current and proposed communications research, policies, and problems. Such a clearinghouse seems to me indispensable to coordinate our efforts, to prevent wasteful duplication, to promote dialogue among people with similar interests, to insure availability of raw data and published analysis — and to assist struggling FCC Commissioners of good will.

Marshall McLuhan, I would like to convey a message, not to say a massage, about a medium. Since this is a mixed audience, technologists and non-technologists, and since I hope I'm capable of integration, I hope that I can convey a message despite little aptitude as a medium.

The communications aspect of the McLuhan model or at least the model I interpret him as suggesting, now provokes general response. This has not always been so. My wife, a non-technologist, suggested I look at his work about 7 years ago. Now that his message is getting across through all manner of media it has become imperative to go to the source. As an engineer, I've tried to model his communications system, and ascribe parameters to the system. I find that his words would appeal to me more if quantitative parameters were assigned to them. The comparison of a pair of communications systems by their relative temperatures is not too satisfying to a systems engineer. I believe a multi-dimensional space has to be called a space, and the parameters must be defined. The discussion of a media (for example television is cool and radio is hot) in terms of relative measurement of pairs of points along a newly undefined temperature scale is enough to make a systems engineer weep.

In desperation I tried to make a simple statement of his work. I think Norbert Weiner states it beautifully in the following observation on the importance of communications: "Society can only be understood through a study of the messages and communications facilities which belong to it. In the future, development of these messages and communications facilities, messages between man and machine, and between machine and machine, are destined to play an ever increasing role." This appeared in the *Human Use of Human Beings* in 1950.

In the first diagram we see that a communications system consists of a series of subscribers, or users, or receiv-



Communications Network (one-way)

ers, or public, etc., who receive information from the network. This is too simple: It doesn't, for example, account for any flow of information into the communication network. The arrows are one-way, and while we think of a TV network this way, arrows are needed to denote the fact that information goes both ways, when describing a telephone or video-phone network. That is, there is complete symmetry regarding either user of the network when the network is being used to provide communications between pairs.

First, I would like to enumerate the parameters which describe a communications system.

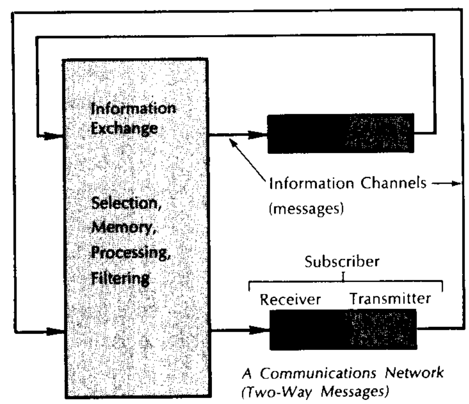
1. Subscribers = Users = Transmitters and/or Receivers
2. Channels for Information Flow
   - Capacity — Quantity & Form
   - Content — Quality & Type
3. Network Information Exchange
   - Switching
   - Selection
   - Memory
   - Processing
   - Filtering
   - Noise

   (Memory, Processing, Filtering, Noise) — Human Component

Properties of a Communications Network

It is the next diagram of a communications system which is more useful as a base model. The actual details of the model and its parameters allow it to be common for most communications systems. It is that of a series of subscribers being bombarded with information.

The communications model below must be made successively more complex, if it is to be valid for our networks. This may be accomplished by looking in detail at each of the boxes, in terms of both their interconnection, and the function each performs. I wish to hold the subscriber, or user, constant, and look at the Information Exchanger.



A Communications Network (Two-Way Messages)

McLuhan criticized General Sarnoff for making the defensive statement about some aspect of television: "We are too prone to make technological instruments the scapegoats for the sins of those who wield them. The products of modern science are not in themselves good or bad; it is the way they are used which determines their value." Now, I believe what Sarnoff was saying is, "Here is a complete communications system; it's called television by name; it has certain properties. Now, the one property which I, a technologist, and perhaps a businessman, want no control of is the actual information which is transmitted." That is, as a technologist, he principally said it is a video/audio link with certain physical properties, technical limitations, and so on. McLuhan is now trying to say that in addition to the actual stuff, the bit patterns or information that is transmitted across the transmission boundaries to its subscribers, the other parameters which affect the way the information is received and re-transmitted have as much effect on the subscribers as the detail bit patterns. The way information flows accounts for behavior of the subscribers, as much as the information itself. Let's look more at the parameters, and then hot and cold can be labeled later. First, the above diagram shows that the users or subscribers are being bombarded with information. Two aspects of the information are separately quantifiable. The most trivial, of course, is that there is a data rate for the information measured in bits (or messages) per second. Though from a technical communications measurement standpoint the meaning is precise in terms of the channel's information capacity, the conversion into actual bits per second that impinge on the subscriber is more difficult to quantify. Of the 3 million bits or so that leave a television transmitter each second, it is estimated that about 10 bits per second enter a person. Critiques of television all argue that it's the wrong 10 bits, not that they don't want the bits.

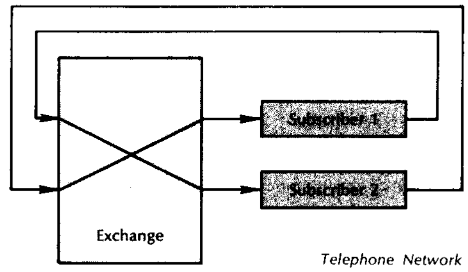
The second parameter, the one of lesser interest to the technologist, or at least the one which society thinks him to be uninterested in, is the content of the information being transmitted. I would be walking on hallowed ground to make any remarks about content, and would only echo the sentiments of Sarnoff in this regard. I must merely lump them as information which has type, and quality, and leave it to the people who quantify parameters relating to human subscribers.

The direction of information transmission is both to the subscribers, and from the subscribers, or users, of the media. In general, there is asymmetry. In connection with the fact that there is information being transmitted at particular rates, and of particular type and quality, there is the actual form that information takes on as it impinges upon the subscribers, though usually only visual or auditory. One direction of new media is to use other media for transmission, as well as improving existing channels. The actual physical media on which images are written, too, seem important, both in terms of color spectrum and image duration.

Where is a facility to copy an image? With the ability to make copies of information locally in each home, we have the instant newspaper one sometimes hears about. Also, the instant letter. I've long given up on the Post-office's ability to make a profit on the mail system, and only look forward to the day when the problem is solved by eliminating letters. Within the detailed media of the auditory transmission, there is a complete range of forms. These range from languages which are common in the face-to-face communications system, to replications of these utterances, to the purely mechanical utterances (like Morse Code), to the case where we read directly coded holes punched in cards. Thus, the actual physical media may be important, but also important is the coding process, so that people recognize it as a message, and not just a machine-to-machine message. I think most of us are able to enumerate uses to which printed material is put which have nothing to do with transmitting messages or coding. Consider the numbers of uses to which the old Sears and Roebuck Catalogs were put, and how paper quality really counted.

Most of the above parameters or characteristics of a communications system are self-evident, or can be explained in terms of the above diagram, just by looking at its inputs and outputs and how they connect. Other properties of the system are better explained by looking inside the Information Exchangers, using specific examples as case studies.

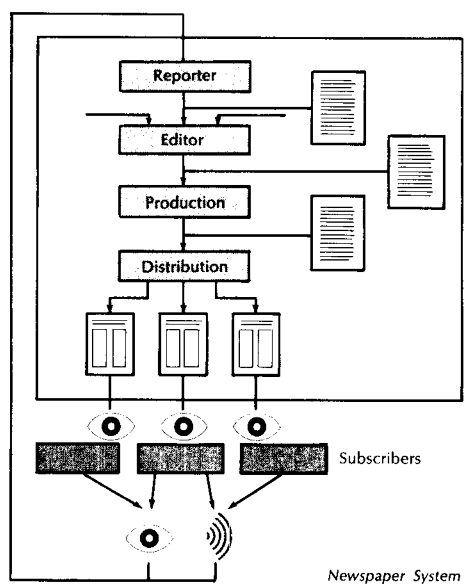
In the telephone network, we see the major function which is performed by the network; that of merely switching information from one subscriber to another. Here, the system is simple in terms of information flow, but complex



Telephone Network

because of the ways in which connections among subscribers take place. A user or subscriber uses the telephone network as a switch or selector, so that a second user (or several users) can be communicated with. Once the selection has occurred, the information is transmitted directly in a limited channel in a verbal format. The system itself doesn't add very much in information nor try to take away much. In terms of transmitting complete auditory information it is somewhat weak, but then again not too many people play records or sing over the phone. Thus, a second characteristic of the Information Exchanger can be seen; that of filtering, or the selective reduction of information.

Now, if we move on to another communciations network, the newspaper,



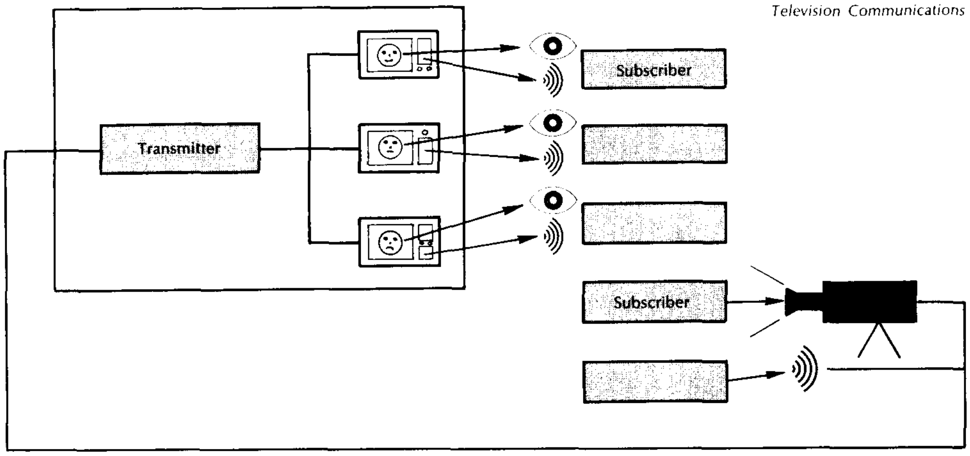
Newspaper System

we see both the selection or switching function, and filtering. Human transducers not only are acting as selectors and filters, but in addition, they may add noise, or unwanted information. At each stage, when a human information transformer appears, filtering isn't quite all that is accomplished. Since we ascribe both memory and processing capability to him, limitless and undefinable properties begin to sneak into what one was hoping to be analyzable. I'm not trying to say that noise and filtering are bad, or even hint at it; merely that they are present, and to a large degree. The filter is precisely why we select one newspaper over another. In essence, I may be selecting a communications system which would perform nearly like myself.

Finally, the last parameter which I'll discuss is the delay function. This is the time it takes for information to go from a single subscriber to another through the Exchange. The delay in similar physical systems gives rise to the system's most important behavior patterns — the ability to operate in a stable, continuous, and controlled fashion. The delay times which occur in getting out the news, or the fact that news is accumulated and then output in bursts, gives rise to the properties of this system. In effect, this parameter tells how quickly the system of subscribers can respond to a particular situation. In order to react to a situation, they have to be told.

Now, if we go on to television, we see about the same kind of system, except that with live television we have a system with no delays; that is, it is like the telephone. (Of course, with the other obvious exceptions of the simultaneity of a common message appearing to a large ensemble of users or subscribers.)

The information path is similar to the newspaper, except that there is no delay. Humans in the link select what is to be transmitted, but no information flows directly through a person. If the selection is not fast enough we get bloopers, which we don't get in films; namely, some filterer hasn't responded quickly enough. (Someone has said mistakes are bad and should be eliminated; so we have to buy them separately and on a record.) The data is instantaneous, and once the information is passed, it terminates in a form which we don't know how to mechanically retrieve from.

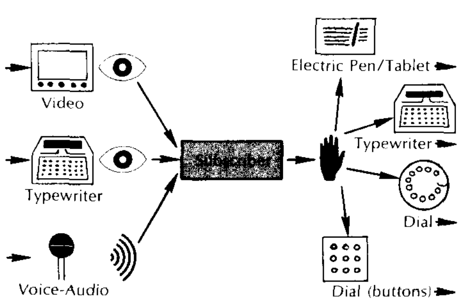


Television Communications

The above model holds for the case of "live" television. It is interesting to note that larger numbers of elements are required to model other forms of television — which account for editorializing, creativity, noise, filtering, memory, etc.

I wish to return briefly to the functions performed by the communications system. These are again listed in the diagram we considered initially.

Now, I'd like to introduce the parts of the present computer, which communicates with its subscribers. With its users, it is a communications network.



Methods or Media of Machine Intercommunication

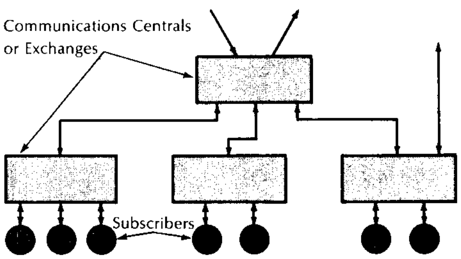
The computer performs functions identical to those of information exchange, and also it has identical structure.

In this figure the user is being bombarded with audio information, typewritten text, and perhaps lights which act like traffic lights. In turn, the communication with the computer is via keyboards; for discrete or typewritten information. The user has a tablet on which to draw or scribble, or can even point at the video data being displayed. He can use a touch-tone dial input like those of the telephone, and perhaps some day the spoken voice. Here I'd like to call attention to the absence of voice input. I don't have enough confidence in our ability to handle this type of input to predict its use within the next 20 years. However, the form of input is common to a number of informations systems; the voice input goes nowhere; it's merely a formal device for venting one's anger — somewhat the way suggestion boxes in some organizations operate.

Now, if we take a look at the functional diagram of a network we have a system which begins to take on a hierarchical structure or organization. There are subscribers at a particular Exchange or using a common computer, or reporting to a single boss. These in turn connect with a higher level exchange.

A computer system with a number of

simultaneous users is called a Time Shared Computer. It has been evolving since 1960 or so, and continues to show promise. All users communicate with a central machine to have questions answered, file data, and, hopefully, receive help.



Structure of Intercommunication Among Communication Networks

One of the first such structures to work well is that of KEYDATA, a Cambridge based firm for handling common billing, order processing, inventory control and sales analysis, for a particular industry. This system was dedicated to a particular task. The communication pattern is principally between the machine and its subscribers. Here the memory and processing capabilities of the machine are being utilized, and the system is functioning with many of the attributes we attribute only to man.

As a designer of a system of this type I want to offer my apologies to potential users for what I think we have oversold. We have been so busy telling everyone how great it's going to be, that they've not had time really to evaluate its strengths and weaknesses, or, on the other hand, make it really work. Many of us are realizing that when a large number of jobs impinge upon the system or computer, its functional characteristics aren't very good, and, in fact, it has many of the characteristics of a human organization. This characteristic of the way a problem solution is organized seems to be constant whether implemented by a machine or with people. Thus, when we replace some aspect of human organization with a machine, then the hierarchy becomes imbedded into the machine or among a group of machines.

This is no surprise, because when particularly inexperienced people try to build a Time Sharing system they look around for an organization. In a particular case it seems that their own human organization was the model, and as such the created system ended up such that over 90% of the computer's activity was concerned with its own self management and less than 10% was available to its users. It churns all day, saying, "Don't bother me; I'm spending my time getting ready to help you."

The system which is used for a single special purpose looks to be most efficient, though limited in its ability to understand other languages or dialects, and limited in its ability to respond quickly to any situation . . . sort of like the specialists we know. On the other hand, the general system can do anything; all that is needed is time; and since it can cope with anything, it is wrapped up in its own internal work. On the surface it looks as if our machines have all the problems of their creators.

The above diagram applies equally well to any tree-like or hierarchical structure; for example, the ensemble of users receiving pictures from common television stations, or the group of subscribers connected to a common telephone exchange, or the subscribers to a particular newspaper. The lines which inter-connect the exchanges are used to transfer information among sub-networks. It may correspond to the wire services of a newspaper, or the common programming facilities of a television network.

In the computer system, one merely has to fill in the parameters of the system to establish its particular form. Unlike the other communications system, this one is a symbiotic system; that is, it consists of parts which are members of different families. The users at the periphery are generally human beings, and the central structure, the Exchange, is a machine. We are relying on the memory and processing features of the computer for behavior which, if it were done by people, we would call intelligence. Thus, the combined system is a partnership of man and machine. The partnership is at present one driven by the man, at the periphery. The peripheral nodes exist as translation devices so that information can be read by both parties. The machine is interested in concise, electrically or optically coded information. The man, on the other hand, likes hand printing, handwriting, or auditory messages, and would be just as happy to transfer messages across the boundary via the spoken word.

A number of the machines I know speak in limited ways; the simplest being just a computer controlled tape recorder. Thus, the machine can convey almost any mood and sex. Some people feel that the machine should speak in the same fashion as people. On the other hand, my feeling is that one expects a machine to have the crisp, quick monotone that is characteristic of synthetic speech, and the machine.

Today, the principle vehicle of communications is the typewriter. Almost everyone can type. Long before my own son could print he could solve simple arithmetic problems using a typewriter connected to a computer. For example, on our own campus, there are about 50 typewriters which are connected to the computers. The typewriters are in offices, homes, and dormitories. A special portable typewriter was developed here, such that all one has to do to communicate with a machine is to make a phone call via the ordinary telephone channels, and place the handset near the typewriter. I'm certain such a portable typewriter will be the standard device used by future reporters in the field with their messages being transmitted directly into central computer files. In this way, immediate acknowledgement of the reporting can occur together with editorial and clerical services. The reporter would communicate with the rest of the corporation via the same device.

So far, we have discussed the computer communications network as a symbiotic one; one in which a subscriber acts, creates a message, while, in turn, the machine responds with pictures on a TV-like screen, typewritten information, or voice messages. In this system, like a video phone, or a telephone, we have the case of direct, instantaneous two-way dialogue. Messages can be originated by either side, and once a message is originated, the dialogue flows in both directions. This is a principle difference between, say, the use of most other communication networks; for example, radio, TV, newspapers, and magazines operate a closed system, taking messages from an ensemble of people forming the objects or information being reported on, converting the information into another form via a series of switching units or selectors or filters, and finally feeding the message back to the reportees — that is, the subscribers.

The differences, then, between the above mediums are both information round-trip time, and a subscriber's ability to direct or influence what the channel is to be. Of course the time between successive publications or messages and the kind of properties one places on the selectors, the switches, or those who decide to dispatch a reporter, or where a TV camera is placed, are important.

In our computer communications system, identical properties are also important. We say how long is it before the machine will run my job, or respond to a demand. The fact that I only receive four messages a day partially describes the system, and to a phenomenal degree determines personal habits in the same way as a newspaper's arrival time or the time news is broadcast.

In the typewriter-or subscriber-directed computer system in which a two-way dialogue is possible, new habits are being formed. These are similar to those created when television changed our lives. At any time, a user is able to converse with the machine and discuss a particular problem. Because of the directness with which communication is accomplished, and the immediate nature of the conversation itself, the process is much like that of talking on the telephone, or, perhaps a better example, of communicating on a face-to-face basis.

I think one of the grossest misconceptions about computers is the way most people feel they communicate with us. The time shared systems are quite helpful, and the solution of a problem using a machine gives about the same sensation as teaming up with a good bridge partner to take on an opponent (the problem). In fact, the dialogue determines whether I want to use a particular facility. Those facilities or programs that type out ? each time I make a mistake, I despise. Unless the program knows that I know what ? means.

Summing things up in regard to a computer's capabilities:

1) It has the same structural properties as other communications systems.

2) All the conversion mechanics, typewriters, video screens, and the like we know of, are present in it. As such, we may expect to be able to fulfill the wild prophesies we hear about: local (or home) newspaper printing; and home teaching machines which children watch, listen to, and respond.

3) In limited situations it can play the role of other networks or parts of networks. For example, machines are being used to take over the switching function in a telephone central office. That is, it routes incoming calls to outgoing lines. Because of its flexibility, it can provide additional functions like being able to change phone numbers by following a person around, or arrange conference calls. Hopefully, a subscriber may even arrange to be unavailable.

4) It is a symbiotic system with memory processing capabilities which provide only a short delay in a communications path. The path of communications is immediate and is directed both into a subscriber and from one. As such, demands to do grocery selection based on cost, or to fill out income tax forms, or balance checkbooks, are possible.

5) It is generally selected by a subscriber, and operates on subscriber demands. When the demand direction is reversed, we have the system of the future, or else it turns out that the subscribers are the slaves.

Now, because of the properties of the machines, I feel that significant changes will occur in organizations that use them. This is again what McLuhan says. Just by setting up a new media, there is a change in the people who become a part of it.

There are many ways of looking at the changes which will occur.

1) We could look at each organization type, classified by what it does, be it government, education, research or industry.

2) We could look at what people do functionally inside the organization.

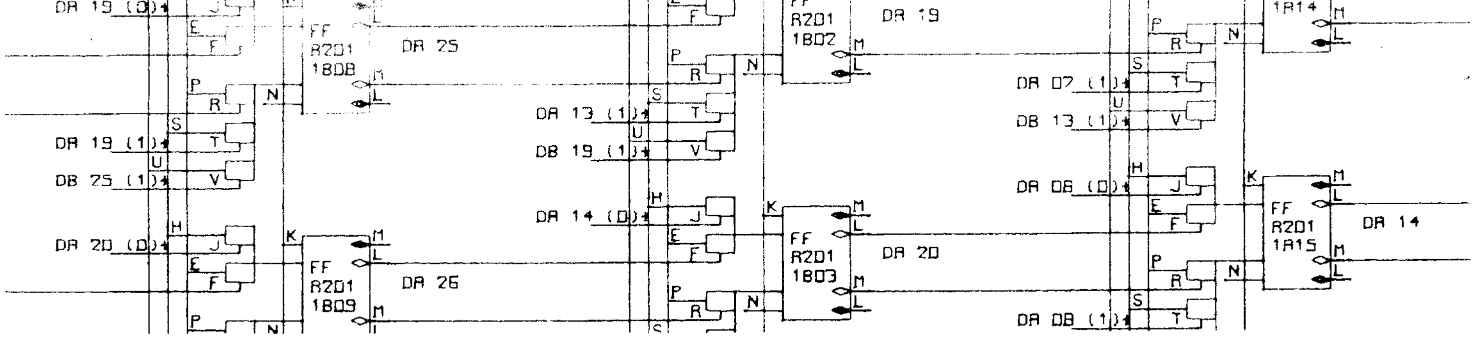
3) We could look at the organization structure in terms of levels of communications.

Let us look at some changes which could occur by function.

I will cite some of my own recent uses of machines to illustrate. These are secretary, drafting, and designer function substitution.

I have used a terminal for the creation of publication text as a natural means of thought formation, coordination, memory, and filing. The body, tables, and bibliography were kept, expanded, contracted, moved, but eventually solidified without extra-system errors. Automatic justification of margins, word hyphenation, preparation of footnotes, table of contents and index construction, and page formatting occurs. Even spelling and simple syntax checking is possible.

To go ahead and construct parts of the secretary as an extension of the



above procedure is possible, but it requires a statement of duties. The exceptional ability of a secretary to detect mid-day hunger pains or coffee yearning, however, appears difficult, along with the presently insurmountable problem of a machine's ability to understand speech, and messy handwriting.

In the case of a drafting program, the goal was to input text describing electronic networks (parts of computers), and to get out schematics which represent the device, together with all forms of production information. The machine's input was in terms of network elements, nodes, and locations. The final system amplified human input to form the schemata or pictures, by extraordinary factors. The abstract producing part of the procedure, or that which produced the pictures, eventually connected to the real part of the procedure responsible for the final instructions which commanded a machine to wire or connect the computer's parts. The above figure is an example of the work. Notice that the lines don't go through the boxes, and are carefully routed around. Very early versions of the programs used to draw lines diagonally to connect the nodes, not caring where they went. I find the same characteristic present in drawings by my three-year-old daughter.

Now with the kind of text editing and communications ability found in the previous description, we could elaborate and try to state just how a publishing industry might change. In other words, try to derive the instant newspaper or magazine that the computer science fiction writers mention. Instead, I want to go on to the general organization changes, and then look at another role which might change, that of a designer.

The image of a corporation consists of conforming men, all wearing identical grey flannel suits. Will this now change to consist of the non-conformist programmers, wearing similar grey flannel shirts?

At all levels and with all functions within the corporation, an emphasis will be on understanding the limitations of the computer. Initially, and in fact in this present phase, we use machines as simple substitutions for people who might perform the function. The structure is almost the same; instead of groups of people doing the work, we have groups of people preparing data for machines that do the work. The type of work the machines do is similar, although more extensive than work done by their human counterparts. It is no accident that the simplest accounting functions were the first jobs to be given to the machine. What followed came about because all the information was in machine-readable form; more elaborate analysis was possible — creating information which could not have been gotten manually because of time limitations.

The next change is that the hierarchy of the organization which represents a communication flow is replaced with a hierarchy of information flow within the computer. The same paths which represent the old system are still present. Thus, since the principle reason for a hierarchical structure is gone, the organization may appear more like a democracy, for there needn't be the superior-subordinate relationship common to most organizations. The individual members exist because of particular skills they possess.

Now, if we look at parts of the organization, we find:

1) The actual workers are transducers, in effect, for the machine, performing functions which are too costly to do automatically. They carry on a dialogue with the machine, and decide what is to be done at a given time. Note that these people in fact will undoubtedly earn premium wages. The unskilled, semi-skilled, and skilled worker with physical dexterity will have more work to do.

2) The people who communicate with the workers to the next level of management, the shop foreman who assigns jobs locally and acts as a crying towel, would *only* serve the function of grievance handling.

3) Scheduling would be done by the computer.

4) Management functions which schedule, take on profit responsibility, and form policy, would consist only of examining alternatives using game playing situations in order that rules for operating the computer could be formed.

5) Policy, to a very high degree, is the way in which data is processed in the network. Policy making then is implemented in detail by writing down exact algorithms which are to be performed. The detailed writing would undoubtedly be done by programmers who know the internal details of the organizational data structure. On the other hand, what the algorithm design is to be would still be the decision of a similar level of management.

6) The top level of management would undoubtedly stay the same, that of establishing broad goals for operating the company, how much capital to employ, and, in general, overseeing.

Undoubtedly, there should be more time for all concerned to perform better. Since more data will be available, all management must be concerned with just what data will be meaningful. Although lots of data will be "around" in the system, consideration will be needed as to what to keep, or have quickly available. "Information overload," will undoubtedly be the cry. Much of the time can be consumed by thinking what structural changes should take place to make the system work better. Simulation and testing for the future will undoubtedly be important.

Game playing may be more prevalent, so that people will be educated in the organization to perform better. Generally, there should be more time for education, since the detailed running-from-crisis-to-crisis can be done with no hands. Skill will be based on building a system which performs smoothly and responds quickly. At present we have management games playing by computers, with a large degree of realism: here, a game player is pitted against a machine which is playing the roles of other corporation members. Fortunately no student has ever jumped from a GSIA window because of failure in the game.

Looking at what a salesman might do, he would communicate his moods and desires so that routing of his sales calls could be made. The minimization of irrelevant and redundant paperwork could be the most significant change. Product status, order processing, and billing would be automatic and not trouble him.

In optimizing, a salesman might be assigned to a particular company, based on the salesman's ability to match the characteristics of a purchasing agent.

Note, that at the time the organization doing the buying discovers a new salesman, a new purchasing agent is assigned, and we get a cycle of oscillation at the boundary.

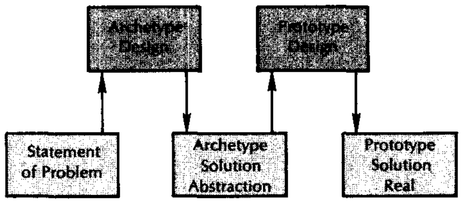
This situation reminds me of a power company which had to put in a computer to defend itself against a computer just across the line which was being used to optimize the flow of power into its own network.

The ultimate, of course, is for a house manufacturer to connect its computer which is responsible for buying, directly to the lumber dealer's machines who sell, so that availability and status data could be used, and order processing done without hands.

The computer is not yet a capable designer:

The programming of a computer to function as a designer is a difficult task to which we are just beginning to turn our attention. The designer may be found in numerous departments of an organization. In fact, designs are the principle output of an architect's office. Design is also what some engineering is. It includes product design, the design of machines to form the products, and the design of the organization.

Over the last ten years a number of goals have been reached in the area of computer aided design. Here design includes synthesis, analysis, decision making, and analysis via simulated operation. Two aspects, analysis and decision making by machine, are now included in design.



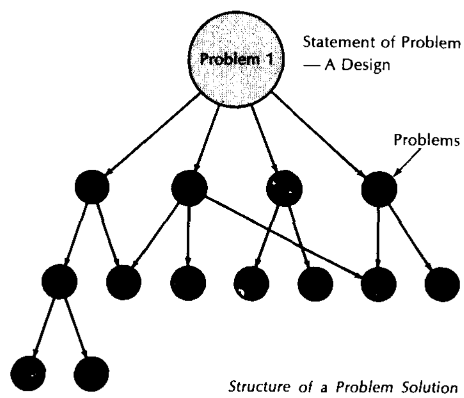
Process of Design

It is now not possible to go through Carnegie Tech or Carnegie-Mellon University, without being proficient in communicating with computers. Students now are able to describe to machines well-formulated numerical or logical problems. This time consuming aspect of design is virtually disappearing from the engineer's duties, leaving one free to formulate the problem for analysis or routine calculations by machine. Design not only includes a single problem solution structure as previously noted, but also the simultaneous solution of a hierarchy of problems. The problems themselves together solve a larger problem. The designer of houses, for example, is given a design situation of a number of constraints consisting of a physical structure to design, a site on which to locate the structure, material to use, a bound on the number of occupants, and specifications regarding the occupants. The above set of constraints can both underspecify and overspecify the problem. The designer must break up the problem as above.

The principle reason that we speak only of computer aided design as opposed to computer design, is that we are unable to describe on a detailed step-by-step process or algorithmic basis just what it is designers do. We know they're busy, because architects work long hours, and architects take longer to train than almost any other profession.

It can probably be shown that any single aspect of a design can be improved upon by better analysis (or maybe optimization) but there is little basis for believing that when faced with solving a number of related and unrelated sub-problems simultaneously, a machine can do a better job. Or, for that matter, that a machine can formulate how to break up the problem into sub-problems.

Herbert Simon, in *The Architecture of Complexity,* begins by stating that complexity takes on the form of a hierarchy. That is, a hierarchy of a complex system is one in which the system is composed of several sub-systems, and each sub-system in turn of sub-sub-systems, etc. Second, for a system of a given level of performance, a system formed from it in a hierarchical fashion will evolve more quickly. Third, in order to analyze the complete system the analysis must be along the lines of the hierarchy or structure. And fourth, there must be a description of each sub-system, part, etc., so their intercommunication can work and so that a description can be formed.



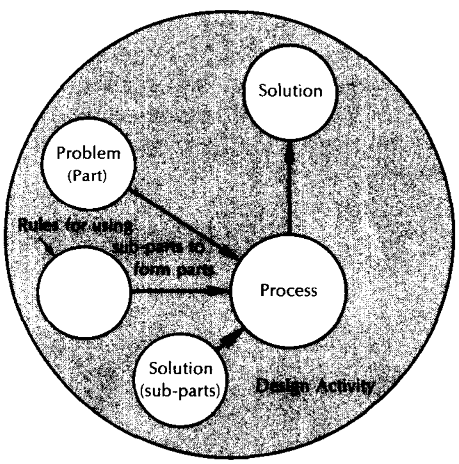
Structure of a Problem Solution

In most structures or designs, the rigor suggested by the above approach is not carried out, and as such, any attempt to determine a part or sub-system is only an attempt in the space of the design which forms the whole of the object being designed. So far, we have been unable to construct a design system which operates in this complete fashion. I see the problems of the hierarchy as:

1) Lack of detailed understanding of how each hierarchical design sub-part operates by itself. To really calculate lighting precisely is unimportant to us in the whole, it is merely a detail which, when left out, makes the house a little less pleasant.

2) Lack of understanding how parts of each sub-part of the design depend on other parts, and so on. Namely, we don't know the structure exactly.

3) The formation of the structure space for carrying out the design instead of being fixed, as I suggest, may just be variable, such for each new design what is really happening is the formation of a structure which can be used to solve the particular design problem at hand.

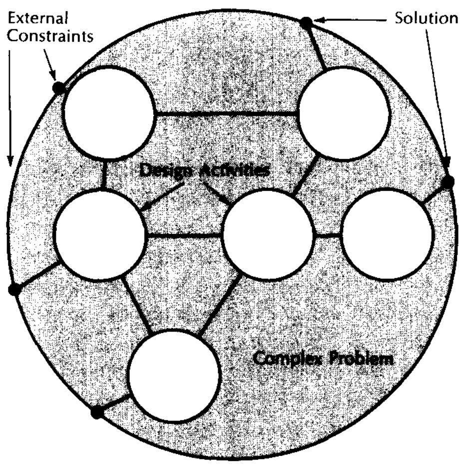


Solution of a Simple Problem

In my own sanctuary, that of computer design, which is absolutely not possible to be done by machine, because of its high degree of dependence upon my own creativity, I'm being shaken. It looks like it may be possible to have a machine design parts of itself. Thus, my own interest is not that of machine design, but of programs which do machine design.

4) Finally, it may not be possible to construct a system which designs really new things with this sort of structure. That is, the occasionally innovative design may just be put together out of a set of rules that weren't evident.

Nevertheless, I feel it is imperative, as a means to our understanding of problem solving, to carry out work which attempts to lead us to the understanding of the design process.



Solution of a Complex Problem

Will better communication help the designer? In several respects the new communication with machines can be used to quickly communicate so that common design problem solutions can be shared. I assume it will be relatively difficult for people working on the design at two independent companies to collaborate on a competing design or even to share any algorithms which may aid the other.

In summary, I have wanted to convey the following:

1) Because of a computer's structure, especially including the devices which allow it to communicate with man, it is able to assume forms which include many of our own communication networks.

2) In a communications role a machine can carry out in detail a gambit of operations: a) subscribers' intercommunication; b) machine-man communication; so that symbiotic problem-solving occurs.

3) Since organizations exist as hierarchies principally for communication, changing the pattern of the people who inter-communicate via machine will undoubtedly change the organization. A change could be along the lines of a democracy, in which each person and machine are paired to solve problems.

4) In one aspect, that of design, I have tried to show how problem solving takes place with both man and machine functioning as a team.

5) Man's simple abilities which are taken for granted, speech recognition and manual dexterity, are currently far beyond the level of our computer science.

Now, I'd like to read from a dialogue between man and a machine.[1] The program is: ELIZA — A Computer Program for the Study of Natural Language Communication Between Man and Machine.

Men are all alike.
IN WHAT WAY
They're always bugging us about something or other.
CAN YOU THINK OF A SPECIFIC EXAMPLE
Well, my boyfriend made me come here.
YOUR BOYFRIEND MADE YOU COME HERE
He says I'm depressed much of the time.
I AM SORRY TO HEAR YOU ARE DEPRESSED
It's true. I am unhappy.
DO YOU THINK COMING HERE WILL HELP YOU NOT TO BE UNHAPPY
I need some help, that much seems certain.
WHAT WOULD IT MEAN TO YOU IF YOU GOT SOME HELP
Perhaps I could learn to get along with my mother.
TELL ME MORE ABOUT YOUR FAMILY
My mother takes care of me.
WHO ELSE IN YOUR FAMILY TAKES CARE OF YOU
My father.

YOUR FATHER
You are like my father in some ways.
WHAT RESEMBLANCE DO YOU SEE
You are not very aggressive but I think you don't want me to notice that.
WHAT MAKES YOU THINK I AM NOT VERY AGGRESSIVE
You don't argue with me.
WHY DO YOU THINK I DON'T ARGUE WITH YOU
You are afraid of me.
DOES IT PLEASE YOU TO BELIEVE I AM AFRAID OF YOU
My father is afraid of everybody.
WHAT ELSE COMES TO MIND WHEN YOU THINK OF YOUR FATHER
Bullies.
DOES THAT HAVE ANYTHING TO DO WITH THE FACT THAT YOUR BOYFRIEND MADE YOU COME HERE

Notice no problems have been solved; but it sure can converse in a barber shop fashion. I witnessed a very amusing computer dialogue which took place when two versions of the above program were connected together on two computers. The dialogue was much akin to a pair of foreign ministers getting together — in both cases neither the inclination or the power is available to contribute to progress. Each is preoccupied with being neutral, and perhaps hoping to gain some information which can be used later.

With machines we have the ability to reduce fatigue due to communication stress caused by too much information.

I'm reminded of an airlines ad which stated that its service was so complete that its computer system knew a Mr. and Mrs. Gavin by the fact that the Gavin's ate chili and salad bowl instead of steak, lobster, or other standard airline foods.

Now, I guess that's what I mean by information overload: the fact that Mr. and Mrs. Gavin's idiosyncrasies get remembered at all. Criteria for computer stored information, if anything, should be more discriminating than man, freeing him for more worthwhile tasks — In comparison, is there any doubt why we have to go to the moon?

[1] J. Weizenbaum, in the *Communications of the ACM.*