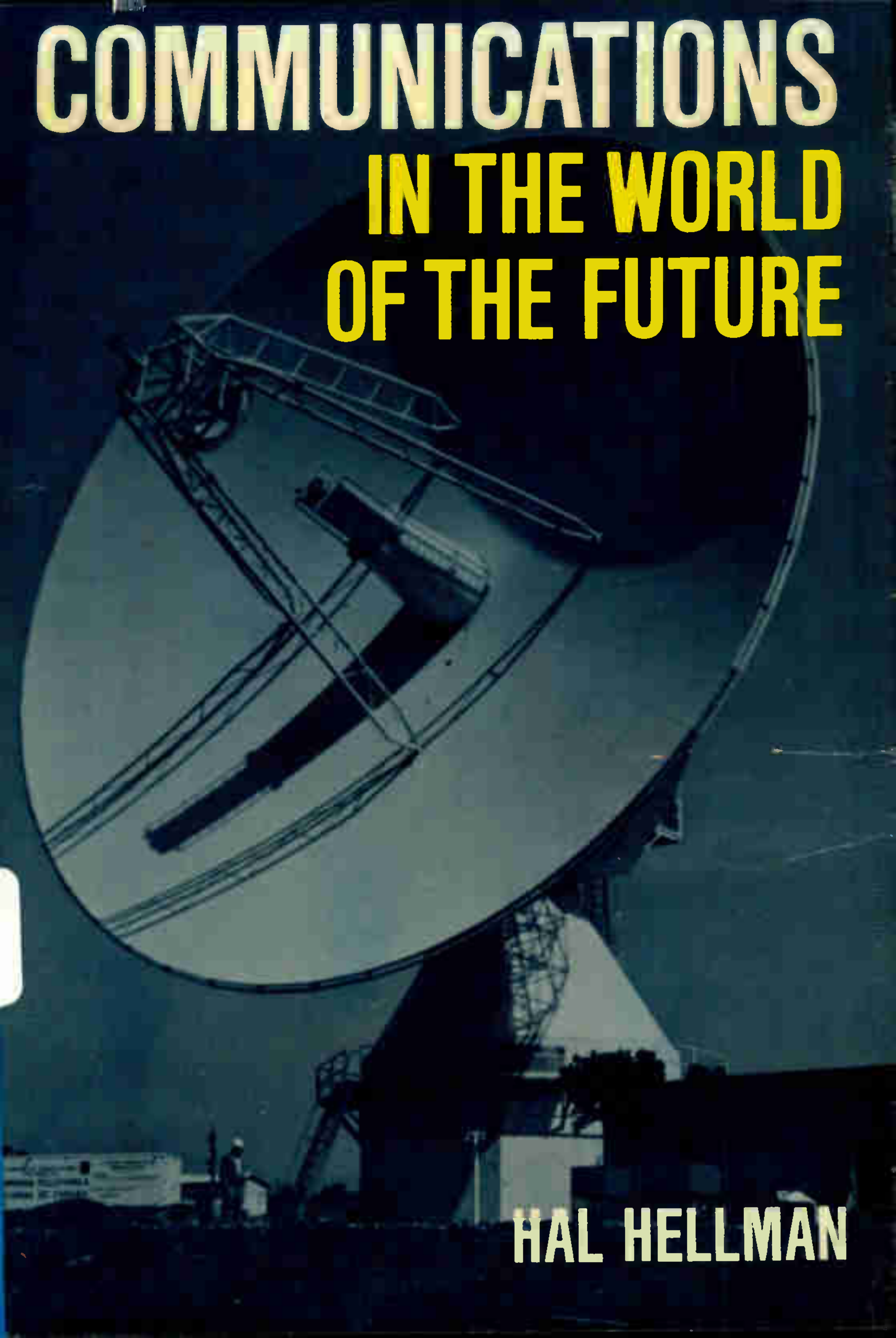
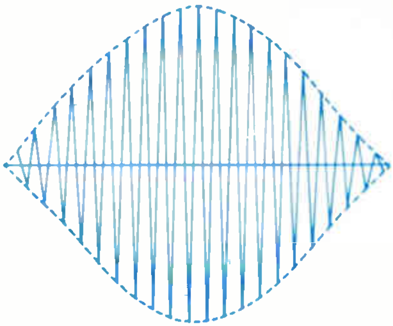

COMMUNICATIONS
IN THE WORLD
OF THE FUTURE
HAL HELLMAN



COMMUNICATIONS IN THE WORLD OF THE FUTURE

HAL HELLMAN

Communications consists of three basic elements: the source or transmitter, the receiver, and a channel which conveys information from the transmitter to the receiver. These three elements make up what is known as a communications system. Each year some dramatic change in our daily habits is brought about by a communications development. Within a matter of decades we have gone from barely being able to communicate by voice across an ocean to interplanetary communications by picture and sound.

Here, in this second volume of M. Evans' WORLD OF THE FUTURE series, is the whole story of communications from the

(continued on back flap)

Illustrated with photographs, drawings and diagrams.

(continued from front flap)

distant past to the near future. Everythin
described in these pages is either actu
or possible. Every dramatic breakthroug
in radio, telephonic and microwave com
munications, television, and publication c
the printed word is either in use in som
way or in the testing stage. Here is a worl
of communications satellites, lasers, ma
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three dimensional full color telephones
transistors and integrated circuits, an
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world in which you will do your homewo
by talking to computers over the telephon
(a method you might use to get informatio
from this book instead of reading it.) Yo
will not only see all these communicatior
marvels in these pages, but you will gai
an understanding of how they work an
the scientific principles that make ther
possible as well.

JACKET DESIGN BY VINCENT TORRE

HAL HELLMAN'S educational background provided perfect preparation for the writing of this book. He holds a Master's Degree in physics in addition to degrees in economics and industrial management. He is the author of seven books and numerous articles on various aspects of science and engineering.

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COMMUNICATIONS

IN

THE WORLD

OF

THE FUTURE

COMMUN

ICATIONS

IN THE WORLD OF THE FUTURE

BY

HAL HELLMAN

PUBLISHED BY
M. Evans and Company, Inc. NEW YORK
AND DISTRIBUTED IN ASSOCIATION WITH
J. B. Lippincott Company
PHILADELPHIA AND NEW YORK

For Gordon Fisher,

Whose love of science and language was contagious.

The author regrets that it is not possible to thank individually all those who contributed in some way to this book. Special thanks are due, however, to Jules S. Tewlowe, Director of Special Projects for the American Newspaper Publishers Association Research Institute, Inc., and David Bikle of Bell Telephone Laboratories' Technical Information Department, who not only provided information but were kind enough to review the manuscript as well.

Library of Congress Catalog Card Number: 69-18831
Manufactured in the United States of America
First Printing

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COMMUNICATIONS

IN

THE WORLD

OF

THE FUTURE

Prologue

AFTER DINNER, Andrew Mann settled down into his favorite armchair and touched the "Program" button on the control box. The lovely fishing scene his wife had chosen that morning to decorate the picture wall faded and a complete listing of the evening's programs flashed on. Seeing that there was nothing of interest at the moment, he decided to watch a video tape of that old master, Arturo Toscanini, conducting Beethoven's Ninth Symphony. His friend Bill had come across it the other day and recommended it highly.

Andrew set the electronic echo characteristics for "Music" and settled back to enjoy the performance.

Just then his son Jimmy came in and said, "Aw, Dad, I wanted to watch the Smithsons."

"First of all," Andrew said sternly, "you can watch them on one of the small sets upstairs. But more important, it seems to me you have homework to do. I'll tape the program for you and you can watch it later. Will you need the computer hookup for your homework?"

"No, not tonight," Jimmy said sadly as he went up to his room.

Again Andrew settled back; but a moment later the buzzer on the InstaMail printer indicated an incoming message. As he pushed the "Stop" button on the control box he thought irritably, "Will these interruptions ever stop?"

But his mood changed as he tore the sheet off the printer. It read:

```
Miss Janis Mann
107 Fairlane Place
New City, California 91202

Your application for summer study of Japanese has
been accepted. Please call to arrange final
details. (Kindly use computer translation if
you do not speak Japanese.)

                        S. Sushiu, Registrar
                        University of Tokyo
                        Tokyo, Japan
                        Call 2303-127-7194
```

Andrew walked quickly into the kitchen to tell his wife the good news. "Fran, Janis' application has been accepted."

"That's nice. She said to call her right away if the message came in."

"Where is she?"

"At the basketball game in the high school."

Andrew went back to the communications center in the living room and touched the "Call" button. A moment later a voice, just audible over the sounds of a crowd, answered, "This is Janis."

"Janis. Dad. We just heard from Tokyo. You've been accepted."

"Oh, that's marvelous. Thanks."

"How's the game going?"

"It's awful. We're losing, 52–42."

"Too bad. See you when you get home."

Andrew then turned his symphony back to the beginning and settled down with a sigh into his favorite armchair.

The next evening the family assembled at the communications console. Janis sat at the picture-phone and placed the call to Mr. Sushiu. (Japanese time is seven hours earlier than California time.) Then she pressed the CompuTrans button and said "English/Japanese."

The signal light flashed on, indicating that the computer had heard, and immediately there appeared on the screen, "CompuTrans English/Japanese Computer Translation Program. Extra cost: seventy-five cents for each five minutes or fraction thereof. Please speak as distinctly as possible."

Andrew also pushed the "Printed Record" button. "This way you won't have to take any notes. And," he added, "you'll have a record of the conversation in both languages to study if you wish."

Mr. Sushiu came on and began speaking in Japanese. A moment later the English translation began to appear under his image, like English subtitles on a foreign film.

After all arrangements were made, and good-byes were said, the image faded. Janis, of course, was bubbling with excitement. Mrs. Mann, though smiling bravely, was obviously wondering just how wise it was to send a fifteen-year-old girl off to Japan by herself.

Andrew looked at his wife for a moment, then said, "You know, I've been thinking; why don't we all fly over a few weeks early and see a little of the country first? I've got some vacation time coming to me."

Mrs. Mann nodded, "That would be lovely."

"Me too?" piped Jimmy.

"Of course," said Andrew. "Incidentally, does anyone happen to have a road map of the country?"

All shook their heads.

"Well, no problem." He tapped out the number for Information Central and asked for a road map of Japan. Thirty seconds later it began to appear on the printer, in color.

They spent a good part of that evening and the next morning planning out their route, making travel reservations, and so on.

By afternoon of the second day, Jimmy began to get restless. "Dad, you promised to take me fishing today, and it's getting late."

"Right you are, Jimmy; I guess we can finish this tonight."

Mrs. Mann said, "Before you go, Andrew, there's something I want to ask you. Bergdorf Goodman in New York is showing its new spring line; I've seen two things I liked very much and I can't decide between them."

She walked over to the communication console and spoke a series of numbers. Two dresses, a red and a blue, appeared. "Which of these do you prefer?" she asked.

"I'm not sure. Let's see how they look on you."

Mrs. Mann stepped into the image of one and then the other.

"I like the blue," said Andrew. "Let's go, Jimmy."

A few weeks later the big day had arrived. As the Manns were driving toward the Long Distance Terminal, Mrs. Mann wondered aloud, "Did we remember to lock the front door?"

Andrew tapped out the proper combination on the car telephone pad and listened for a moment.

Hearing a low-toned buzz, he answered confidently, "Yes, we did."

1

It All Boils Down to Communication

IN THE LATE 1400's the great kingdom of the Incas extended from northern Peru down into northwestern Argentina, a distance of some 1,500 miles. Although the Incas lacked writing, they had nonetheless built up a remarkable system of communications which included wonderful roads, bridges, and inns, plus a system of swift message bearers. Running in relays of about a mile each, the messengers could cover about 150 miles a day; this distance was later to take the Spanish conquerers almost two weeks to cover.

The Inca ruler Huayna Capac extended the realm still farther when he brought what are now Ecuador and much of Chile, as well as more of northwestern Argentina, into the empire. The empire was by this time some 2,000 miles long by 500 miles wide, making it one of the greatest in history.

But the empire had now outgrown its means of communication. The outlying regions were just too far away to be effectively ruled from the center of power in southern Peru. Huayna Capac, in an attempt to remedy the difficult situation, divided the empire between his two sons. Unfortunately, the two men, who were half brothers, fell to fighting. Had they not, the Spanish conquerer Pizarro and his followers would not have had the easy task they did in conquering Peru.

It should perhaps be pointed out that the Incas were not unique in having their communications problem. Ancient empires were always unwieldy because of slow, uncertain communications. And, as a matter of fact, things did not improve materially until the advent of modern electrical communications. For example, as recently as a century and a half ago one of the cruelest battles of all time took place for the same reason—slow communications. This was the last battle of the War of 1812, in which Andrew Jackson successfully defended New Orleans against the British. A thousand men died in the course of that battle; yet a peace treaty had been signed two weeks earlier in Belgium.

It is true, as some would point out, that the treaty had to be ratified by the U.S. Senate before it became binding, and that this might well have taken longer than two weeks. Nevertheless, it seems unlikely that the battle would have been fought had knowledge of the treaty been available. Unfortunately, the only means of communication between Europe and the United States at the time was by ship, and the ocean voyage took a full month to accomplish.

Today, of course, things are quite different. Results of a survey indicate that within half an hour of the tragic assassination of President Kennedy, 68 per cent of all adults in the United States knew about it. Indeed, information can be relayed to any point on the globe in a matter of seconds.

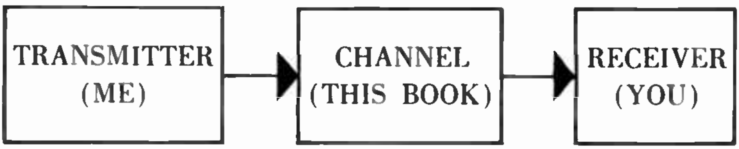
Strategic Air Command's underground communications center monitors military and civil information by using a telephone-radio net and graphic screens.

In a very real sense, information is the glue that holds society together. Life in our modern, complex world has come to depend more and more upon "technical" means of communications such as the telegraph and telephone, radio and printing. Without these extensions of our eyes and ears a country like the United States or the Soviet Union could not exist as a unit for a week.

Furthermore, we have become a *post-industrial society*. That is, the "center of gravity" of our economy has shifted from manufacturing to such services as transportation, education, and communications.

Communication and Information

Traditionally, communication (without the "s") has referred to the transfer of information from one mind to another, for example, from me to you via this book. In schematic form the system might look like this:



Regardless of whether the act of communication takes place across a dinner table or a continent, the "system" will consist of at least the three parts shown above: the source or transmitter, the receiver, and a channel which conveys the information from the transmitter to the receiver.

The channel can be as simple as the air which carries the sound of your voice, or as complex as the many-branched electronic network required to carry a television program across an ocean. And the "information" being carried, as we shall see, can take many forms.

A more detailed diagram would add coders and decoders, for the message must generally be prepared for its flight through air or wire, as when speech is changed into dots and dashes. This might be done for one or more of a number of reasons: convenience, accuracy, reliability, cost, or secrecy.

It All Boils Down to Communication

One of the problems in communications is that noise, or unwanted signals, is often injected into the channel along the way. It is the job of the communications engineer to cut down on the noise as much as possible—to keep the signal-to-noise ratio high as the signal proceeds along its way. It has been found, however, that special ways of coding the information to be transmitted can also aid in improving the process.

And once the message reaches its destination, what then? Are we sure we have communicated? It has been well said that a message may take only seconds to cross a continent, but months to penetrate a man's head. Indeed it may never get in.

This can occur for a variety of reasons. For example, strong evidence suggests that World War II was continued unnecessarily in Asia, and also that the atomic bomb was used, because of a mistake in translation. By 1945 the tide of battle had definitely turned against Japan, and the Allies had sent an ultimatum to surrender. The Japanese reply contained the word *mokusatsu*, which the Domei news agency turned into the English word "ignore." The Allies thus thought the Japanese were quite set on continuing the war.

However, *mokusatsu* also means "withholding comment" (pending decision), which is quite a different matter. This may have been the most tragic mistake in translation in the history of man.

It is clear, then, that communication consists of two major aspects:

1) How accurately can the symbols of communication (speech, pictures, dots and dashes) be transmitted?

2) How precisely does the transmitted message convey the desired meaning?

The Information Age

One of the major characteristics of a message or signal is the following: A small amount of energy or matter in the source brings about a large (or at least larger) redistribution of energy or matter in the receiver. For while there are many definitions of communication, all presuppose *effect* as well as *interaction*. That is, unless there is some effect, we must assume that the transfer of information has not taken place. One may, of course, decide to do nothing about the message; but even in that decision activity has certainly taken place.

By the same token, a small control signal can send a six-million-pound rocket soaring into space—which brings us smack into the middle of one of the most striking developments in communications, if not in all of science and industry. I refer to the joining of communications and computers into so-called information systems, which has occurred only in the last decade or so.

Out of this "marriage" have come our space program, complex banking, economic and management information systems, and many other developments that we shall discuss as we go along.

In spite of all that has already taken place, it seems that we are only at the beginnings of what some have called the Second Industrial Revolution and others simply the Information Age. Surely it is a kind of revolution, but one whose consequences we can only surmise, one in which the power involved is not so much physical as mental or intellectual. All we can see now are the shadowy forms of new developments in automation, education, and communications. We may well see machine translation of any language on earth to any other, man-machine partnerships which will lead to "intelligence amplifiers," and many other fantastic developments.

Yet at the heart of it all lies the basic idea of communication—between ourselves, between ourselves and machines, and between machines!

All of these shall be our concern in the chapters to follow.

2

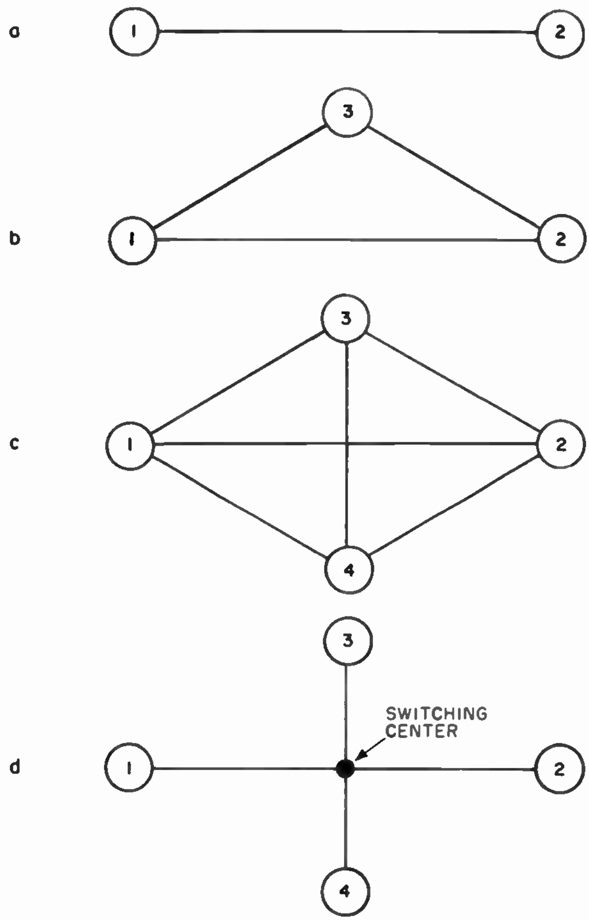
The Telephone

AN INTERCOM is a two-way communications system whereby two or more people can speak directly with each other without having to go through the regular telephone system. For two people, or two stations, only a single wire is needed to connect them. See drawing *a*).

If we wish to tie one additional person into the system, so that he can speak to either of the other two, we must add not one but two wires, one for each existing station, as shown in drawing *b*). In other words, for each additional station we must add as many wires as there are existing stations in the system.

Multiply this by 100 million and you see the problem facing the telephone companies in the United States. Clearly, a separate wire for each connection is a poor way to accomplish the task. A simpler, more logical approach is to somehow switch the calls from person to person. In drawing *d*) we see that two wires can do the job that required six in drawing *c*) if some kind of arrangement can be made to switch the calls.

In the early days of the telephone system, when there were



Simple communications systems

relatively few telephones, human operators did the job. That is, the caller would ring up the operator, tell her the number he was calling (there were no dials on the telephones), and the operator would make the necessary connections. Sometimes a series of operators was required before all the connections were made for a single call.

This kind of thing still goes on in many of the less industrialized countries. In some cases the switching centers are in the Post Office, which closes down for the night! As a result, (and this happened to me a few years ago in Yugoslavia), one cannot even make a call to a neighboring town after a certain hour.

Today the United States (and many other countries of the world) has a fine system, called Direct Distance Dialing, which makes it possible for us to dial practically anywhere in the country at any time of the day or night. The big difference is in automatic switching, which began here as long ago as 1892 with the introduction of the first dial exchange in La Porte, Indiana. In the dial system, each spin of the dial causes a particular switch to flip, making one particular connection in the multiconnection path.

But for each of the 100 million telephones in the United States to be able to reach any other, the system has to be able to make more than 10^{15} (a million billion) different connections. The American telephone industry has calculated that if dialing and other automatic devices had not been developed in the Bell Telephone Laboratories, it would require the entire female population of the country, at the old switchboards, to handle the present volume of calls.

Modern switching equipment makes the connections in a few seconds, and it also routes the signal around crowded centers. Furthermore, if the telephone companies are to make some money for their efforts, someone or something must keep track of the details of each call. This includes the telephone number of the calling and called phones, the time the called party answered, and the disconnect time. All of this is done automatically, as is the billing from the information gathered.

International Dialing

Now that Direct Distance Dialing has been accomplished in the United States, the telephone companies are turning their attention to the problem of accomplishing this internationally. And it is a problem, for the equipment used varies widely in different parts of the world, which makes mixing the systems a formidable task. In the United States, for example, we use a dial with 24 Roman letters (Q and Z are missing). But the Russians and many parts of the Slavic world use a different alphabet altogether, the Cyrillic. And the Danes have no W on their dial. How could they dial a WAlnut exchange in this country? They can't; but this problem disappears when the system is converted to all-number dialing, which we'll get to in a moment.

Presently, at least two operators are required on intercontinental calls. For example, in a call from Chicago to Paris you first dial the Chicago long-distance operator and tell her you wish to call Paris. She connects you with the "gateway" operator in New York City, who in turn rings up the proper overseas operator. Until a few years ago the same process had to be repeated on the receiving end of the call. Since 1963, however, overseas operators have been able to dial directly to telephones in a number of countries. And more countries are being added to the list each year.

The New York City gateway is one of four in the United

States, and the largest in the world; it handles more than seven thousand incoming and outgoing calls each day. The others are in White Plains, New York, Miami, Florida, and Oakland, California. From these four points, we can reach some 98 per cent of the world's telephones. (The routes taken by the calls—cable, radio, and satellite relay—will be covered in subsequent chapters.)

In one of the great examples of international cooperation, considerable progress has already been made in the quest for international dialing; agreement has been reached in a number of areas, including worldwide switching arrangements, techniques for language assistance, and a global routing plan.

Also, a standardized numbering plan has been developed. (This was one of the basic reasons for the present movement to all-number dialing; another is that it opens up new number combinations, which are becoming increasingly necessary for the increasing demand.) The world has been divided into nine numbering zones. Code numbers have been assigned to each zone, just as area code numbers have been assigned to zones within the United States.

The numbering plan sets up a maximum of twelve digits for a world telephone number, plus a special access code (similar to the U.S. area code) that tells the equipment the call is meant to go overseas. To call Geneva, Switzerland, for instance, you would first dial the overseas access code, then the country code, then the area or routing code, and finally the local number. In this case the total is ten digits, not including the access number. While this may sound complicated, remember that we are in this fashion selecting one particular telephone out of almost 200 million in the world today. (By the year 2000 the number is expected to grow to more than a billion.)

Although conversion of all systems here in the United States to all-number dialing has by no means been completed, limited overseas customer dialing was introduced on a trial basis in 1967 between selected central offices in New York and several European cities.

Picturephone® Set

Another area that is occupying telephone engineers right now is the Picturephone system. This is the Bell System's name for equipment which enables two telephone users, each of whom has such a set, to see and be seen by the other as they talk. Just as the telephone was a great improvement over the telegraph, whose terse messages were often ambiguous and led to endless misunderstandings, so too will the Picturephone be a great advance over the telephone. For although most of us don't realize it, the visual aspect is very important in person-to-person communication.

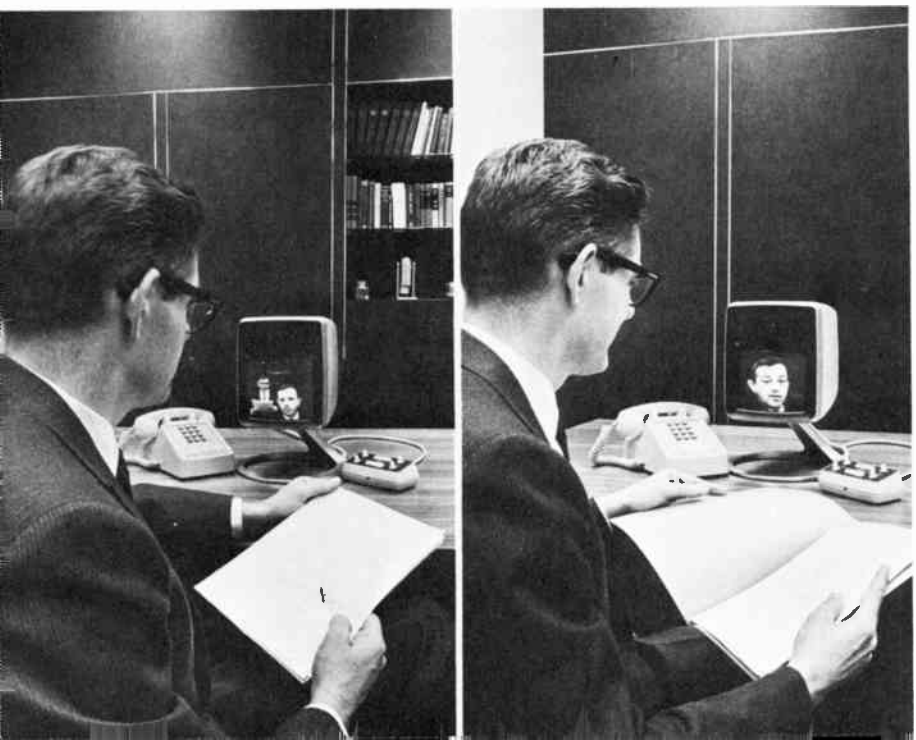
An often-heard comment in business telephone calls is, "Let's get together and talk this over," which implies that whatever the problem is, it can't be handled in a telephone conversation. What is missing, of course, is the visual dimension—the facial expressions and hand movements that tell us so much when we are in face-to-face conversation. Picturephone service will add this dimension, and may well eliminate much costly and time-consuming travel for conferences. Business in the future may be run by executives who are rarely in each other's presence. Picturephones will also be widely used in the area of international affairs.

There are other possibilities too. Far-away job applicants can be seen as well as heard; magazine layouts can be viewed and new packaging concepts demonstrated to distant distributors and retailers, taking some of the load off the mails.

Of course, one can foresee some strange goings-on, such as corporation executives and politicians receiving a hurried application of makeup before taking a call, or a shabby office with a painted or photographic backdrop showing plush furnishings and suggesting prosperity.

A T & T (American Telephone and Telegraph), parent company of the Bell System, is in the process of introducing Picturephone service to a limited number of customers; Westinghouse Electric is now engaged in a trial use of the service.

Bell Telephone's Picturephone set can be adjusted for a close-up view.



A machine part is demonstrated on both Picturephone sets—the sender's and the receiver's.

An early model was demonstrated at the New York World's Fair in 1964, and at various times and places since then. In the newer, more sensitive model it is possible to alter the field of view for close-up or wide-angle viewing. Thus display drawings, illustrations, and samples can be shown. And you needn't hold a phone to your ear. The sound comes in over a loudspeaker and is picked up by a sensitive microphone in the equipment.

Nor need milady fear that she will be caught in pin curlers. Four push buttons enable the user to 1) initiate or answer a Picturephone or voice-only speaker-phone call, 2) see the picture being sent out, 3) prevent the picture from being sent out (a pattern of three horizontal bars is sent instead so that the caller doesn't think his set is not working), and 4) end the call.

Tubes, Transistors, and Integrated Circuits

Even though Picturephone sets are similar in many ways to television, we saw the widespread development of TV long before picture-telephones. The major reason is that the early TV sets, and many of the present ones, depend upon vacuum tubes for amplification and processing of the weak sound and picture signals that come in through the air. While there is little question that the vacuum tube had a revolutionary impact on communications—making possible radio, television, talking movies, and a host of other developments—it is also true that tube equipment is large and has a disconcerting habit of going on the blink relatively frequently.

All electronic equipment depends upon the control of a flow of electrons. The idea is rather like a valve on a pipe. A relatively small turn of the handle causes a large change in the flow of water. Electron tubes act like valves, but must provide their own flow of electrons. They do this by "boiling" them off a coiled wire (the filament) that is heated to high temperature by electricity. It is this high temperature that causes the trouble.

Since telephone equipment often gets very hard wear (and is maintained by the telephone company), servicing of electron-tube Picturephone sets would have been a real problem. The cost of sending out a man to repair a standard telephone set is higher than the cost of the equipment. In other words, telephone equipment must be extremely reliable.

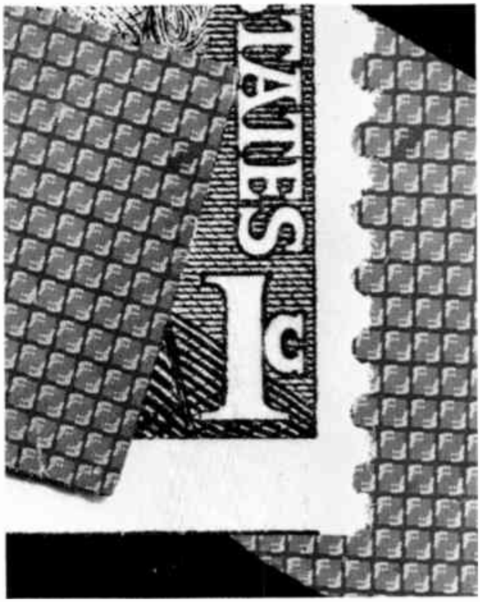
There is also the fact that telephones are often involved in life-and-death situations, such as calling for a doctor, an ambulance, the police. It would have been devastating if ordinary telephones had to rely on vacuum tubes for amplification and power. (Long-line equipment does require electronic amplification, and the transistor was originally developed for this very purpose.)

Picture-telephones, however, do require electronic equipment in the sets themselves, and so other techniques had to be used before Picturephone sets could become a reality. The transistor was an important step along the way. But even transistors were too large and expensive for the very complicated Picturephone sets.

What was needed was a major change in approach. Finally, instead of working with individual electronic components such as transistors, resistors, and capacitors, engineers found a way to put together a group of these components into one small unit called an *integrated circuit.* Now exquisitely minute integrated circuits can do the jobs of tube and transistor circuits hundreds and even thousands of times their size. The cost too is brought down considerably, for many circuits can now be manufactured at one time rather than separate components which must later be interconnected.

Integrated circuits have finally made Picturephones a reality. But they will change our lives in many other ways. One possibility is a vest-pocket telephone that will permit the busy executive to be in touch with his home or office, no matter where he is.

Shown here are two experimental stages. One, now being tested by Bell Telephone Laboratories, is a battery-operated, lineless extension telephone. The unit connects with the regular



Electronic components developed at Bell Labs for use in integrated circuits. Each square, smaller than a stamp perforation hole, contains 672 transistors and resistors.

telephone network via a radio link. Unlike the usual push-to-talk walkie-talkies, the cordless telephone permits simultaneous two-way conversations, dialing and ringing. However, range is presently limited to between one hundred and fifteen hundred feet from the fixed station, depending on the surroundings. The fixed station can be installed in the home, office, construction site, or wherever regular telephone lines can reach.

The other illustration depicts a completely portable telephone that provides direct service to any regular telephone virtually anywhere in the world. The Portable Executive Telephone operates on the same principle as the modern car radio-phone, but weighs one fourth as much. When the user wants to make a telephone call, he signals a mobile telephone operator, who then connects him with the number he desires.

But this kind of thing is only a small sample of what is to come. Telephone engineers look to integrated circuits as the key to communications *systems* of higher reliability, capacity, and flexibility. Prominent among the programs

Bell Labs' battery-operated mobile phone unit, equipped for dialing and ringing.

A portable telephone at a construction site saves installation of temporary phone lines.

already under way is *electronic switching*. This is a faster, more flexible way of handling the intricacies of connecting customers to each other than the old electromechanical system. That is, there are no moving parts; all connections are made electronically, with transistors taking the place of relays and switches. Electronic switching works rather like a computer does, with both stored instructions and with computer-like accuracy and speed.

The first electronic central telephone office was placed in service in 1965. Over the next few decades it will become commonplace. Among the services it will provide are:

1) Call forwarding, in which a customer can have his incoming calls routed to another number.

2) Speed calling, in which the central office will "remember" the numbers of your most often called friends; you'll only need to dial one or two digits to reach them.

3) Three-way calling, which will allow you to add a third person to a conversation; businesses will find this feature particularly useful, although you may want to use it now and then for homework conferences.

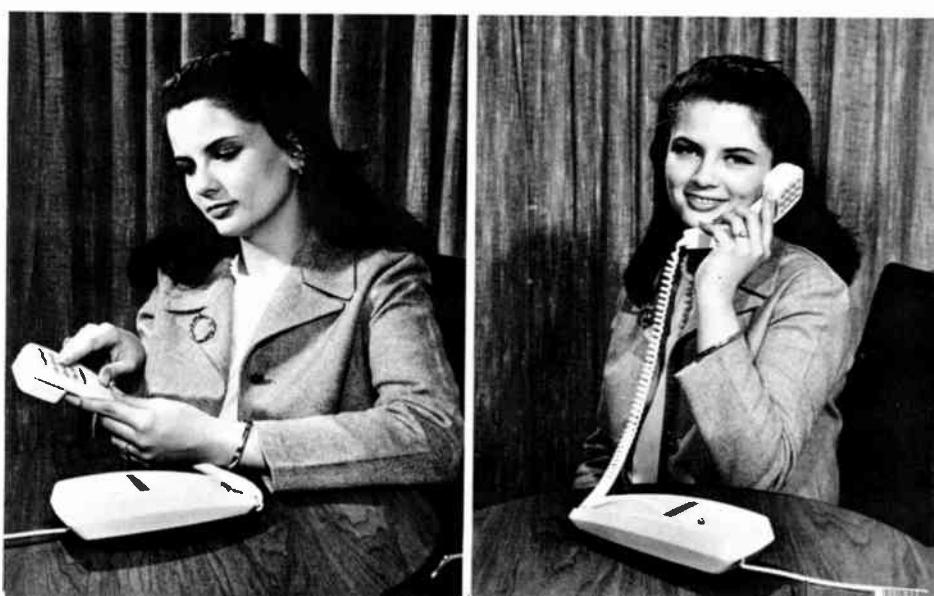
4) Call waiting, in which a tone signals a customer who is on the phone that another caller is trying to reach him.

Touch-Tone

Another very important innovation in telephones is that called "Touch-Tone" calling in which push buttons replace the dial. With this device, calling time is cut at least in half since you don't have to wait for the dial to return to zero. It is interesting to note that this wait was not due to any deficiency in the design of the dial; the wait had to be "programmed" in to allow for the slow switching speeds of the old electromechanical systems.

The Touch-Tone system ties in very logically with the elec-

Experimental electronic telephone.



tronic switching systems. Each digit—from 1 to 0 on the telephone set—is represented by a different tone or frequency. When you touch a 4 on the pad, a certain tone is generated which stands for the 4, and which is "recognized" by the rest of the system. That tone is a data input no different from that which goes into any computer. The system is programmed to do something, such as make a certain connection, when that tone is recognized.

Although, for the present, the major advantage is that of convenience and speed in placing phone calls, we can look forward to some exciting uses when the Touch-Tone system becomes more widespread. For example:

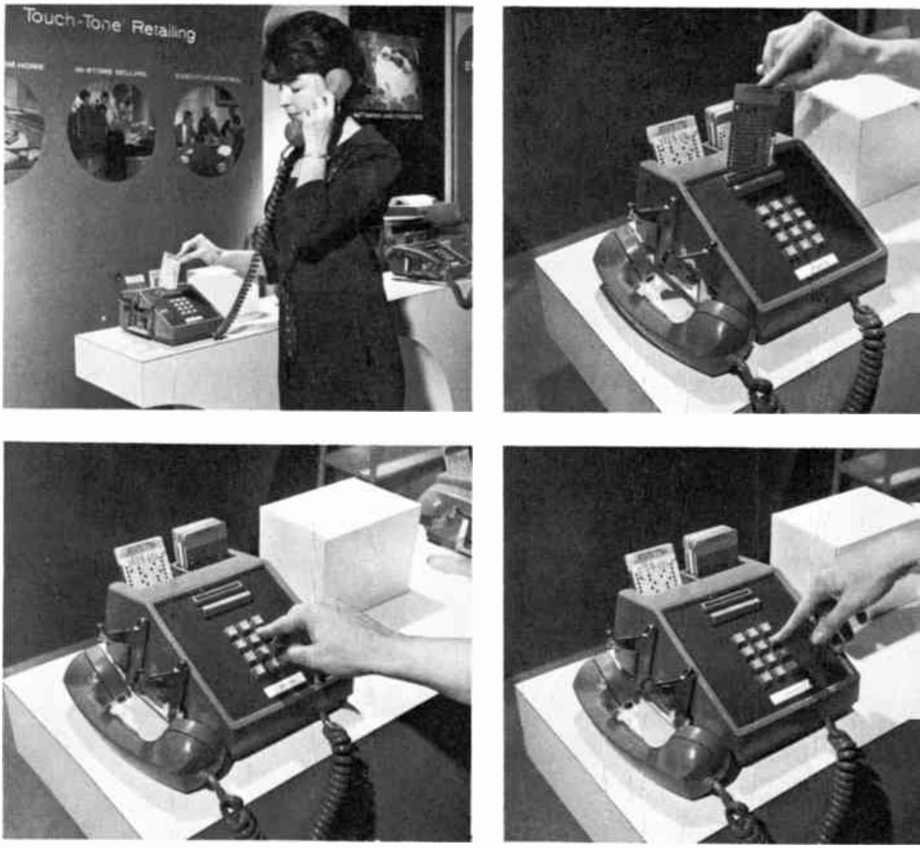
1) If you forgot to lock the back door or turn off the oven when you left on a trip, call the house on your car telephone and touch a few buttons; the door will lock and the oven will turn itself off.

2) A traveling executive will be able to call his home office, be connected to a dictating machine, then control the machine by pushing the proper buttons on his Touch-Tone phone.

3) Paying bills may someday be done without cash or checks. Simply call your bank's computer and punch out coded instructions for transferring funds from your account to the ones to whom you owe money.

4) If used with the Picturephone, the Touch-Tone set can be used for purchasing goods. This would be the twenty-first century equivalent of ordering from a catalogue, except that you could see equipment in operation, as well as various aspects of whatever it is you are interested in buying.

5) It might even be possible for the system to take its cues directly from the human voice. That is, the telephone system may have some kind of device which will recognize the sound



Touch-Tone phone to be used for purchasing: (a) Insert dialing card for store number (b) Insert housewife's account card (c) Use push buttons for codes of merchandise wanted (d) Use push buttons to itemize quantity wanted.

of the human voice saying the various digits—one, two, three—and which will then convert these into the required tones. It may in this way be possible to control computers, including telephone switching systems, by simply speaking to them.

Progress has also been made on automatic identification of speakers by means of their voices. After all, your voice is as much a part of you, and is as different from everyone else's, as is your handwriting, your fingerprint, or even your face. Hence signatures, credit cards, and number combinations can be dispensed with in banking and other credit arrangements.

How much of all this actually comes into existence will depend largely on consumer interest. For it all costs money. In any case, however, the number and use of telephones will continue to rise in the future as it has in the past. The annual number of local phone calls has tripled since World War II, and the number of long-distance calls has quintupled. The average American now makes 648 calls a year. For some reason New Jerseyites use the phone much more often, averaging 806 calls per year.

In 1945 there were less than 28 million telephones in the United States. Today there are more than 100 million. By the year 2000, A T & T foresees 500 million phones in use in the United States alone. Since the United States is expected to have a population of about 350 million, it appears that there will be almost half again as many phones in the country as people!

3

Radio and Television Broadcasting

In 1919, President Woodrow Wilson wanted to sell the Treaty of Versailles to the nation. To this end he traveled more than eight thousand miles in seventeen states. He delivered more than forty formal speeches and many informal ones, only one of which had the benefit of a public address system. This took him twenty-seven days, and exhausting ones at that.

By contrast, the President of the United States can now be in instant touch with tens of millions of Americans via radio and television.

In other words, it was not so long ago that a man had to shout to be heard by a few thousand people. Today he can whisper and be heard—and seen—around the world.

Broadcast communications—radio and television—have also brought a sense of immediacy to the scene in the presentation of news. Who can forget the excitement and suspense of a rocket shot seen on TV? What a difference there is between reading about it later and actually seeing the first few seconds of the rocket's struggle with gravity—or even hearing the radio reporter saying, "Ten, nine, eight, seven, six, five, four, three, two, one! We have ignition. It looks good so far . . . She's a few feet off the pad now . . ." And so on. We are there; we are experiencing the action.

As a matter of fact, there are only two kinds of mobility. We can go to the experience; or we can bring the experience to us. Radio and television have brought the experience to us as it happens. They are extensions of our ears and eyes.

For many listeners and viewers, broadcast communications is no longer a minor part of their experience. It *is* their experience—at least with respect to the events and personalities of the larger world around them. Broadcast communications are an important part, but not the only representatives, of the so-called *mass media* (as opposed to personal or individual communication forms such as mail and telephone). Other forms of the mass media are newspapers, magazines, books, and movies. No matter where we turn we are bombarded with the written or spoken word. The nation has approximately 10,000 newspapers (daily and weekly), 8,000 magazines, 7,000 radio stations, 800 television stations, and publishes millions of books and pamphlets each year.

James Reston of *The New York Times* has written that "the mass communications of this country probably have more effect on the American mind than all the schools and universities combined."

Broadcast Media

The vast and increasing importance of broadcast media comes about for several reasons. We mentioned the sense of immediacy. In addition, many who would not take the trouble to read a written message will listen to a spoken one. This is a kind of mental laziness, but it is a fact of twentieth-century life. It is also true, however, that persons with limited education or poor learning skills can understand what they hear and see much better than what they read. We all learn first from the spoken word; the problem is that many never advance very far beyond that point.

There is also the fact that the spoken word can rouse people to action much more readily than the written word. Many of the most successful leaders never had to put their ideas down on paper. (Indeed, doing so might have spelled the end of their careers.) Their success depends upon personal appearance and the hypnotic effect of their words. For you can do many things with speech that are impossible or not acceptable in writing: shouting, whispering, changing pitch, and repeating certain words or phrases (one of the most effective methods). Writing does have such possibilities as capital and italic letters, underlining and the exclamation point. But these are not really as effective as their verbal counterparts. As Colin Cherry, Professor of Telecommunication at the University of London, puts it, "It may take a page of the finest print to convey the effect of one piercing scream."

On the other hand, the spoken word supplies no visual impression; it is received only by the ear. Yet ideas received by the eye are generally remembered longer than those that are heard. This is one reason why television has had so much greater impact than radio. Another is that our understanding of a speaker is aided greatly if we can see his lips and expression. But the major reason, of course, is that television hits both the eye and ear.

Television

Television can do everything that person-to-person speech can do—it can supply expression, personal appeal, even warmth—with one exception: it cannot tell the speaker if he is getting across.

The television set is being used more and more for instruction. In this way, the good and inspiring teacher can instruct many rather than few. He becomes two, five, or a hundred teachers rolled into one. Yet even the greatest teacher can be speaking over the heads of one group or talking down to another. This problem has been recognized by educators and is being helped by setting up subsequent discussion groups whereby students can have someone to pop questions at and can get the information more firmly set into their minds by simply talking about it.

Television is probably the most "massy" of the mass media. This was strikingly demonstrated a while ago during a performance of Shakespeare's *Hamlet.* More people watched that one TV performance than the total of all those who had ever seen it in theaters in the 370 or so years since it was written.

Video Recording

People read, listen to the radio, or watch television for one of two principal reasons. These are:

1) Promise of reward, such as, "Double your income!" Under this category we include pure entertainment or escape from a mean, humdrum life.

2) Convenience; it is easier to remain staring at the TV set than to get up and turn it off.

Richard Schickel, writing in *Harper's Magazine*, points out that "the most extraordinary documentary . . . provides less information—in the usual sense of the word—than a very ordinary article in a slick magazine. Yet we sit there, eyes glued to the set . . . and even find ourselves compelled to stay tuned to whatever follows . . ."

But suppose *we* could decide what is to appear on our sets and when. Some recent developments have made this a likely possibility in the relatively near future. As a first step, Dr. Peter Goldmark of the CBS Laboratories has developed a device which enables the viewer to play back through a standard television set programs of his own choosing. The system is called Electronic Video Recording (EVR) and promises to have the impact on viewing that LP records had on listening. It has been stated that of all the mass media the LP record is the most "democratic." For with a relatively small investment in equipment, we have at our fingertips a fantastically wide choice of material, from rock to opera, from western to chamber music, from serious dramatic plays to nightclub acts to poetry; even the sounds of cars and railroads have been brought to those who are interested.

Now this factor of selectivity is being introduced to tele-

Phonovid still-picture sound system.

vision. No longer need we be restricted to a "lowest common denominator" of taste, or to watching the rare good program at an inconvenient time (or missing it for the same reason). By combining electronics, physics, and chemistry, we come up with a device that enables any kind of visual material—concert, motion picture, Broadway play, or baseball—to be placed on a convenient cartridge, which can be sold or rented. Perhaps, as is now true with records, they will even be available at libraries.

EVR cannot be used for home taping. The cartridges will be commercially produced, just as records still are today. But, as I am sure you have guessed, work is proceeding on a home video tape recorder. And there is no reason to believe that we won't see one in the near future. As with available audio tape recorders, they will start off expensive and then the prices will drop. However, we have something today that tape recorder manufacturers did not have when they began, and that is integrated circuits. These will make possible the introduction of the necessarily complex video tape recorder at a price and size that would be inconceivable in a tube or even transistorized set. Hence when you cannot watch a certain program as it is being presented, which happens often enough, you will simply tape it and view it later.

Such a tape recorder should not be confused with the video recorders already on the market, which are the electronic equivalent of home movies. These utilize a TV camera and create the program material from scratch. They are used to tape selling aids and low budget educational programs, and are used in place of photographic home movies. They are simply the logical outgrowth of the video tape machines used in all the big studios.

It is likely that the home recorder and the commercial video tape will exist side by side, just as audio tape recorders and commercial records and tapes all do very nicely today. And, very likely, they will cause some major changes in viewing habits. It may well be that many people accept mediocre programming simply because not enough better programming is available at convenient hours. Video recording will make it possible for everyone interested in a program to see it. This will widen the market and make commercially feasible all kinds of programming, such as experimental theater, table tennis, and chess games.

Change of Emphasis

There is another aspect to the television industry. We are likely to see a change in emphasis from the transmitting end of the process—the studios and cameras—to the receiving end. A point normally overlooked is that even in areas like New York, which has seven operating channels, there are still five channels which are quite wasted. If the newer, less often used channels 14 through 83 are considered, it is seen that the number of unused channels far outnumbers those in use.

The advent of additional, program-of-your-choice capability will emphasize the fact that your set is a very simple means of electronically reproducing programming from sources other than the television stations.

Closed circuit TV (CCTV) has already seen widespread use in medicine, industry, and education. In CCTV the signal (live or taped) is not broadcast but is sent by wire directly to one or more sets. Hence the system can be used to monitor industrial operations which are dangerous or inaccessible to human beings, such as laying a cable on the bottom of the ocean. Educational television too is often a closed circuit process; and classrooms or rooms in hospitals can be linked in this way.

CATV, of which you will be hearing much more in the future, is a large-scale extension of this process. It began as a method of bringing the usual programming to areas with poor reception because of location. In this application CATV stands for Community Antenna TV. That is, someone builds the best television antenna in town (usually on a hill nearby) and then wires it into the viewers' sets for a fee.

But, not only does CATV provide much improved reception, it also provides the means for additional programming. As a result, CATV, which has also come to mean CAble TV, is being used in metropolitan areas as well. For the system can send out special programs of limited appeal over the normally empty channels. So for a few dollars a month viewers can receive, in addition to the standard programming, local events, a 24-hour news service, stock market reports, and the new UHF (Ultra-High Frequency) channels as well.

After all, why should it matter whether the information is coming over the airwaves, through a cable, or from a cartridge in the set itself? The great versatility of the television receiver is only now being realized. With the additional use more research will go into this part of the system. Someday we may even be able to draw at will upon a central and constantly updated file of entertainment and information.

Toward Realism

The trend since the beginnings of commercial broadcasting some half a century ago has been toward greater realism. The first sounds emanating from radio receivers were rather tinny and full of static, but were quite magical nonetheless. A major advance was the introduction of FM (Frequency Modulation), an improved way of impressing information on the radio waves being transmitted, which produced better fidelity, or higher "fi." Stereo has provided a more natural sound.

A big step toward realism of course was television, or, more specifically, the addition of a picture to the sound. In a rather interesting parallel, the development of photography more than a century ago provided the same sense of excitement. For even the most realistic painting is still far from realistic, being in truth a major simplification of the actual scene. Early viewers of photographs were stunned by being able to see, as one man wrote in 1839, "all the minutest indentations and divisions of the ground . . . even the small stones under the water at the edge of the stream."

Television combined the realism of photography with the instantaneousness of radio.

Further development of TV brought clarity, mobile cameras, and then color. Always the objective has been to reproduce the actual scene in as true a representation as possible.

Well, what is missing now? There are two major objectives still to be obtained: the third dimension and true size.

By true size, of course, we mean people size. It is hard to imagine how it will ever be possible to squeeze a full-size Niagara Falls into your living room, no matter how advanced our technology. The picture tube approach doesn't seem to be the way to obtain wall-size TV; it would take a full room to house the mechanism. What is needed is some sort of flat panel which can do the same job. A number of solutions are being investigated and it is very likely that wall-to-wall television will come to pass. (Curve the wall and you've got Cinerama, almost.) Projection television is another possibility, and indeed was one of the first approaches to the viewing problem.

Three-dimensional pictures have been in existence almost since photography was developed. Viewing a set of stereoscopic photo pairs with a stereopticon was once a favored

Sunday afternoon activity. But the novelty and realism offered were counterbalanced by the awkwardness of the apparatus and the fact that only one person could view the scene at a time.

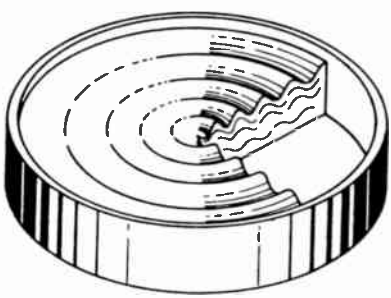
There have been periodic flurries of interest in "new" approaches to 3-D, such as movies at the 1939 New York World's Fair which provided the third dimension when viewed through special glasses. But again there were drawbacks—the glasses posed a problem and viewing gave some people a headache.

Although few recognized it at the time, the invention of the laser in 1960 provided the first real capability for a practical stereoscopic system, at first in monochrome and then, very recently, in full color.

Before we can see how this is done, however, we must first be sure we understand the concept of a wave, for both light and radio radiation are examples of wave motion.

If we drop a rock into a quiet body of water a series of waves spreads in circles from the point of impact. Eventually the waves die out and that's the end of that. But suppose we tie the rock to the end of a rod and move it up and down a

Imagining a pie slice taken out of a pan of water illustrates a sine wave.



certain number of times per minute. Then we would create a steady pattern, a wave pattern, in the water.

If we could cut a "pie slice" out of the water (as shown in the diagram) we would see that the waves take the form of the well known *sine wave*. The distance between crests is called the *wavelength*, and the number of waves that pass a given point on the way out from the center is called the *frequency* of the wave. The faster the up and down movement of the rock the more waves we create per unit time, and the shorter the distance from crest to crest. In scientific terms we say that frequency is inversely proportional to wavelength.

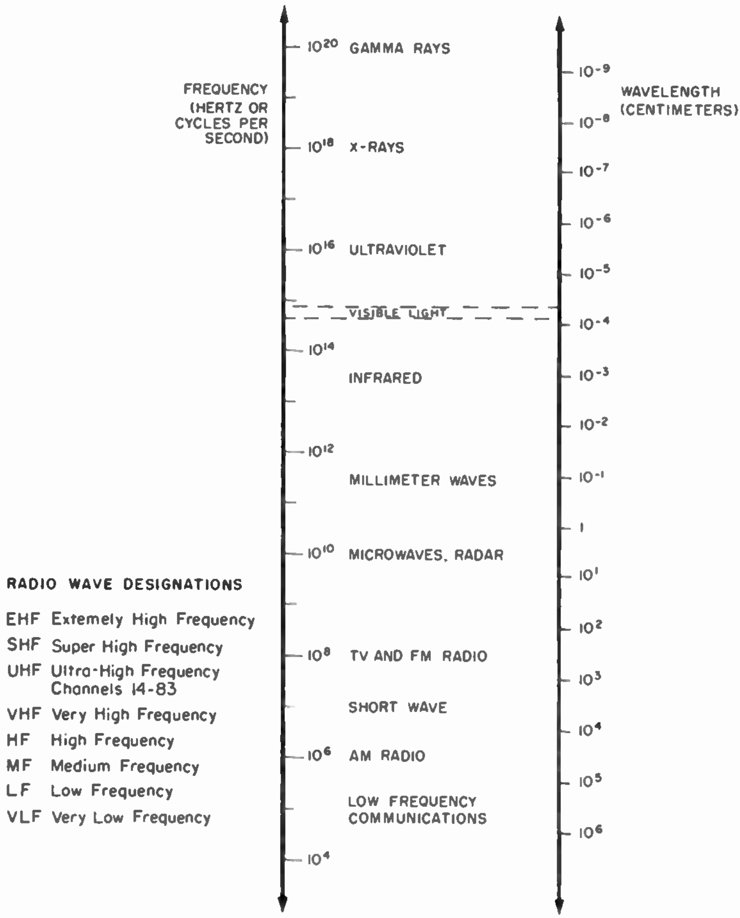
Light and radio radiation are not only wave forms, but are also examples of a form of energy called *electromagnetic radiation*. As shown in the chart, the electromagnetic spectrum includes a wide variety of radiation from the very short, high-frequency gamma rays to the very long, low-frequency radio waves.

As you can see, the visual portion (light) comprises a very small portion of the entire range. Normal white light consists of a mixture of all the wavelengths of the visual portion of the spectrum, which means everything from roughly 4×10^{-4} cm. to 7×10^{-4} cm.

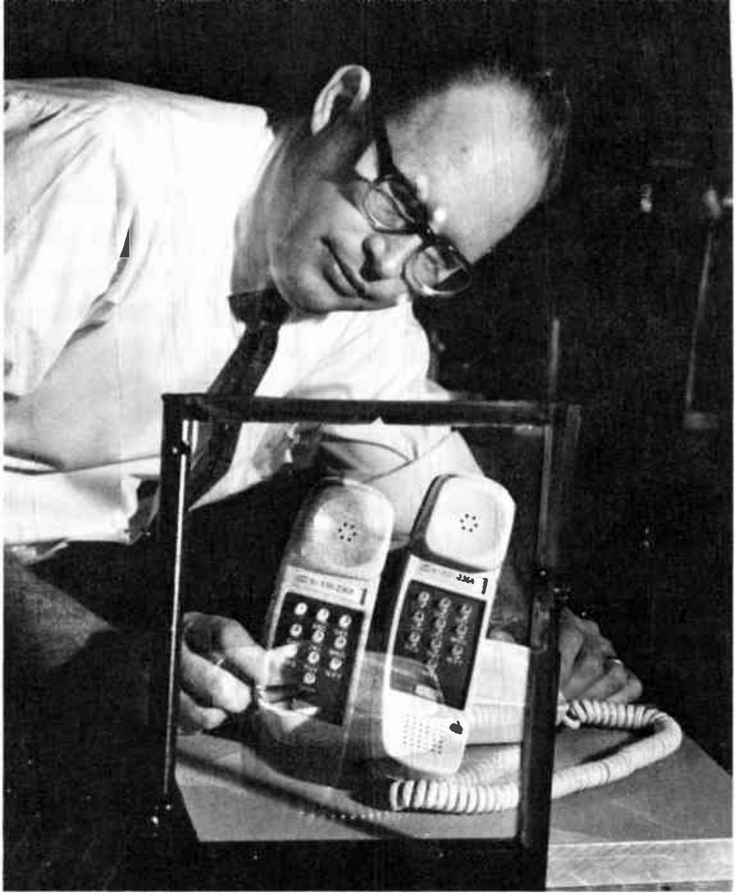
But laser light is made of waves which are all of the same wavelength and which are all in step. Thus in a scene shot by laser light, the distance from each object to the photographic plate is represented by a particular number of wavelengths. In this way information about the actual distances of the various parts of the scene from the plate are recorded, rather than just lights and darks, as in ordinary photography.

The finished plate, which is called a hologram (for whole picture), seems at first to contain only a meaningless pattern.

THE ELECTROMAGNETIC SPECTRUM



Indeed, it looks like nothing more than rain splashes in a puddle. But when viewed in the proper way, the hologram provides the most incredible experience. For not only do we see the roundness of objects, but by moving our heads from side to side we can actually see around the objects. For example, hold up your two hands one in front of the other and perhaps six inches apart; the rear hand is hidden by the front



An actual Trimline telephone is held beside a 3-D image of the same phone, illuminated on translucent film.

one. Now move your head to the left and the right. You can see "around" your front hand. A hologram permits you to do the same thing! The realism of the impression is startling and is not matched by any other three-dimensional process.

Thus we can look forward to the ultimate in viewing—full color, full size, and three dimensions. If we then add stereophonic sound, which is already a reality, we come very close to the ultimate in overall realism. Except for smell, feeling, and taste, that's all there is. (Actually, "smellies" have already been tried in the movies. But, except for the novelty, it hardly seems worth the effort.)

However, don't throw out your color set just yet. A few "small" technical problems remain. For one thing, the scenes that can be photographed by laser light are still small, a few feet across at most. Larger scenes cannot yet be photographed. As a matter of fact, one of the major features of laser light is that of its narrow, concentrated beam. Widening the beam too much weakens it to the point where it is useless.

Second, making holographic images of moving scenes is very tricky; but this probably will not be a major stumbling block. Already short, computer-generated holographic movies have been made. Perhaps this will be the approach taken.

Foreground console in Philco-Ford's House of Tomorrow controls all entertainment and lighting functions in home; 3-D (holographic) TV screen in background will provide wall-size full color scenes.

That is, a computer may have to be used somewhere in the process.

The third problem is one that has been plaguing the communications industry for some time already. We mentioned earlier that a hologram contains more information than a normal picture. Indeed, it contains on the order of 1,000 times as much. This additional information would have to be transmitted if we are to have three-dimensional television (holovision?). But the vast increases in communications that have taken place in recent years have already strained the carrying capacity of the used channels.

Let us see what these channels consist of, and what can be and is being done to increase these capacities.

4

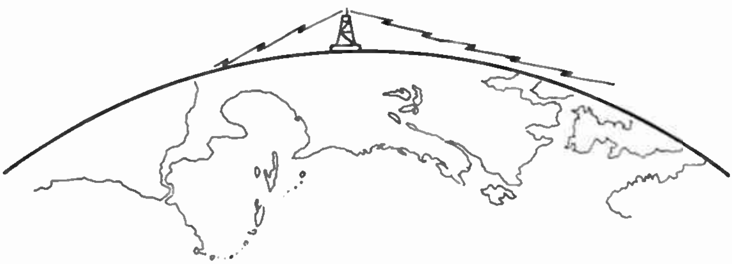
Common Carriers

ASK TEN of your friends what it takes to get a television picture from its origin to their television sets and you'll either be met with a bland expression or some vague comment like, "It's broadcast over radio waves . . . isn't it?" If he knows something about physics, he might also talk about the "electromagnetic spectrum."

But a little thought convinces us that this approach, namely broadcasting the signal from origin to destination, cannot be the answer. For 1) it would be uneconomical, 2) it wouldn't work, and 3) it would create utter chaos throughout the country if it did work. Let's examine these points one by one.

In order to broadcast a TV picture from Florida so that it could be received anywhere else in the country, a tremendously high-power transmitter would be required. This is why it would be uneconomical.

Secondly, broadcast television does use radio waves; and radio waves, as we know, do span continents. But the waves used for TV are of much higher frequency and thus, as shown in the chart on page 43, are shorter (of smaller wavelength) than normal or AM radio waves. As a result they cannot "bend around corners" as a typical radio wave can; generally speaking, TV signals travel in a straight line, as light waves do. Thus a signal beamed from a tower in Florida will travel only twenty or thirty miles before the curvature of the earth causes the signal either to strike and be absorbed by the earth or, if it is aimed higher, to simply fly off into space (see drawing).



A signal from a TV tower can travel only 20 or 30 miles before it strikes the earth or is lost in space.

The third point, that it would create chaos, is a little harder to understand, but is unquestionably the most important of all. For if the TV signals were simply sprayed out into space with enough power to blanket the United States, then that frequency band would be effectively used up and could not be used anywhere else in the country.

We can take as a more "down-to-earth" example the two-way radios in police and fire vehicles, taxis, delivery trucks, and so on. These are so widely used that in many areas we have actually run out of the frequencies on which they operate. This means (and this has happened) that the operator of a delivery service in New York can't improve his efficiency because he can't obtain a mobile radio frequency. When, after long delay, he finally obtains one, he finds that he is sharing a "party line" with fifty other active businesses.

Even more serious was the case where a house burned to the ground in Los Angeles because crowding of a radio channel prevented fire-fighting equipment from being properly dispatched.

Examples could be multiplied indefinitely, for electromagnetic frequencies are used in a wide variety of applications, including radio-marker beacons, garage-door openers, model-aircraft control, marine and aircraft communications, and long-range navigation. Other, newer applications are in the offing too. For example, the Automobile Manufacturers' Association has requested that a service be established to provide emergency radio communication for the motorist.

Because of crowding we get some strange cases of interplay. In the Far West, for instance, radio-operated garage-door openers produced interfering signals that invaded vital aviation and navigation frequencies. A total of 285 offending units had to be located and removed from the air.

Television broadcasting, it turns out, is one of the most avaricious of all users. A single TV program uses six times the spectrum space occupied by the entire AM broadcast band. By restricting the power and therefore the range of a broadcast signal, we make it possible for the same frequency to be used by different stations in various parts of the country.

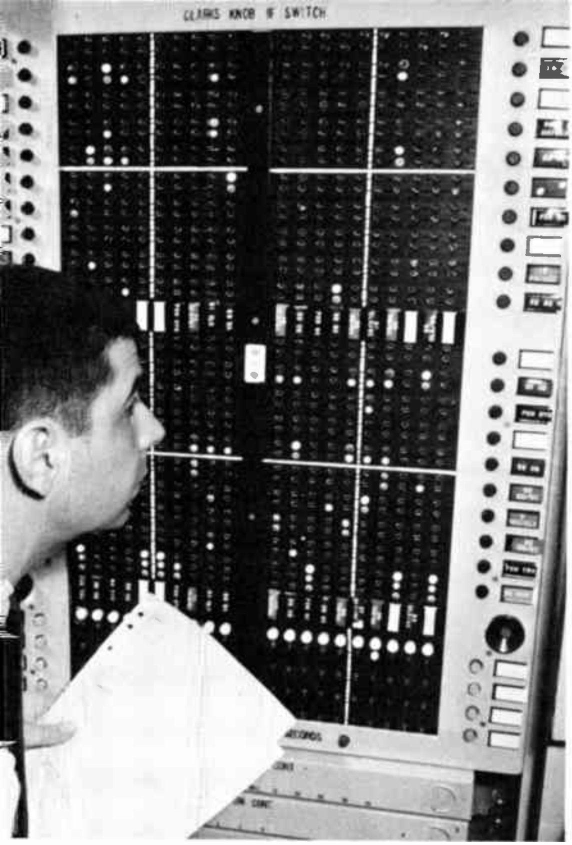
The Common Carrier

How then does the TV crew get the signal from the camera in Florida to your set in Seattle or Chicago? The answer is simple. They don't. They are concerned with originating the program material. Another type of communications company—the common carrier—is given the responsibility for getting the signal from one place to another—typically from the source to one of your local TV stations. It is not until this point that the signal is broadcast on a given channel, and within a specific power level.

The carrier will use one or more of a number of different techniques in the transmission of the signal from place to place. He is the "shipping" or "pipeline" company, except that his cargo is information rather than oranges or oil. His "vehicles" fall into two major areas, with a third coming up fast. The two major techniques are microwave radio relay and guided methods such as wire and cable; we discuss these techniques in this chapter. The third method is the communications satellite, which we cover in the next chapter.

Examples of common carriers are A T & T, ITT (International Telephone and Telegraph Corporation) RCA Communications, and Western Union. For TV programs A T & T is usually the carrier; and the job of getting the package of picture plus sound is done by their Long Lines Department, whose communications network interconnects the individual companies of the Bell System with the various television companies.

In addition to transmitting the signal, the Long Lines people have another job which contributes to the dramatic impact of TV, as in the televised newscast. This is the quick switch from one location to another. On Election Day, for instance, you may see announcers from half a dozen cities across the country flash on your screen one after another. When the announcer says, "We now take you to Central City, Nebraska,"



Bell Telephone technician observes switch that determines route TV image will take.

Bell Telephone engineers monitor television channels that their carrier transmits.

somebody has actually had to make the switch. As you can imagine, this is an exacting job. The technician who will make the switch is told in advance the last words the announcer will say before the switch is to be made and probably also the exact time that the switch will be made.

Or perhaps you are watching a professional football game one Sunday afternoon. At an appointed instant in time, the national hookup may be dissolved into more than twenty regional pieces so that local stations can show local commercials—surfboards in California, farm machinery in the Midwest, and snow tires in Maine.

To make sure that split-second timing is maintained, there is a clock in the operating center which is accurate to the second. It is interesting to note that this accuracy is aided by a radio station in Washington, D. C., which broadcasts nothing but the time! Clocks all across the country can thus be kept in perfect synchronism.

One remarkable aspect of today's communications is that the same circuits that are carrying one or more TV programs may also be carrying telephone conversations, facsimiles of pictures from distant news gathering services, and data collected on machines and transmitted to central offices for handling on a computer.

Circuit Capacity

A major factor here is the large capacity of the circuits used. Let us see what this means. A station wagon can carry a bike but not a Volkswagen. In communications systems the determining factor is bandwidth—the number of electro-magnetic waves, or cycles, that can be transmitted each second in a radio beam or through a wire.

Traditionally, the unit used to describe this capacity (and frequency, as well) has been "cycles per second." Recently, however, the term "hertz" has been introduced and is coming to be used more and more. A table of some commonly used frequency designations is given here.

1 cps	=			1 hertz	=	1 Hz
1,000 (10^3) cps	=	1 kilocycle /sec	=	1 kilohertz	=	1 kHz
1,000,000 (10^6) cps	=	1 megacycle/sec	=	1 megahertz	=	1 MHz
1,000,000,000 (10^9) cps	=	1 gigacycle /sec	=	1 gigahertz	=	1 gHz
1,000,000,000,000 (10^{12}) cps	=	1 teracycle /sec	=	1 terahertz	=	1 tHz

Some frequency designations

In essence, the more hertz (cycles per second) transmitted, the greater the amount of information that can be carried per unit time. Thus, certain low-capacity circuits can carry telegraph or voice signals but not video. In the early days of telegraphy and the Morse code, the only information being transmitted were dots and dashes, and these went out only as fast as the operator could press the key. Telegraphy required a signal of only about 60 Hz, which was easily carried on a single thin wire.

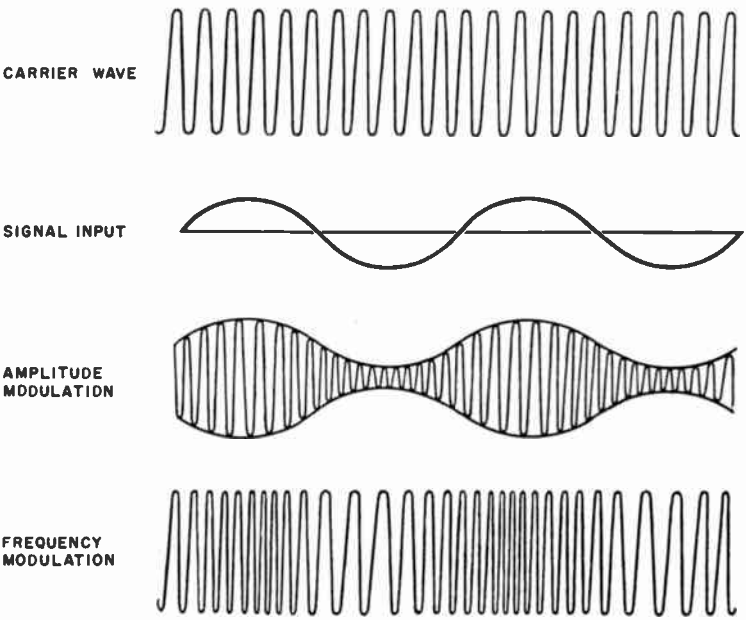
Satisfactory transmission of speech, however, requires a path capable of carrying a range of about 3 kHz. The thin pair of twisted wires coming out of every telephone (one for each direction) does have that capacity, with some to spare.

But how about the "trunk lines," those which connect telephone offices within and between cities? These may have to carry dozens, hundreds, or even thousands of simultaneous conversations. They must have much greater capacity if a separate pair of wires is not to be needed for each two or three conversations.

In the last few decades, modern technology has made possible broad-band communications paths which can handle many conversations simultaneously (as well as hertz-hungry video signals and other kinds of data). One of the most significant developments was that of the coaxial cable. The modern coaxial conductor is usually a ⅜″ copper tube. A thin copper wire (10 gauge or .102″) is held exactly in the center of the tube by small plastic disk insulators spaced about one inch apart. The name coaxial derives from the fact that the centers of both the wire and the tube lie along the same axis.

A typical coaxial cable consists of eight or more coaxial tubes sheathed in metal and plastic for protection. In order to obtain many different voice channels for separate telephone

This 20-unit coaxial cable can carry 32,400 telephone conversations at once.



Amplitude and Frequency Modulation of a Carrier Wave by a Signal Input.

conversations within a tube, a broad-band signal of several megahertz is transmitted. However, it is "chopped up" into separate sections, much as the frequencies shown on a radio dial are given over to individual stations.

The broad-band signal is called the carrier frequency or *carrier wave.* Each of the conversations is "funneled" into a different portion of the carrier wave. There it is superimposed on the carrier wave (see drawing), which is then said to be modulated. Because the carrier frequency is so broad (many hertz), this can be done many times. The process of putting more than one signal on a carrier is called *multiplexing,* a term that will probably be familiar to anyone with a hi-fi stereo radio.

Coaxial tubes (not cables) must be used in pairs for two-way communications, since the signal can travel only in one direction. With present equipment, each pair can carry as many as 1,800 simultaneous conversations, or 600 conversations and one TV program in each direction. Should one of the tubes fail, an automatic device immediately throws a standby into operation, preventing interruption of service. Experiments are now being run on equipment that would permit the simultaneous transmission of a third of a million conversations on one circuit.

To provide the necessary amplification along the cable route, repeater stations are installed some 100 to 150 miles apart. Smaller, unattended stations are placed at about 4-mile intervals. At the receiving end the conversations are separated by an electronic filtering process and sent to various recipients.

Transoceanic Communications

Coaxial cables have had a great effect on overseas calls as well. A major breakthrough in this area occurred in 1915 when the first transatlantic radio-telephone transmission traveled from Arlington, Virginia, to the top of the Eiffel Tower in Paris. Twelve years later commercial radio-telephone service was inaugurated between London and New York.

These calls have always been a marvel. But because part of the connection was by radio, they were often quite an ordeal for the users. Voices would fade out and fade in; static would sometimes obliterate the message completely. The problem is that transmission by radio is at the mercy of atmospheric conditions, which include rain and snow, changes in temperature and pressure, electrical and magnetic activities in the atmosphere, and many others. All can have a powerful effect on long-distance radio transmission. That is why aircraft flying across the ocean often find it impossible to communicate with ground stations for an hour or more.

But now when you phone Europe, you might easily think that you are speaking to your neighbor across the street; for chances are that you'll be connected directly by undersea telephone cable, the first of which went into service in 1956.

And just as a trucking firm might rent you a truck for your exclusive use, so too will common carriers rent you a circuit for your exclusive use, if you are willing to pay for it. Many types of business use rented circuits to connect home office with branches. Certain offices at the United Nations complex in New York have direct lines going back to government offices in their home country. For this reason, it may happen that two offices in the same U.N. building can reach Europe faster than they can reach each other.

Among the first uses of coaxial cable was a 1½-mile link connecting NBC's New York City television studio with the transmitter atop the Empire State Building. Starting with the first transmission in 1936, thousands of New Yorkers were introduced to TV by means of images sent over this cable.

Coaxial cable will not handle microwave signals, however. For these high-frequency signals, another form of guided transmission must be used, namely, a square or round metal tube called a wave guide. The analogy with pipeline transmission suddenly is a very close one.

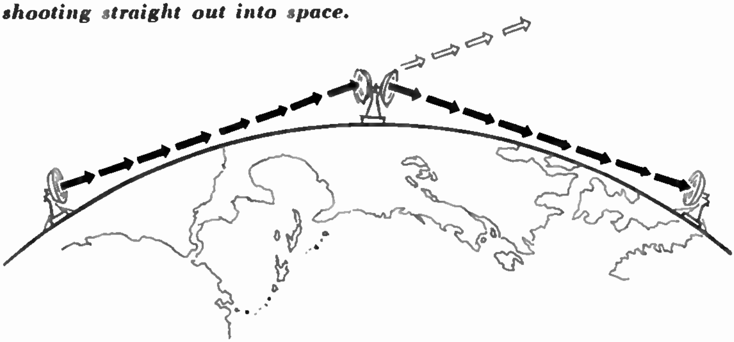
Confined media such as wire, cable, and wave guide will, with the further crowding of the airwaves, undoubtedly see even wider use in the future. Point-to-point services already make extensive use of cables. But other possibilities present themselves, such as "leaky" wave guides or other types of surface transmission that provide high-capacity communications and automatic control of trains and motor vehicles along main routes.

Still, cable communications require a physical link between transmitter and receiver, which can be inconvenient and is always expensive. It's a little like the railroad as compared to aircraft. Cables, as well as rails, require the acquisition of rights-of-way, preparation of land, laying of equipment, and maintenance of the physical channels.

Microwave Relay

In 1950 we saw an entirely new approach to communications come into its own, the microwave relay system. See

Each transmitting antenna in a ground microwave system faces the next receiver in the circuit. This is necessary to keep the signals from shooting straight out into space.



drawing. In essence, this system sends signals in the super high-frequency range between towers about thirty miles apart. As in a relay race, the signal is caught by each tower and sent off with renewed energy (amplified) until it reaches its destination. Thus you will often see tall towers soaring above fields, or perched on buildings or mountainsides. But instead of wires connecting them, there will be antennas of varying sizes and shapes mounted on the towers. These are catching broad-band signals and retransmitting them with renewed vigor to the next tower.

As you can see from the chart on page 43, microwaves are even shorter than the waves used for television. As such, they exhibit more of the characteristics of light; they travel in a straighter line and they can even be focused. The horn- and parabolic-shaped antennas used in microwave transmission are actually the equivalent of the reflectors on a large searchlight. And so a substantial amount of the power that is normally wasted in broadcasting is saved.

But there is an additional and very significant advantage to the use of microwaves. As we have seen, the shorter the wave the higher its frequency. Hence microwaves are inherently broad-band, which means they are capable of carrying a considerable amount of information. Microwaves are generally considered to be those waves with frequencies lying between 1,000 and 300,000 MHz. In contrast, standard (AM) Radio broadcasting lies in the .55 to 1.6 MHz range.

Coaxial cables and microwave beams perform identical functions except that the latter eliminate the need for a physical link between stations. (Within the station, the signals are handled by wave guides.) Microwave systems do not require rights-of-way, poles, or cables. Therefore they are not exposed

to being plowed up or otherwise damaged, as are cables and wires. Transmission by microwave is generally immune to such atmospheric problems as static and lightning.

However, fading does occur now and then due to unpredictable peculiarities in the atmosphere. For important events like a national TV hookup, the signal is then routed through standby circuits. After all, a nationwide one-minute commercial during one of the professional football games costs about $70,000. The carrier wouldn't like to lose it.

At this time microwave relay carries about 60 per cent of all long-distance telephone traffic and about 90 per cent of all television transmission. There is also some private use by "right-of-way" carriers such as railroads, utilities, and pipelines.

Although the first transcontinental microwave relay system was not completed until 1951, microwave services, as with all users of the electromagnetic spectrum, are already congested. In approaches to major metropolitan centers such as New York and Los Angeles, access often requires several extra hops or "dog legs."

The problem is reaching near-critical proportions. There is even the threat that our excellent system of communications will someday break down, just as any vehicle will if heavily overloaded.

In the next chapter we examine communications satellites, a partial answer to the problem.

Microwave radio-relay tower.

5

Satellite Communications

THERE WERE about a million overseas telephone calls in 1950. By 1960 the figure had jumped to nearly four million. And six years later the number was up to ten million. Data communications are increasing even faster.

Already gigantic by any measure, the overall telecommunications industry is expected to increase more than 500 per cent by the year 2000. One approach to handling this explosion is to build more and ever more cables. But we have seen that cables are expensive, both to build and maintain. Microwave systems are cheaper and are widely used. The problem here is that for long-distance communications many towers are needed.

For land communications these can be built (assuming the frequency-crowding problem can be licked). But overocean transmission presents a problem of quite a different magnitude. Assuming a tower could be built in the middle of the Atlantic

Ocean, it would have to be 475 miles high for its top to be "seen" from both sides of the ocean. The Empire State Building is about a quarter of a mile high.

Of course, we could station some ninety ships across the ocean as a kind of bucket brigade. But this seems rather impractical. And the results during a rough sea would undoubtedly leave something to be desired. Fortunately, as so often happens in science and technology, what transpired in one field had a great impact on another. For the development of satellites over the last decade provided a perfect "hook" on which to hang antennas.

While realization is recent, the idea is not. As far back as 1945 the distinguished author and scientist Arthur C. Clarke suggested the use of satellites, spaced equally around the equator, as "extraterrestrial relays." The satellites would be some 22,000 miles high. At this altitude, he pointed out, a satellite takes just twenty-four hours to complete an orbit. It thus speeds along in space at exactly the same rate as the surface of the earth that is turning under it. In other words, it remains over the same spot on earth. The result is called a "synchronous" or "stationary" satellite and we are supplied with an invisible relay station 22,000 miles up in space.

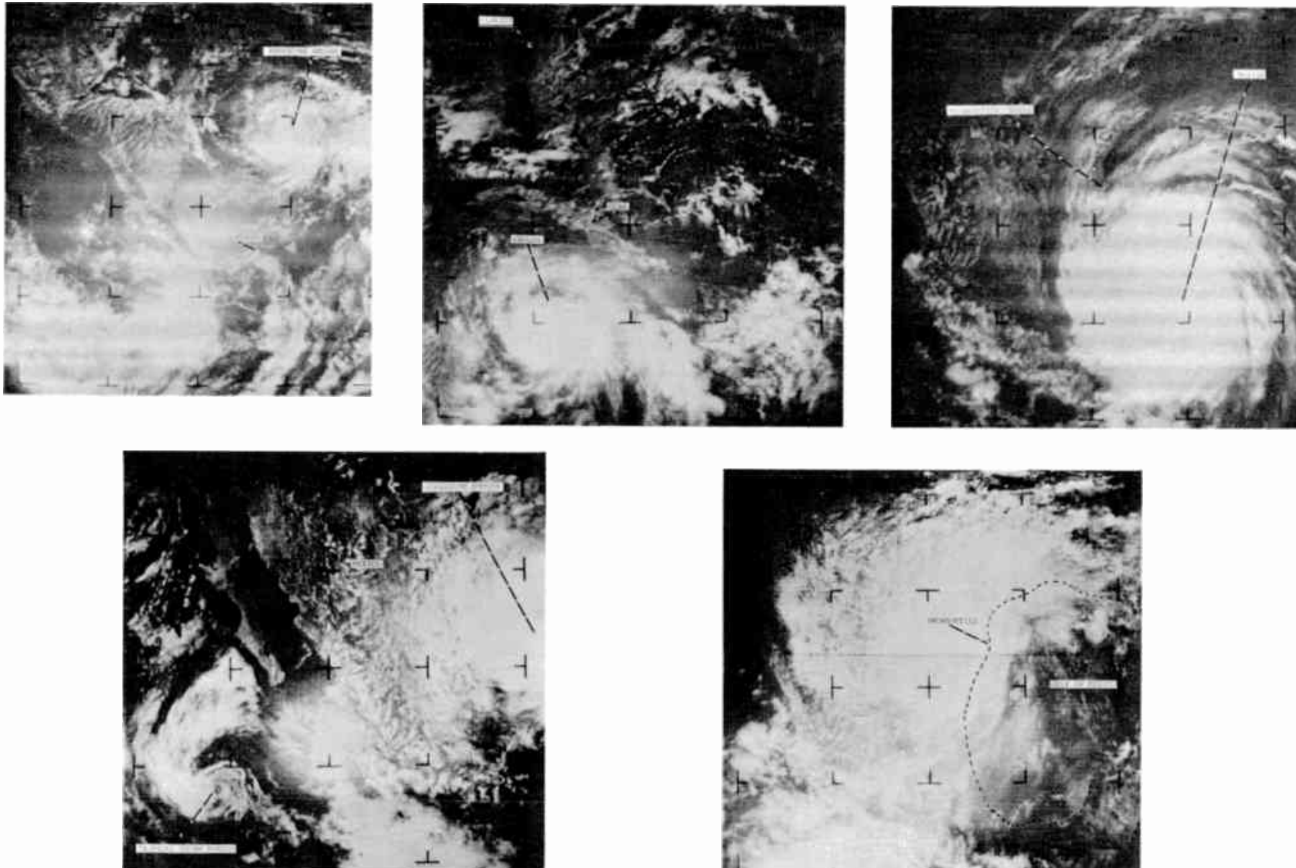
Another advantage of this great height is that each satellite can "see" a large portion of the earth, and so is theoretically capable of relaying simultaneous messages between all points in a large field of view. This field of view is so large—about 40 per cent of the entire earth—that only three satellites are required to span the entire earth. (More may actually be required to handle high traffic volumes.)

Although Clarke's proposal seemed highly visionary at the time, events were soon to catch up and even surpass the original idea. Clarke himself never thought that it would take only twenty-five years for satellite communications to come to pass. After all, the now familiar transistors were still three years away; they weren't announced until 1948. And without them any kind of practical system was out of the question.

Remember too that the first successful satellite, Sputnik I, was not launched until 1957, or twelve years later. Interestingly, advances in radio technology were absolutely basic to the development of rocket and space technology. The functions of tracking, telemetry, command, and control—which are so important in the locating and directing of space vehicles, plus experiments contained therein—all depend almost entirely on the use of radio.

Now, of course, space technology has returned the favor. Thanks to satellites, the world has already shared live TV broadcasts of public debates between leaders (and students) of countries on both sides of the Atlantic, the Olympic Games in Japan and Mexico, the dramatic recovery of spacecraft and astronauts from the ocean, and many other events. Medical students in Switzerland have observed open-heart surgery performed in Texas. And an international exchange of photographs and data on wanted criminals resulted in the apprehension of one of them a few days later.

Also weather satellites, introducing automatic global and local-weather surveillance, have been a great help to airlines and farmers. The "World Weather Watch" and "National Disaster Warning" similarly depend on satellites and therefore are, similarly, telecommunication concepts.



Satellite weather-watching pinpoints storm centers.

Comsat

We won't go into any detail here regarding the historical development of COMmunications SATellites (comsats). Suffice it to say that satellite communications made so swift a transition from development to operational status that it has outdistanced even the most optimistic estimates of its growth. Accordingly, after a number of experimental satellites had proved the basic soundness of the idea, Congress passed the Communications Satellite Act of 1962, placing the operation and further development of comsats into private hands for development. The Communications Satellite Corporation (Comsat, with a capital C) was set up in February, 1963, for this purpose. Shortly thereafter, an international satellite communications system was established. The latter, now comprising more than sixty nations, is called the International Telecommunications Satellite Consortium (Intelsat). Comsat owns some 55 per cent of Intelsat and is the manager of the space or satellite segment of the overall organization.

Comsat's first satellite, the 85-pound Early Bird, went into commercial operation in June, 1965, with a capacity of 240 two-way voice channels. In January, 1967, Comsat successfully positioned a second "bird" over the Pacific, adding another 240 circuits in that area.

The second step was the placement of three Intelsat 2 satellites, one over the Atlantic and two over the Pacific. (Early Bird was the equivalent of Intelsat 1.) All of these are performing commercial service as well as functions for the National Aeronautics and Space Administration (NASA), and particularly for the Apollo program.

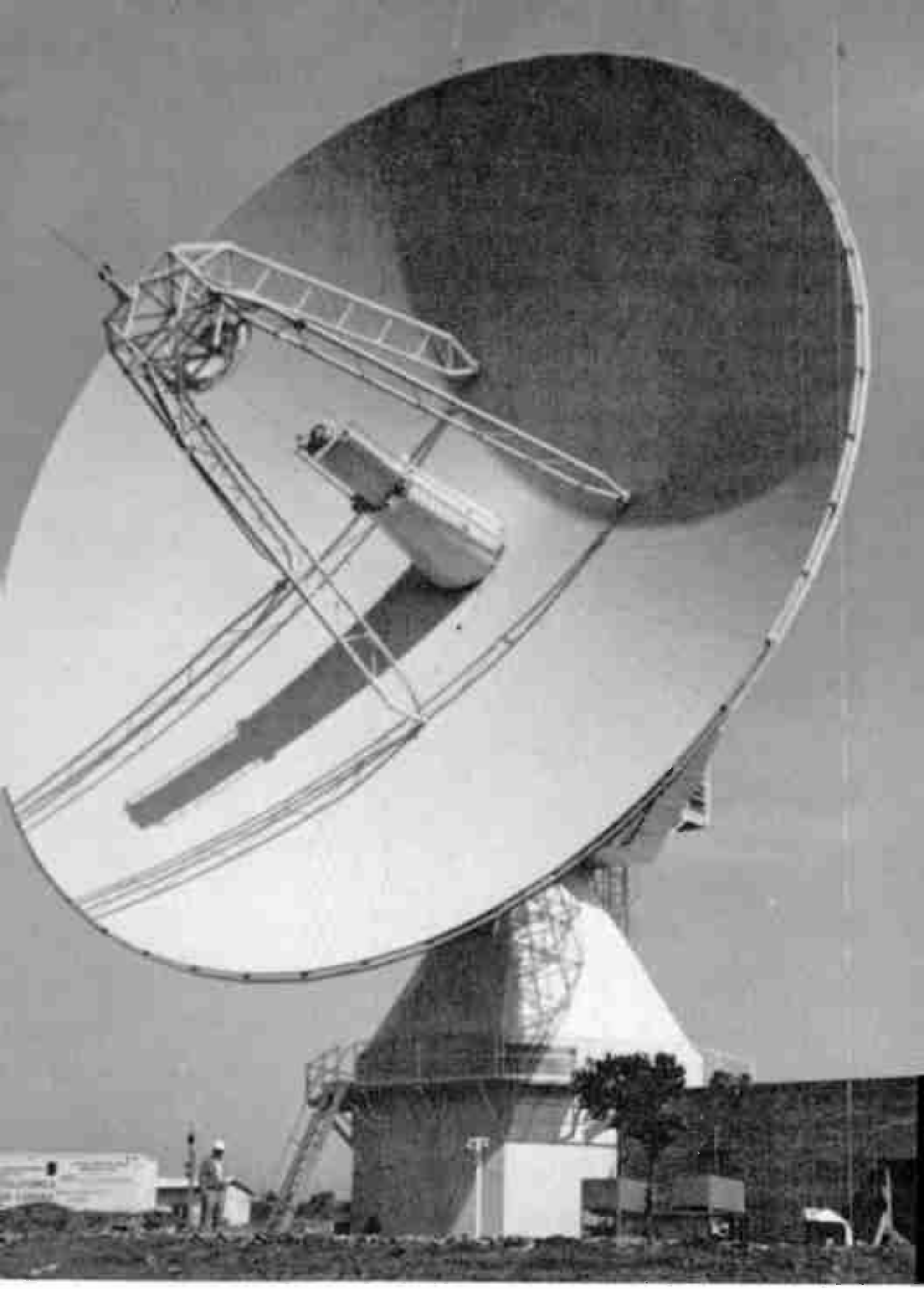
But as has happened so many times in the past, introduction of a new communications service has been followed by much faster than expected growth in demand. So we find the focus shifting to development of high-capacity satellites for ever increasing international communications as well as domestic television distribution. Key elements of a recent system are three Intelsat III birds, one each over the Atlantic, Pacific, and Indian Oceans. These each have a capacity of about 1,200 circuits, or more than double the 500-circuit total of the four cables now in transatlantic service.

Underdeveloped Nations

Utilization of the Intelsat III system is being paced by the completion of ground terminals to feed into the system. Spaced in various countries throughout the world, these are equipped with 85-foot, or larger, antennas. With a relatively simple investment like this, plus membership in Intelsat, a country is suddenly a part of the first truly global communications system. Thus comsats are having an even greater impact on underdeveloped nations than on the more advanced ones.

Consider, for example, the plight of Abidjan, capital of the Ivory Coast. This city is only 500 miles up the coast from Lagos, Nigeria. Yet, because there are no direct connections between them, a call between the two cities may have to be routed through both London and Paris, some 3,500 miles to the north. The newly developing nations find this kind of thing both expensive and demeaning.

The Latin American countries too will benefit greatly from satellite communications. The need for improved communications is emphasized by such staggering facts as a survey show-



85-foot-diameter antenna at ground terminal in Buitrago, Spain was designed and built by ITT to serve as communications center for intercontinental message traffic.

ing that Brazil has a backlog of half a million orders for telephones. One woman received her telephone just recently—after waiting twenty years! There simply are not enough circuits available to fill the demand. Businessmen in Rio de Janeiro often find that it is easier to make the one-hour plane trip to Sao Paulo than to attempt to place a telephone call to a client. Argentina's position is similar; a six-year wait for telephone service is not unusual. Here, too, the problem is not so much in the telephones themselves as in the lack of connecting services. In South and Central America alone, comsat ground stations are either in construction or in prospect for operation within the next year or so in Argentina, Brazil, Chile, Colombia, Ecuador, Mexico, Panama, Peru, and Venezuela. Aside from the stimulus to economic progress that is promised, most of these operations are expected to show a healthy profit in two or three years of service.

Another area of major importance lies in distribution of television. In an underdeveloped country like India, a satellite over the Indian subcontinent could relay information to TV receivers in village marketplaces and schools. These would be especially valuable for emergency instruction in times of epidemic or other national catastrophe. The system could also convey daily information on monsoon rains and tropical storms and would be of great value to agriculture by providing instruction in modern farming methods. In really isolated rural areas it could even teach reading and writing.

Plans for domestic television systems, both for mass education and entertainment, are already being made in India, Indonesia, and Brazil. These systems would generally require one satellite, one major transmitting station, and a large number of low-cost receive-only stations. (The question of whether all commercial satellite communications will eventually be operated through a few giant-capacity comsats, or many special-purpose smaller ones, has not yet been decided.)

Characteristics of Comsats

Although each satellite is theoretically capable of relaying simultaneous messages between all pairs of points in its field of view, we have by no means reached that point as yet. Thus far, virtually all the communication that takes place is between large transmitting and receiving antennas on the ground (see photo on page 68), which act as switching points for TV signals and local calls. For example, in one early demonstration of the linkup between telephone and satellite, a call from Goddard Space Flight Center in Maryland to NASA headquarters in nearby Washington, D.C., had to take the following route: 1) telephone land line from Goddard to a radio-transmitting station nearby, 2) radio signal from the ground transmitting station to the satellite, 3) radio signal from the satellite to a radio receiver at a ground communications station in Lakehurst, New Jersey, and finally, 4) telephone land line from the Lakehurst station to NASA headquarters.

In other words, even when telephone conversations go by way of satellite, a fair percentage of the cost is still that of switching and use of local land lines. For this reason, use of comsats will not bring the price down appreciably, at least not at first. However, in all other methods of transmission, distance is a major factor; not so in satellite communications. We may one day see the advent of a flat fee for all long-distance calls.

In contrast to the complications inherent in telephone communications via satellite, television transmission fits in perfectly. TV involves one-way transmission of large blocks of information between a relatively small number of points (stations); hence, relatively little switching is involved.

Furthermore, because synchronous or "stationary" satellites (there are other kinds) are so far away from earth, there is a short but discernable delay due to the time it takes for the signal to travel the minimum of 44,000 miles from ground station to ground station (22,000 miles up and an equal distance down again). In a two-way conversation it takes a full six-tenths of a second before an answer can arrive to your question. Although this has not turned out to be as bad a problem as was feared at first, when it occurs between fast talkers it can be disconcerting. Since television transmission is one-way, the time delay is no problem.

Direct Usage

Still more powerful satellites (Intelsat 4's), with capacities of some 5,000 circuits each, are already in the works. With these we will begin moving into what might be called Phase 2 of satellite communictions.

In Phase 1, satellites are in contact with large transmitting and receiving stations which are used as switching centers for more local users, as in the Goddard telephone example. In Phase 2 we move into direct-usage applications. Here we refer to situations in which the information is received at or transmitted from the *using* location directly. Examples would be plane-to-plane or ship-to-shore communications, direct broadcast of radio or television to the home (each home would have a microwave antenna pointed skyward), or perhaps instant "airmail" delivery from home to home.

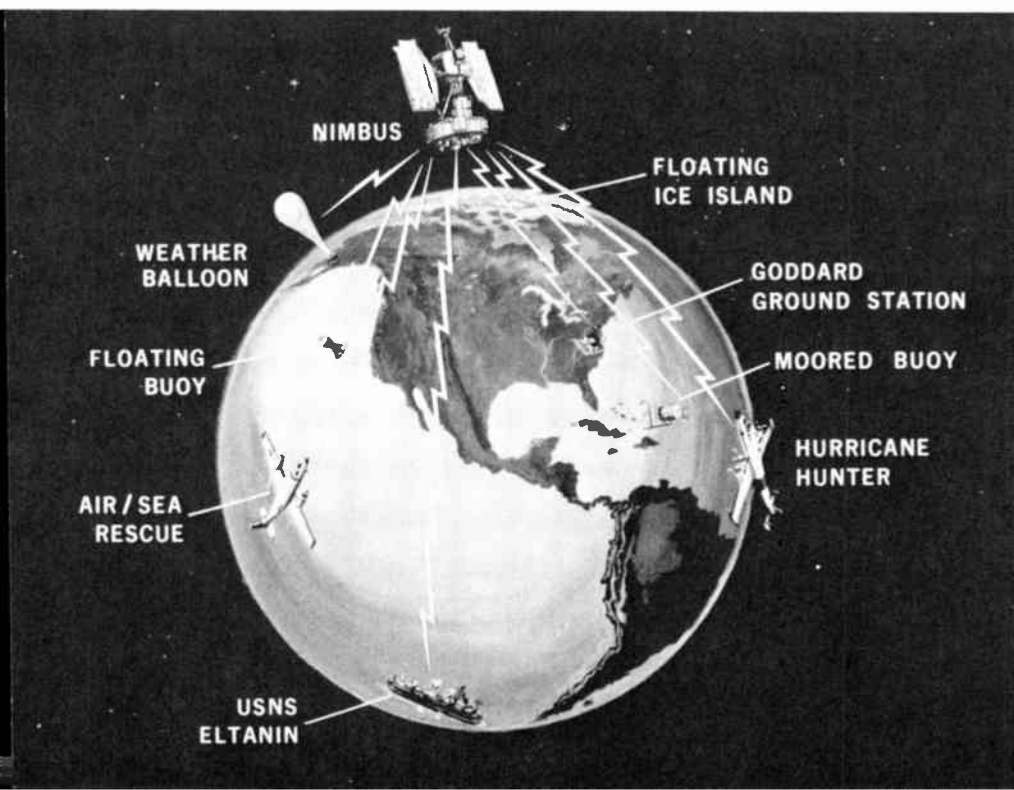
Any and all of this is quite possible. Indeed, plans for aeronautical and naval services have already been proposed by Comsat and are under study by national and international groups. Overocean aircraft communications, relying on densely used high-frequency channels, has been called the weakest link in transoceanic aviation. Over land, ground radars do the job of keeping track of commercial aircraft. On transoceanic flights, however, about 55 per cent of all communications have to do with the question, "Where is the airplane?"

At the moment a pilot can reach a ground station on a very high-frequency radio band (uhf) only within line of sight, which means a maximum of about 300 miles. Farther away he must switch to hf. While this band will "reach" farther, it is much more subject to atmospheric disturbances. Such disturbances can often disrupt communications to the point where pilot and traffic controller may have to hunt through several frequencies before contact can be made, if at all. It can sometimes take a hour to establish contact. The Supersonic Transport (SST) can cross half an ocean in that time, clearly a dangerous situation.

Satellites will change all this. The pilot will be able to use vhf to relay voice and data to faraway ground stations. Indeed, reliable communications will be possible over distances as great as 7,000 miles. With the increasingly longer ranges of aircraft and wider use of polar routes (which are often shorter than standard routes, in long-distance flight), such capabilities will become a necessity. Additional functions that can easily be phased into the system are tracking of the aircraft from the ground and navigation within the aircraft itself.

In spite of its obvious advantages, the airlines want to be sure that satellite communications are economically as well as technically advantageous. This is why they chose the familiar vhf band rather than the microwave band; vhf offers the advantages of low-cost ground stations and minimum modification of existing airline equipment. They will have to change from AM to FM, however, and higher power transmitters will

Artist's rendering of projected weather satellite (Nimbus), a 1,260-pound butterfly-shaped weather eye, and the activities it will track.



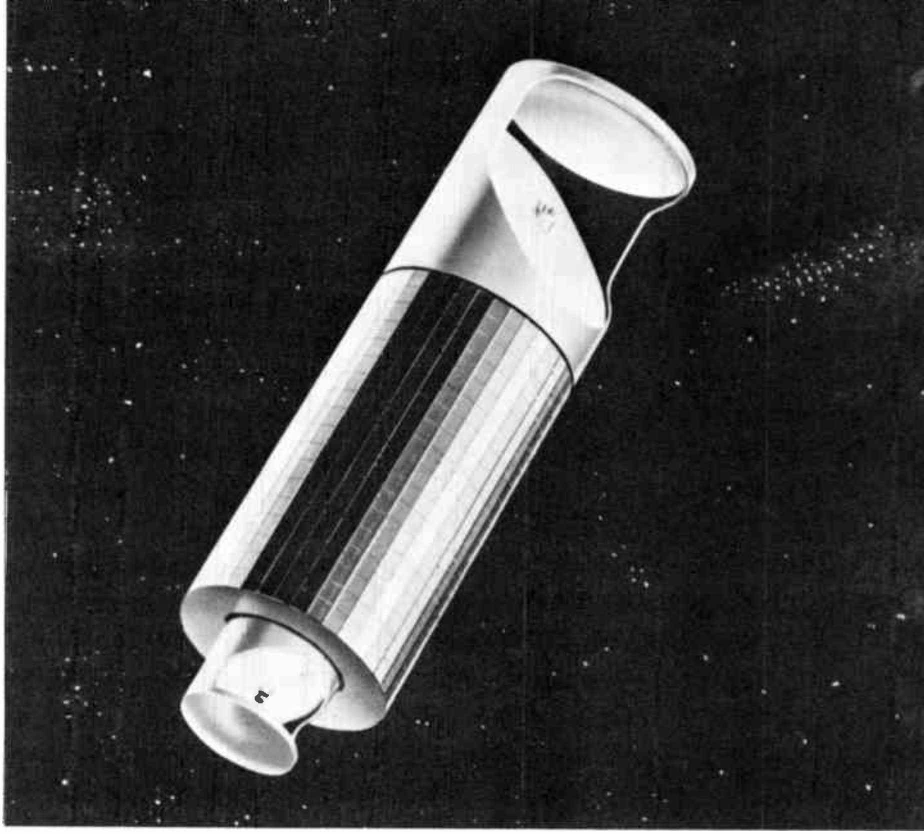
be required. The experience they gain will undoubtedly be put to use later on in consumer use.

The feasibility of using satellites for this purpose has already been partially demonstrated using NASA's Applications Technology Satellite series (ATS). In other areas plans for various kinds of information retrieval are being considered, primarily in connection with world weather watches. As shown on page 73, the satellites would be used to collect data from and, in some cases, transmit to the surveillance equipment (balloons, buoys, underwater stations). The collected data would be relayed automatically from the satellite to processing centers. This would provide the additional data that is required for really accurate weather reporting and forecasting.

It has also been seriously proposed that comsats be used for such scientific and conservation purposes as monitoring the migration of animals which are hard to follow around. In one experiment polar bears were "shot" with a harmless drug that put them to sleep for a short time, and a small radio transmitter was attached to their backs. By this means their movements could be recorded by comsats and thus monitored by interested scientists.

Experimentation with international computer-to-computer communication is in an advanced state. Plans are being devised for service first between Europe and North America and eventually on a global scale. The service would require 48-circuit channels to handle the massive flow of data.

Direct access naturally puts great demands on the satellites' capability, but ever improving microelectronic facilities make possible capacities and techniques we couldn't have dreamed of a few years ago. For example, A T & T has proposed a high-capacity domestic comsat system which is intended to supply



The A T & T design proposal for a satellite utilizing pulse code modulation and frequency modulation techniques.

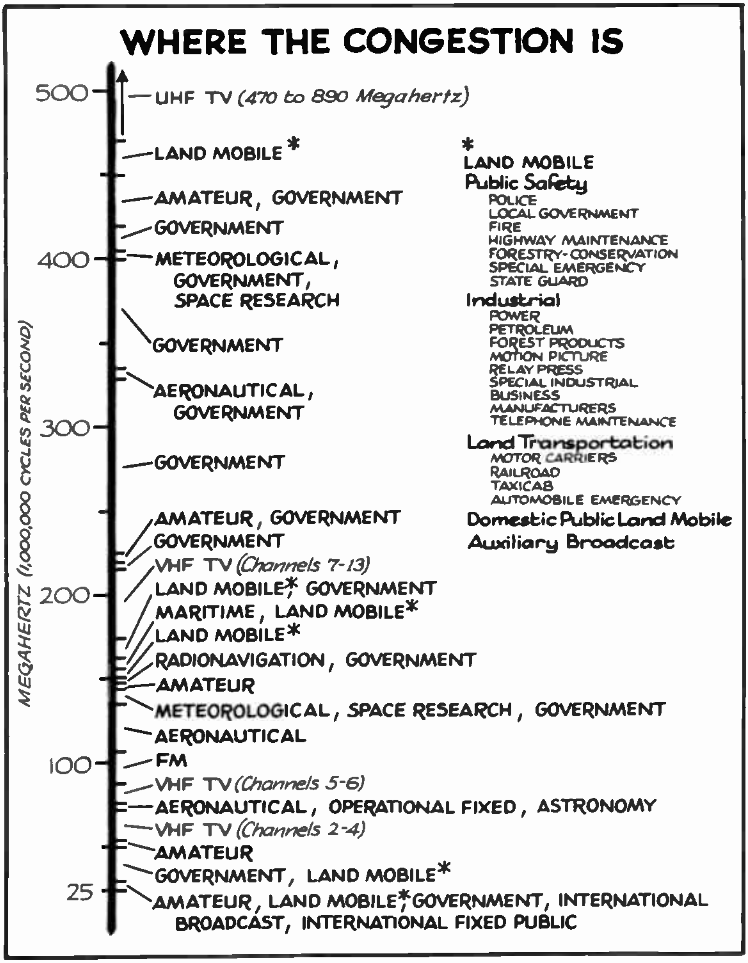
our needs through 1980. Each of the advanced-design satellites (see drawing) would be capable of simultaneously providing twelve TV channels and over thirty thousand voice circuits.

A big problem is reliability. It's going to take a while yet before we can send men up into space to repair orbiting comsats. But with integrated circuits we can build reliability into the satellite. Since the circuits are so small, any important electronic component that might fail has a duplicate on board which can automatically be switched in to take over the function of the failed one. This is already being planned for Intelsat 4, which would give it a long life, obviously an important factor in an expensive and complex operation like this. The idea of spare circuits, as explained earlier for the coaxial cable, is also used.

Further, the fact that the signals must travel great distances to and from the satellites, each direction being roughly equivalent to a trip around the world, means that they are relatively weak when they arrive at the receiver. To keep them from getting lost in noise FM is generally used because it provides a higher signal-to-noise ratio than AM. However, FM frequency division requires a wider band width, and band width is exactly what we are short of.

The great distances over which satellites are useful pose the additional problems of interference with ground services. Most technically usable regions of the electromagnetic spectrum had been allocated to short-range ground services prior to the advent of satellites. In 1963 some bands were reallocated for satellite and space applications (see chart). It is clear, however, that the possibilities for satellite applications vastly exceed the allocated frequency bands.

Comsat hopes that direct access (Phase 2) by frequency division will satisfy most of its needs for at least several years. As mentioned, however, frequency division is not the most efficient method with respect to frequency conservation. And it is probably not the best way to provide multiple access among large numbers of small, inexpensive stations like aircraft, ships, weather stations, and homes. A T & T's proposed satellite system utilizes a number of advances in communications technology. One of them takes advantage of the fact that high frequencies make narrow beams possible. Hence, instead



The frequency spectrum is particularly crowded at levels below one thousand megahertz.

A projected use of advanced-design satellites for wide-area TV coverage; three satellites orbited earlier continue to provide TV service.

of (or in addition to) blanketing a large area with a wideband signal, from which users must pick out their messages, the satellites would utilize narrow point-to-point beams (see drawing). One writer applied the descriptive term "narrowcasting" to the technique.

Closely allied is a method of coding the information being transmitted. The next chapter is given over to this method, which is called pulse code modulation, and to other attempts to cope with the communications explosion.

6

Stuffing the Pipe

LET US say a friend asks, "Are you going to the basketball game tonight?" Suppose that you speak the words, "The answer to that question is . . ." and stop there. You will have given six words but no information whatever. On the other hand you might have said simply "Yes" or "No." In this case the one word was far more useful than the other six. The wanted information was easily transmitted by a single word. So one way to save time and carrier space is to send only the needed information.

Another way is by coding the information to be sent or presented. The most famous example of this approach is probably Paul Revere's use of "One if by land, two if by sea." Use of this prearranged signal (either one or two torches in the Old North Church tower) made it unnecessary for a messenger to come to him in order to recommunicate the entire message, namely, that the British were on their way toward Salem, Massachusetts, and that they were going by sea (two torches).

In other words, a code is simply a prearranged way of sending information. It need not always be used for purposes of secrecy. Sometimes, as in the case of Paul Revere, it is simply the fastest and most expeditious way of sending information.

Let us look at another example of coding. Suppose you and your friend lived on opposite sides of a valley and had no telephone. And suppose that the two of you were too far apart to hear each other directly and that you had to get the "yes" or "no" answer to your friend under these circumstances: without actually walking or riding over there. You could paint a giant "YES" or "NO" on a card which he might read with a telescope. Or, more simply, you and he could decide in advance that if your room light is on at a certain time, it means "Yes"; if the light is off, "no."

Digital Communications

Anything which can exist in two states—a toggle switch (up or down) or a light bulb (on or off)—is said to be *binary* in nature. It turns out that the simplest type of components that can be used in message transmission are of the binary type. Examples are relays and transistors, each of which can be either on or off. Each of these states can be taken to mean yes or no, or, more likely, 1 or 0 (we shall see why in a moment).

In binary notation each symbol represents a simple choice between two possible choices, and this has many advantages for expressing or transmitting information. (It is also why a true-false test is so easy to mark!) One of the advantages is reliability or accuracy of transmission. For example, Paul Revere could have told his informant to use one torch, putting it up to full bright if the British were coming by land, and half bright if by sea. But this arrangement could have been misinterpreted. Some torches are brighter than others, or perhaps some haze in the air would make it difficult to decide whether the torch was at half or full bright. By deciding to use a varying number, one or two, the clever Americans were working with numerical or *digital* information, which is less likely to be confused than a degree of brightness.

Why, then, you may ask, did Paul Revere and his fellow conspirators (there were two other riders) not use a single torch or the absence of one as the signal? The answer is that the man in the tower had to provide more information than the simple difference between two states (land versus sea). He also had to provide information on *when* the movement began. Hence the simple on/off code would not have been sufficient, for the riders would have had no way to distinguish between *no* signal and an *off* signal. And so they used the next simplest set: one or two.

You have all seen the punched cards or tapes used in computers. Each punched hole represents one digit of information. Each is therefore a binary digit, or "bit." In a 1952 article in the magazine *Scientific American*, Gilbert W. King wrote, "It is almost certain that 'bit' will become common parlance in the field of information, as 'horsepower' is in the motor field."

This is a remarkable statement for two reasons: first, because he was so right, and second, because it is so few years ago that he still had to hedge a little by saying, "almost certain." This gives us some indication of how quickly things have moved.

Telegraphy is undoubtedly the best known example of the use of bits in communications (sometimes referred to as *digital communications*), although of course it was not recognized as such at first. The telegraph sends out a series of dots and dashes, with each dash three times as long as a dot. By creating a special code, the American artist and inventor Samuel F. B. Morse made it possible to transmit any combination of letters and numbers by wire—the famous Morse code.

Least Effort

But Mr. Morse did more than invent a practical and working telegraph. In setting up the still widely used Morse code, he took into consideration a principle that is so obvious we never notice it. For instance, there is a remarkably steady correlation between the commonness or frequency of a word and its length. The words (or phrases) we use most often are the shortest and easiest to pronounce. Examples are *the*, *or*, *a*, *go*, *eat*, *run*, *old*; *mom* for mother and *dad* or *pop* for father. This is the major reason for nicknames and abbreviations.

If we put words into a list, with those most often used at the top and those least often used at the bottom (and this has been done), the regularity shows up quite astoundingly. It has even been given the name Zipf's Law, for the man who showed the effect quite clearly.

A recent and most interesting example is that of the term deoxyribonucleic acid. Probably few of you will recognize this, although it is a term that has been around for years. However, it had been used by relatively few specialists until the compound was found to be of great significance in the process whereby parents pass on various characteristics to their children. As the term came to be used more widely and often, even the scientists began to use the easier to pronounce, and now quite familiar, DNA.

We could ascribe this kind of thing to the fundamental laziness of man. A more dignified description was given by Zipf, who called it the Principle of Least Effort. This principle has produced some strange results. A common method of shortening long phrases, titles, and terms is to form the acronym—using only the first one or two letters or syllables in each word. Perhaps the best known acronym is radar, which stands for *ra*dio *d*etection *a*nd *r*anging.

When carried further, the process of forming acronyms can lead to such things as PACAFBASECOM, for Pacific Air Force Base Command. While formidable, this combination can still be pronounced. An even wilder concoction has been made for "special ordnance depot tool identification, classification, inventory, and obsolescence analysis program." Granted that's a mouthful; but just try to say SODTICIOAP!

(It has been pointed out that the Principle of Least Effort, if carried to its ultimate, would result in all speech being reduced to a steady hum. The only problem is that no one would be communicating any more.)

Now, to what use did Morse put the principle? He considered the fact that, as with words, some of the letters of our alphabet are used more often than others. E, A, and T, for example, are far more common than X, Q, and Z. In making up his code, Morse gave the shorter, simpler combinations to the most often used letters. E, for instance, consists of only a single dot, while Z is dash-dash-dot-dot. (There are some differences between Morse's original code and the one widely used now, but these needn't concern us here.) And because it is used relatively rarely, a simple period turns out to be dot-dash-dot-dash-dot-dash!

The way that Morse determined the relative frequency of occurrence of all the letters and punctuation marks is worth mentioning. It would have taken considerable study to figure this out for himself. He simply went into a printer's shop and obtained a count of how many A's, B's, C's, etc., the printer kept in stock. For at the time (about 1840) the letters were set by hand and were stocked in a "type case." Over the years printers had learned how many of each letter to stock.

The result was that Morse was able, by intelligent design of his code, to stuff more words into the wire per unit time than if he had simply parceled out the code in alphabetical order. Many writers date the beginnings of communications or information theory from this time.

Telegraphy

Of course we have come a long way since then. A significant advance was the invention of the telephone in the 1870's. Many thought this would lead to the disappearance of the telegraph. But telegraphy has the unique advantage of providing a permanent record of the intelligence transmitted; for many kinds of communication this is essential. Hence telegraphy has remained an important part of our communications system.

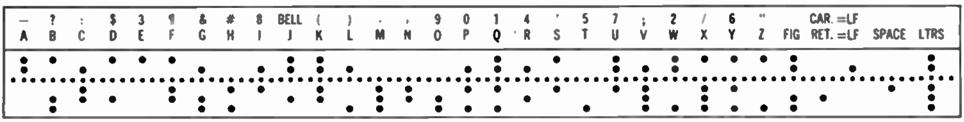
In 1920 telegraphy provided another step along the road to today's high-speed data-transmission techniques. This came about with the introduction of teletypewriters and teleprinters. Telegraph operators no longer needed to be highly skilled and "click-sensitive." The only skill necessary was typing; the machine did the rest. That is, the operator needed only to depress the proper keys on the teletypewriter; the machine then delivered the proper set of impulses. At the other end the teleprinter performed the reverse operation accurately and automatically. In addition, message speeds could be increased from the normal rate of forty to fifty words per minute to a constant speed of sixty words per minute, and later to even higher speeds.

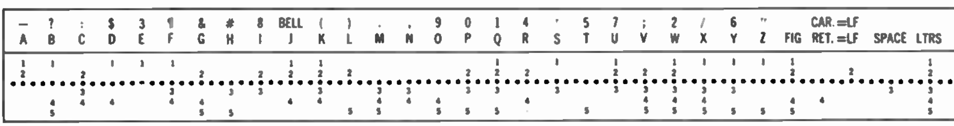
With machine operation, however, a different kind of code came into being, one with the same number of bits in each character. This provided uniformity, a useful characteristic for machine operation. A five-element code has been the most commonly used code in modern printing telegraphy, and is still universally employed for teletypewriter operation.

In the five-element code each character consists of a combination of five signal elements; and each element consists of either of two basic signaling conditions. These are the mark or pulse, and space, and are equivalent to the bits (on/off) we mentioned earlier. The total number of possible combinations is therefore 32 (two possible states and five elements = 2^5 or 32).

But 32 possible combinations cannot handle the entire alphabet plus the 10 numerals, since 26 are required for the letters alone. However, use of a two-shift teletypewriter permitted two of the signals to be used for shifting the carriage as on a regular typewriter. The use of this plan enables 30 of the available 32 combinations to have two meanings.

For more complex transmissions (foreign language, mathematics, special business or science terms), it is necessary that a wider "world" of symbols be available. This is accomplished by increasing the number of bits in each character. A six-





The positions of the holes in the punched or perforated tape represent digits, letters, and punctuation.

element code provides a choice of 64 symbols; seven elements give 128. Each has been used. Samples of five- and seven-element tapes are shown.

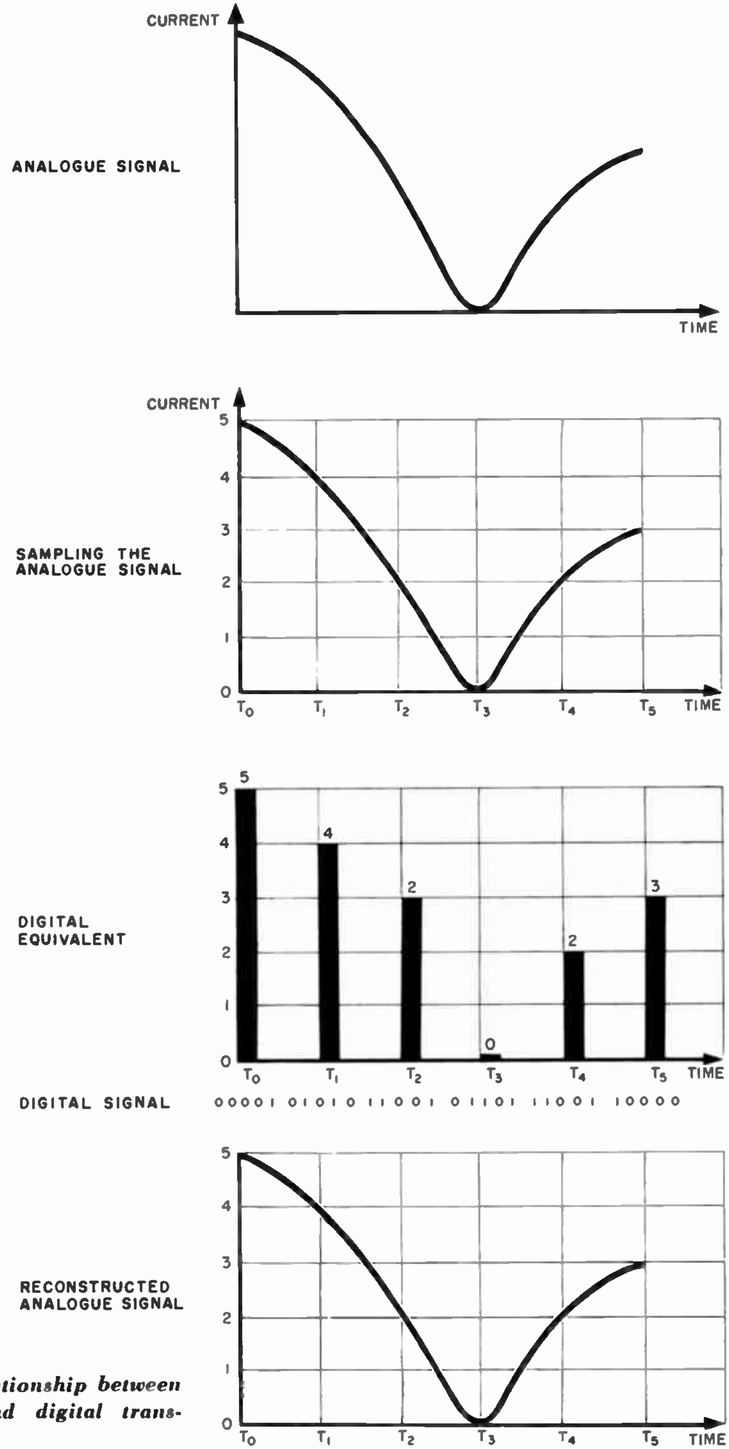
For a long time it seemed that there was some inherent and unbridgeable gap between the kinds of signals used in telegraphy and telephony. Telegraphic signals are, as we have mentioned, digital or numerical in nature. Speech signals, on the other hand, are ordinarily represented by a wave form—a continuously varying wave shape. The height or amplitude of the wave at any point represents the strength or voltage of the signal at that time. This type of information is called *analogue*, as opposed to digital. The wave shape has a physical connection with, or is analogous to the speech signal. That is, there is some physical correlation between them. A temperature measurement, for instance, is an analogue measurement. The higher the mercury, the higher the temperature. The numbers are incidental. And indeed many thermometers do not use our Fahrenheit scale, but are marked with the centigrade scale, which is quite different.

Another important aspect of an analogue signal is that it varies continuously—the height of the mercury does not jump from 98.6° to 98.7° but moves continuously from one to the other. In a so-called digital readout, and on certain clocks, you would see only one number or the other.

In other words, the telegraph is an example of digital transmission and the telephone of analogue transmission. But the distinction between the two types of signals began to dim as telegraph signals were multiplexed, or sent several at a time, over telephone lines. And recently it has been shown that telephone signals, *i.e.* speech, can be transmitted directly by on-off impulses, using a method known as *Pulse Code Modulation* or PCM.

Pulse Code Modulation

In this technique the varying strength (amplitude) of the telephone (or television) signal is sampled at frequent intervals and is translated into numerical values (see diagram). These are then converted into binary digits for transmission;



The interrelationship between analogue and digital transmission.

the number 5, for instance, might be sent as 00001 in a five-bit code. At the other end, the receiving apparatus reverses the process.

In other words, the speech signal is sent as a sequence of numbers, each of which tells what the pressure of the sound against a microphone is at a moment of time. When "looked" at in sequence we have an almost complete record of the original. It's a little like plotting a graph and then connecting the points to make a continuous record. (In TV transmission the numbers represent shades of gray. High-quality television transmission requires a seven-bit code; a five-bit code would not provide enough shades of gray.)

Although man can "read" both analogue and digital information, his nervous system does not distinguish between them. Nor does it distinguish between the signals our senses send to the brain and the signals returned to the muscles which control our movements. All these signals travel through the nervous system as spikelike pulses—digital information—which when necessary are converted *from* analogue-type information such as pictures, speech, or music *to* nondigital forms such as smooth muscular movements.

In spite of the rapid growth of computer networks, the great bulk of communications traffic still consists of speech and television pictures, both of which originate as analogue signals. Nevertheless, some people feel that the communications system of the future should transmit digital signals exclusively. PCM (which is one form of digital coding but not the only one) is already being used for interoffice telephone trunk lines and is being adopted quite widely by military networks for transmission of speech.

The Bell Telephone Laboratories began development of a commercial PCM system in the late 1950's, and the first such system, designated T-1, went into operation in 1962. Currently, over 400,000 channels have been installed in the United States. The T-1 system can transmit the output of twenty-four telephone voice channels over a single pair of conductors in a coaxial cable. It was designed primarily for application in metropolitan areas.

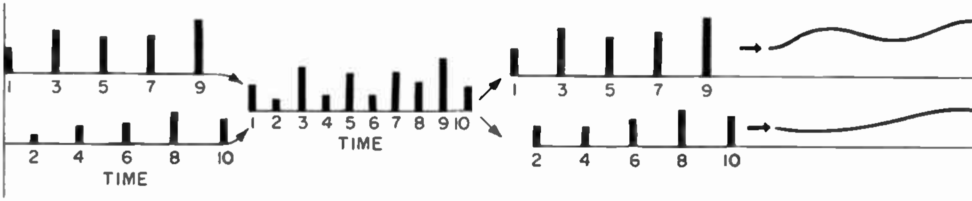
A T-2 system, also designed for use in urban areas, is scheduled for operation in the early 1970's. This equipment is expected to have a capacity more than four times that of T-1, or 6.3 million bits per second.

An experimental PCM system has been developed by Bell Labs that groups thirty-six T-1 line signals, one television signal, and six hundred frequency-multiplexed voice channels, all of which can be transmitted simultaneously on a 224-million-bit-per-second line. It is expected that experiments like this, plus rising demand, will lead to yet a third level of commercial use by 1975. The T-4 PCM is being designed for long-haul toll use. It will have a bit rate of over 280 million bits per second and will provide some four thousand telephone voice channels.

Advantages of PCM

One advantage to using PCM is that digital and analogue information can be sent with equal facility.

Another is that multiplexing becomes a relatively simple operation. As shown in the diagram, two or more signals are simply "interleaved," much as two suits of a new deck of cards would be if perfectly shuffled. At the receiving end it is an



Pulse Code Modulation is used to transmit signals.

easy matter to separate them and reconstitute the original signals.

A third reason for using PCM goes back to our discussion of Paul Revere. The difference between two states (on or off) is far easier to transmit and amplify than a signal that can have an infinite number of values, such as varying wave form, or even only ten different values, as for instance the tones in Bell's Touch-Tone system. Recall, for example, how easy it was for you to tell your friend across the valley that you could or could not go to the basketball game that night. All you had to do was put on or leave off your light. But sending any additional information would have been much more difficult.

Nevertheless, even in binary transmission, errors can occur. In ordinary language the loss or garbling of a few words here and there is not of major consequence. If a message comes to us saying, "Woll ve homx on Tuusdqy," we can still read it.

However, with increasing transmission of business data, of which we shall have more to say later, absolute accuracy becomes essential. Once again, special coding techniques have come to our aid. One possible source of trouble was the accidental loss, or insertion, of an extra bit. This would shift all the remaining bits to the left or right, in which case all the remaining information would be wrong. Development of so-called *synchronous codes* ensure that each character starts properly; hence only one character will be mixed up (as in "Woll"), rather than all those which follow.

Increasing use of and advances in microelectronics have made it possible to detect immediately the mix-up of even one single bit. This is done by transmitting an extra bit in each character. For example, in a seven-bit code the system may require that each set of seven bits (each character) have an even number of "one" or "mark" bits. Suppose the character in question is 0110010. As you can see, the number of ones is odd and so a one bit is automatically added at the end by the transmitting apparatus. The signal is sent as 01100101. The receiver equipment will scan the group, count the number of ones, and, assuming all is well, will discount the last bit. If, however, any one of the information bits has gotten mixed up —if the character were received, for example, as 0*0*100101— the number of ones would be odd and the equipment would signal a mistake in transmission.

But how about transmission of language? Does each letter of our language really require eight, seven, or even five bits for accurate transmission? After all, the probability of a *u* following a *q* is 1, or a certainty, just as the probability of an *x* following a *j* is zero. Taking such factors into account, Claude E. Shannon, an expert on telephone switching and a major figure in communications theory, showed that a letter of English text really contains only about 1 to 1.5 bits of information. Thus we see that our use of even the communications channels we have is still very wasteful.

In other words, with an efficient coding scheme we should be able to transmit English text using only one or two bits per letter. Even using the higher number we find that a 300-word page of text contains only 3,600 bits of information (figuring an average of six letters per word, or five letters and one space). Sending 300 words with present data-transmission techniques, however, requires about 12,600 bits, using a seven-bit code.

In line with our earlier statement that various kinds of information can be sent over the same channel, we find that the page of text can also be sent as if it were a picture. This is called facsimile transmission and is used, for example, by news services to send photos by radio or wire. The page or picture to be sent is put on a drum, which is rotated and scanned electronically. Transmitting a page in this manner requires about a million bits, regardless of the fact that most of the page consists of white space.

Another alternative is to read the text aloud and send the sound via a pulse-code-modulated channel; but this would require more than eleven million bits. For here we are sending not only the information, but the quite complicated sound of the human voice as well.

And, finally, we could televise the page of text for the time needed to read it aloud. Figuring that this would take about 2½ minutes, the transmission would require almost ten billion bits! An obvious way to reduce this, however, would be to transmit the page once, as in facsimile, and then send the few additional bits required to say, "Hold picture for 2½ minutes."

Considering the fact that a voice grade telephone line can effectively carry roughly ten thousand bits per second, we find that transmitting the picture by facsimile would take about a minute; however, one would require a facsimile reproduction machine to receive it. A fast teletypewriter, operating at a hundred words per minute, would require three minutes.

New Telecopier permits receipt of documents through an unattended telephone.

The television approach would be the most desirable since the information would be presented almost instantly. It should be noted, however, that the ordinary home receiver does not provide a high enough resolution (fine enough detail) for reading a page of text comfortably; higher resolution receivers would be required. A more important problem is that we cannot squeeze a television signal into a telephone line since the telephone's bit-carrying capacity is far less than that required even by standard TV.

Carrier Capacity

Let us look more carefully at the problem of line capacity. You have undoubtedly noticed a relationship between the bit-carrying capacity of a transmission method and the total time required to transmit the page of text in our example. Clearly the greater the capacity, the shorter the time needed to transmit.

Total Information = Bit Transmission Rate x Time.

Another way of writing this:

Total Information Capacity = Bandwidth x Time.

In other words, the transmission capability of a line is directly proportional to the effective bandwidth that the line can carry. A telephone line is designed to carry some 3,000 hertz. (The human voice actually contains about twice as much information as the telephone line can carry. But it has been found that cutting off the sound at about 3,000 hertz leaves enough of the voice signal intact for effective communication.) A TV signal, on the other hand, requires about 4,000,000 hertz.

Or does it? Is it possible to somehow cut down on the band-

White dots in this actual video-telephone picture shows areas of significant change during face-to-face communications in one-sixtieth of a second. Experimental technique transmits only these changes to update the previous picture. The new technique might allow transmission of three video-telephone calls over facilities that would otherwise carry only one.

width needed to transmit the signal? For example, the change from one TV picture to the next is normally small. It may be possible to transmit only the changes, rather than the whole picture at each scan (which is done at the rate of thirty times a second). One experiment along these lines is shown here.

In another experiment, bandwidth requirement was brought down from the normal 4,000,000 hertz to 160,000 hertz, with only a small degradation in quality. But this is still more than fifty times the capacity of a telephone line.

Millimeter and Optical Frequencies

So one approach is to cut down on the information to be carried. The other approach, of course, is to use carriers with high capacity, and this means higher frequency. Look at it this way. A large ocean liner can carry several thousand passengers per trip, while the Supersonic Transport (SST) can only carry a few hundred. Yet over the course of a year one SST can transport ten times more passengers than the liner. Clearly this is because it goes back and forth so much more quickly.

A similar situation obtains in the movement of information. High-frequency electromagnetic waves can carry more information than low-frequency waves because of their more rapid alternation.

We must be careful, however, to distinguish between the terms bandwidth and frequency. Returning to the passenger transport analogy, we might compare bandwidth to the size of the vehicle doing the transporting, while frequency is more like the number of trips made per year. For example, a bandwidth of 3,000 hertz centered around a 200,000,000-hertz carrier can carry twice as much information per unit time as a 1,500-hertz band at 200,000,000,000 hertz. But the latter region (also called the gigahertz or millimeter wave region) can carry a thousand times as many such bands as the million hertz or megahertz region. And this is the reason for the recent push toward millimeter waves, which as you can see from the chart on page 43 are of even higher frequency than microwaves.

But here we begin to enter a strange, intermediate land between radio and optical frequencies, a land where both radio antennas and optical lenses play a part. The technology of sources, detectors, antennas, and other components for millimeter waves are today where microwave technology was in World War II—right at the beginning. However, due to the importance of the problem, rapid strides are being made.

Moving up still higher on the electromagnetic scale, we reach the optical frequencies. Communications men have long eyed this region, for here we are up in the 10^{14} (100 trillion hertz or 100 terahertz) range. As the chart just referred to shows, the optical spectrum lies between the infrared and ultraviolet regions, and is quite small. Yet in that small visible portion there is about a million times more room for information transmission than there is in the entire range of frequencies we now use!

But light frequencies are produced quite differently than are radio waves; they depend upon emission by atoms rather than on the movement of electrons, which are more easily controlled. And, for a long time, there seemed no way to control this emission. However, the advent of the laser has changed all that, and a great deal of work is going on in an attempt

Light modulator for gas lasers is being marketed for industrial research and student experiments.

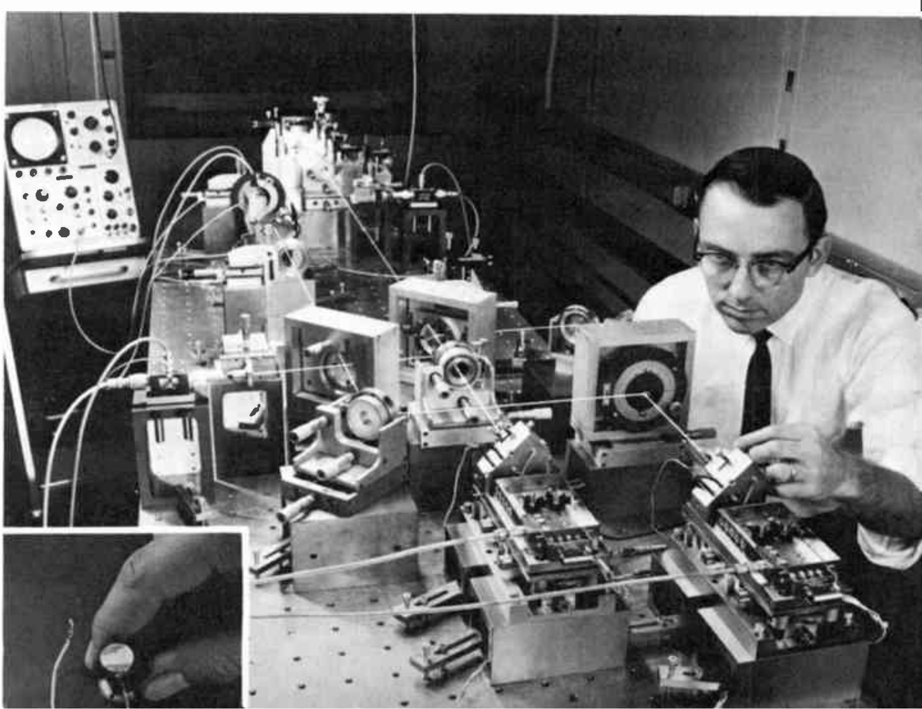
to put the optical part of the spectrum to work for communications. One of the major problems is to find a practical way to impress information on (modulate) a laser beam. Although some success has been achieved in this area, we are still a long way from a practical system.

An additional problem is that a light beam won't go around or through buildings. (A radio wave will; if it didn't you wouldn't be able to receive a radio program inside a house without an outside antenna.) Nor will a light beam penetrate clouds, fog, or heavy rain or snow. It even has trouble going very far through the atmosphere. Hence it is likely that the first applications will be in space. To aid earthbound transmission, special "light pipes" are being developed which will channel, guide, and protect this potentially useful servant.

Charles H. Townes, one of the inventors of the laser, recently wrote in *Science* magazine:

> The new device was so far out of the normal tradition [of communications] that its value for applied work was not immediately obvious to everyone. Bell's patent department at first refused to patent our amplifier or oscillator because, it was explained, optical waves had never been of any importance to communications and hence the invention had little bearing on Bell System interests.

Two PCM signals are hooked up to one laser beam. Insert shows one of the two lithium tantalate crystals used in the system.



The situation was shortly to change, and rapidly. Now there are probably as many people working on adapting the laser to communications as on all other laser projects put together.

When success is achieved, as it undoubtedly will be, then broad-band communications will become as widespread and inexpensive as narrow-band transmission is now. In 1950, for example, a coast-to-coast telephone call cost $2.50; today the price is as low as $1.00. And as we have seen, usage has soared.

The advent of inexpensive broad-band communications will make feasible such things as 3-D television, which we have already discussed, plus a wide range of other interesting items, a few of which we discuss in coming chapters.

7

Computers and Communications

LESS THAN two decades have passed since the installation of the first large-scale computer, Univac I, at the Bureau of the Census in 1951. But in that short time there has been a far greater application of these machines than any pioneer could have foreseen. In 1956, for example, there were 1,000 computers in the United States. A decade later there were more than 35,000. By 1975, 85,000 are foreseen, and the numbers are expected to climb even more steeply for the more distant future.

But numbers do not tell the whole story. Dr. Vannevar Bush, an early worker in computer technology, has this to say of the impact of computers:

> Man has already relegated to the machine many of the repetitive processes of his thinking . . . Moreover, the day is coming when man at his best will be far more able to cope

with the complexities of life under modern civilization, by reason of the extension of his mental power . . . This is a revolution in the offing far more important than the extension of automation in industry.

The impact of the computer has been felt in virtually all fields, including basic science, engineering, industry, banking, psychology, education, transportation—and communications.

We of course are concerned with communications. But here we find a two-way street. In one direction, we find that computers have been used to increase the efficiency and convenience of communications. At the same time, communications technology has had an equivalent impact on computers.

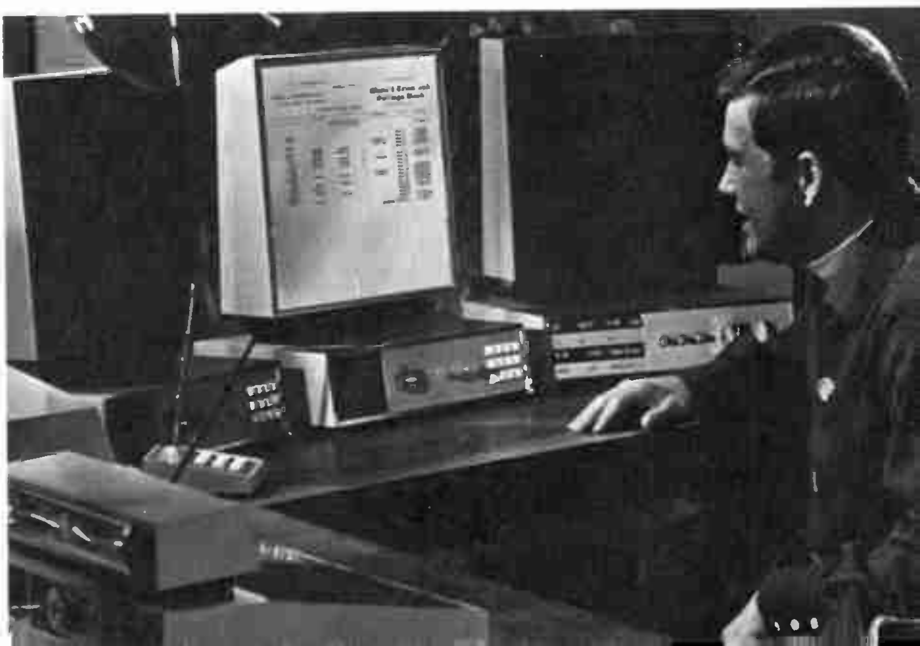
We shall cover the second point later in the book. Here we are interested in what computers have done, and may do in the future, for communications. One major example is the electronic switching systems we mentioned in Chapter 2, for these are indeed computers. They are programmed to quickly make particular connections when certain data (telephone numbers) are put into the system. They also keep track of time, and bill your account accordingly.

But communications includes much more than person-to-person conversation and even broadcasting. It covers all fields where information is transferred from one mind to another, or at least from one point to another. Thus we find that we are involved with information storage and retrieval (libraries, airline and theater reservations, telephone operators looking up numbers), education, management information systems, the study of the human voice, communication with banks and stores, and many more applications.

One interesting development is that of "compressed speech."

Control console for the woman of the house, envisioned in Philco-Ford's House of Tomorrow. The video shopper scans shelves through a camera in the store and the lady selects what she wants by pushbutton.

Control console for the man of the house gives his current bank balance. He can also find out weather conditions and receive his news, mail, and stock market reports at the touch of a button.



Equipment is already available that increases the word-per-minute rate of a speech recording without changing the pitch or tonal quality. One of the major problems with obtaining information via the spoken word is the slow rate of information transferal. A fast reader can cover 1,000 words or more per minute; an average reader will do 300 or 400. But speech takes place at roughly 200 wpm. Simply speeding up a record or tape does not work; it raises the pitch, producing a Donald Duck effect, and very quickly makes the voice completely unintelligible. (Try playing a record or tape at a higher than designed speed.)

Experiments with the equipment have shown that some people can understand speech at rates up to 900 wpm. Think of what such a device can mean to the blind, who often must rely on voice recordings. But its use is hardly restricted to the blind. With greater use of educational aids such as tapes and records, it is possible that all classrooms and libraries may one day be equipped with compressed speech devices. Many universities already use them, although so far mainly for experiments with speech and comprehension.

Information Retrieval

Another area where the computer will find even greater application is that of information storage and retrieval. Consider, for example, this startling statistic: The expansion of scientific information is estimated to be approaching the rate of 250 million pages a year. This is newly published information. Not all of it is new or valuable, of course, but how does the scientist know that if he (or someone) does not evaluate it first? Getting the information from the pages of a book or journal (more properly from the mind of the writer) to the man who needs it is a problem in what is generally called "scientific communications," of which information storage and retrieval is a major part.

Professor Philip Morrison of Cornell University once described the problem of keeping up with the scientific literature in terms of the number of books on a shelf. He pointed out that if the number of pages published annually continues to increase rapidly (it is doubling about every ten years), we will eventually reach a point where the end of the bookshelf will be receding from us at the speed of light!

It is now often cheaper and easier for an organization to do a piece of research from the beginning rather than research the literature to see if it has been performed before. According to one estimate, business and science spend $1.5 billion a year just looking for answers that have already been found.

What can be done to help the scientist or other professional man find what he needs when he needs it, and also to keep up with this rapidly increasing fund of knowledge? Most workers agree that (under the present system) the best way to increase one's knowledge is to have a talk with someone who knows. This can be by telephone or letter, as well as in person. But we are assuming that such a man exists, that he can be found, and, finally, that he is willing to give up valuable time. None of these assumptions is a safe one.

There was an idea once in vogue that each scholar would have in his desk a comprehensive library in some miniature form (such as microfilm or miniature computer) for use in his research. For example, I have actually seen a process whereby the entire Bible—1,245 pages or over 700,000 words—was contained on the 2″ x 2″ photographic slide! A large personal library could be housed in one drawer of a desk.

Nevertheless, this does not seem to be the direction in which we are moving. Due to the huge mass of data being generated, the problem of personally obtaining, evaluating, and storing the desired information *so it can be found* seems, at the moment anyway, out of the question.

Further, improvements in communications have made another approach both possible and more likely. It appears now that central or regional information centers will develop, and that additional improvements in communications and computer processing will make the information contained therein no farther away than the touch of a few buttons, or the speaking of a few words into a telephone mouthpiece.

The term "library" derives from the Latin word for book, *liber*. It is, in other words, a place which houses a collection of books and, by association, magazines, pamphlets, and other printed matter. Some libraries have expanded their reach and also have circulating collections of records.

Nevertheless, the basic idea of a library is presently that of a repository, a resting place, for printed matter. This will have to change. After all, the primary function of a library should be to provide information, not documents. The system of the future should be able to "read" and "understand" the documents themselves and not just their titles. As with a human, it should be able to organize the information internally and give back facts and summaries on request. If you read two books on photography the chances are you don't remember

Ampex's Videofile handles document filing and retrieval, replacing file folders with television recordings that may be updated electronically.

them individually (unless you have a photographic memory). The information tends to merge in your mind. And if someone asks you a question about developers or printing paper, what you answer will probably be a summary of the information presented in both books.

The computerized library system will have the additional advantage of perfect recall of all the facts, including date of publication. If a scientist has been out of touch with a field, he needn't search through dozens or hundred of journals for a recent review article in that field (even looking through the lists of titles that are available can be tiresome). He will call the National or Regional Research Library and ask the computer for an up-to-date summary of the status of the field, or for a particular aspect or fact. This will come back to him in a matter of seconds. Some of the techniques by which this will be done will be covered in the next chapter.

Language Translation

Language translation is another area that holds great interest for everyone, and is a "natural" application for the computer in the field of communications. Suppose we want to translate Russian into English. All we need do is program a Russian/English dictionary into the computer, right?

Wrong.

That approach was tried, with some rather strange results. In a technical paper, for example, the English translation had the expression "water goat" in it. This made no sense at all until one imaginative reader realized it should have been "hydraulic ram."

English to Russian fared no better. In what has become a classic example in the field, the expression, "The spirit is willing but the flesh is weak," came out "The vodka is fine but the meat is rotten."

Our tendency is to blame the computer or even the programmer. But the problem does not lie in those directions. The real culprits are our languages; these are so illogical that even communication between friends in their own language is often uncertain. The problem of machine translation is therefore being attacked from two directions. Not only is it being studied by computer experts who know something about language, but also by linguistic (language) experts who know something about computers.

We will have more to say about language *per se* later on. At this point we can state something that is not generally known: the capability for machine translation *already exists*—but only in specific areas such as science, which has a large vocabulary of specialized words and fairly straightforward presentation. (It is estimated that English has some 600,000 words, fully four-fifths of which are specialized—music, sports—and technical.)

Although even scientific translations often contain boners, the point is that someone who does not know a foreign language can through machine translation understand most of a technical paper written in that language. Considering the fact that a skilled human translator can only translate some 2,500 words a day, and that a machine can do this in a minute or two, we begin to see why we can say progress has been made and also why the ultimate objective, machine translation, is worth striving for.

Literary and ordinary language translation, however, present problems of much greater magnitude. It will be a long time before we have machines which can translate *Treasure Island* or *The Children's Hour* into a foreign language. For novelists and poets will often change the usual sentence construction to emphasize a point or simply because they like the way it sounds. Further, ordinary language is often inconsistent and full of vague terms and assumptions.

The major problem in translation is not one of grammar but of vocabulary—the same word having a variety of meanings, for instance. We often do not know the meaning of a word in the middle of a sentence until the sentence is completed. That is, we evaluate the meaning of ambiguous words on the basis of their context, or what comes before and after. The French word *fond* normally means "bottom." But *le fond de la salle* is "the back of the room."

Once computers can take all of these problems into consideration—and the first small steps have already been taken—we can look forward to being able to speak to anyone in the world via the telephone and a computer that is doing rapid two-way translation. True "simultaneous" translating is of course not possible, for the computer will always have to be at least a few words behind the speaker in order to allow for variations in word order and sentence structure, as well as to give the computer time to analyze the context of certain ambiguous words.

Computer Capability

What is happening in the world of computers which would lead us to believe that such capabilities may indeed come to be? The term "artificial intelligence" refers to the capability, or presumed capability, of computers to think. This book is not the place to go into the question of whether computers can indeed "think," fascinating though the question may be. More to the point for us is a test of machine intelligence that was proposed a number of years ago by A. M. Turing, one of the pioneers in the field. The test is simple. Put a man and a computer in one room, and an examiner in another. The examiner asks questions, and either the computer or the man can answer them. The number of times the examiner mistakes one for the other is an indication of the "intelligence" of the machine.

Many will exclaim that such a test is unfair because everything the computer can answer depends ultimately on the *man* who programmed it. But this is no longer quite true, for we are already beginning to hear about "learning" machines, machines which learn from experience. For example, a computer can be, and has been, programmed to play chess. But the game has so many possible moves and combinations that programming the machine to be capable of handling every single one is simply out of the question. Hence it has been possible to program computers to play a fair game (in itself a marvel), but not a master game.

Another approach, and this after all is the way man learns to play the game well, is for the computer to profit from experience. Computers are indeed being experimented with that can do just this. Thus they are called learning machines, as opposed to the teaching machines being used more and more in education and industry.

Learning machines may make significant contributions to the information retrieval system we discussed earlier. In order to make a truly useful retrieval system we must put the existing library of man's knowledge into machine-processable form, that is, onto tape, disk or drum. Now this could be done by having keyboard operators actually read the information and type it into the memory device. There are several problems with this approach. First, humans are prone to make errors. But more important, the process is painfully slow. A fast typist can type 60 or 70 wpm, though certainly not continuously. At such a rate an army of typists couldn't keep up with new material, let alone make a dent in the old.

Actually, optical scanners ("reading" machines) are available that can "read" and convert text to machine language at the rate of 1,500 characters per *second*. But each scanner can only read one or at most a few kinds of type. Just open a few newspapers, magazines, and books at random and the problem will become clear.

Here we see a perfect example of both the strength and weakness of the typical machine. It can do what it is designed to do at incredible speeds. But hand it something a little different, as a different type face, and it is in trouble. This is why all banks have standardized on those funny looking numerals you see on checks.

It is quite conceivable, however, that machines will one day be built which can learn to recognize different kinds of type over a period of time, just as we do. The machine might have in its memory a generalized picture of an A, both upper and lower case. It might then be shown a succession of A's in different type styles and, by a system of "rewards" and "punishments" be taught to recognize what it sees.

It might even be better to start out with a "clean slate." That is, the connections in the computer are quite random, as they seem to be in an infant. A letter is shown and the machine makes a guess. If the guess is incorrect, as it is likely to be, it is "punished"; that connection is broken. When it makes a correct guess, it is "rewarded"; that connection, whatever it might be, is reinforced and a pattern is gradually built up in this way. A computer teaching machine might even be used to teach the learning machine much faster and even better than a human might.

Carry this a long step further and the machine may even be able to be taught to read handwriting. For it is simply not possible to *program* a machine to recognize all the multivariate scrapes, curls, slants, and shapes that we call handwriting, and that we recognize and read with relatively little trouble. Consider what such a device would mean to the Post Office (a present user of optical scanners), which processes over 70 billion pieces of mail per year.

As Bell scientist J. R. Pierce points out, however, the computer does not normally excel at old tasks. More importantly, it opens up the possibility of entirely new ones. For example, we all know people who can speak for hours without really saying anything. And we know others whose words are full of meaning. Dr. R. H. Thouless applies the term "non-communicating discourse" to unnecessary verbiage. As we might have been able to predict from Zipf's Principle of Least Effort, Thouless has shortened the term to N.C.D.

Of course N.C.D. often serves a purpose, as in the following sprightly exchange: "Hi." "Hi." "How's everything?" "Okay. How about you?" "Fine. Nice day." "Sure is. Well, gotta go. See ya." "Right. So long."

Marston Bates, professor of zoology at the University of Michigan, writes:

> In any social bird or mammal [including us], a great deal of ordinary sound production is simply what might be called "conversational clucking," which might have developed from the interchange between parents and offspring. There is reassurance in the exchange of sounds, whether it be among hens in a chicken run or people at a cocktail party. There is really no transfer of information—it is the sort of sound that the communication scientists call "noise"—yet it serves a useful function in promoting togetherness.

Eliminating this kind of N.C.D. would be cutting the foundations right out of our society. But much of the verbiage which pretends to be something when it really isn't, the kind of thing we often get from windbags, politicians, and various kinds of know-it-alls, we can generally do without. For this kind of hot air, Thouless proposes the "N.C.D. eliminator." (See *The Scientist Speculates* edited by I. J. Good.) Thouless writes:

> We can imagine, in the future, a statesman about to make an election tour. Before he leaves, his secretary says: "We have just run your fifty-minute speech through the N.C.D. eliminator. You will be happy to know, sir, that it is now altogether communicatory and that you will be able to deliver it in three-and-a-half minutes."

Man and Machine

In a sense the example of machine capability that we gave earlier, namely chess playing, is a poor one. For it emphasizes an unfortunate tendency that some people have, and that is to pit the computer against man, to ask for instance which is the more intelligent. But this is a useless endeavor. Each has certain strengths and weaknesses. Man excels (so far) at such tasks as pattern recognition and insight; machines are better at those jobs requiring long numerical or symbolic calculations, large memory capacity, and so on.

At a panel discussion a few years ago Professor Walter Rosenblith, of the Harvard Medical School and M.I.T., suggested:

> My inclination is to substitute coexistence and cooperation for competition. The real challenge then consists in creating a novel, more powerful, self-modifiable . . . system that will combine the assets which a long evolution has bestowed on man with those which man's inventiveness has bestowed and will bestow upon the computers of tomorrow. I am therefore less tempted to stress what computers can do better than men than to envisage the benefits that we might derive from an intelligent division of labor between men and computer. Such arrangements are very likely to enhance human capacities in just those areas that are crucial to the functioning of a world whose technology is rapidly evolving.

But partnership and cooperation imply, indeed are based on, communication. In the next chapter we explore the fascinating field of man/machine communication.

8

Say Hello to Computer Central

A SCIENTIST is off fishing in the backwoods somewhere. He gets an idea and wants to try it out, but he needs a computer, a big one. Must he pack up and go home, or wait until his vacation is over? No. He goes back to the lodge and settles down in front of his telephone—fortunately one of those new Touch-Tone types. He starts punching buttons, then listens for a second. Good, he's got a connection right to his company's computer, a thousand miles away.

He punches more buttons; he's inserting the problem into the computer . . .

Farfetched? Not at all. Phyicians attending a recent World Health Organization conference in Copenhagen, Denmark, "spoke to," and were answered by, a computer in the labs of the System Development Corporation in Santa Monica, California. Actually, they used a teletypewriter, which is better suited for this kind of work because it has a regular keyboard and automatic print-out; but the buttons of the Touch-Tone telephone could be used in a pinch. As you can see in the photo, experiments along this line have already been tried.

On the other hand, how will the computer answer back? Of course, our fisherman-scientist may one day be able to take along a portable teletypewriter—just in case. Or perhaps every home, and lodge, will have one.

But let us suppose that a teletypewriter is not available; what then? One possibility was introduced a few years ago by IBM —a computer unit that talks over the phone with a human voice. A vocabulary of up to 126 words for a particular application (to a credit manager, bank teller, or insurance agent) is recorded and stored on a magnetic drum (see photo). When a phone inquiry comes in, words from the computer's memory, which is constantly being updated, are assembled, and the answer is spoken back automatically.

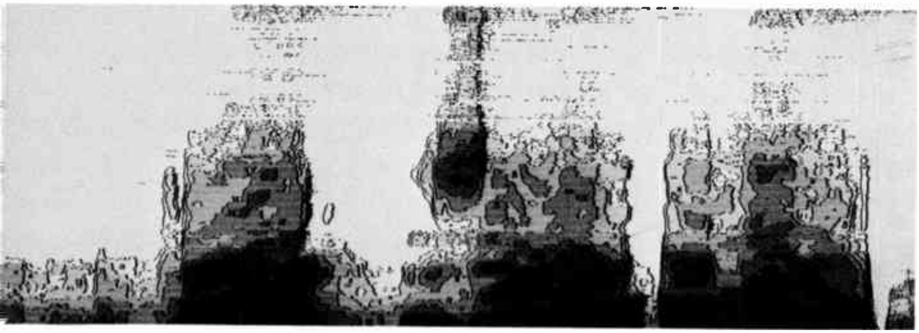
It must be realized, however, that when these words and numbers are put back together into a sentence, the result is hardly what we would call natural speech. Try, for example, reading the following aloud without any change in emphasis or timing: "Balance on account number two one four seven is five hundred sixty dollars and three cents."

The accenting and phrasing that we are used to depends on context. For example, a word used at the end of a sentence will usually have a rising inflection. Since the words in the computer unit are prerecorded, this kind of flexibility is beyond its capability.

However, progress is being made on synthesizing or creating artificial speech, that is, on producing speech without having someone record the words first. Again, an obvious application would be a machine that reads aloud for use by the blind.

A Touch-Tone telephone is used by a student to do homework.

A telephone "spoken" reply from an IBM computer is given to an engineer's inquiry. The magnetic drum, a recording and storage unit, is shown at top of uncovered circuitry panel.



The sonagraph charts the spoken words, "four zero Ohio," by "spreading out" the voice on a sonagram.

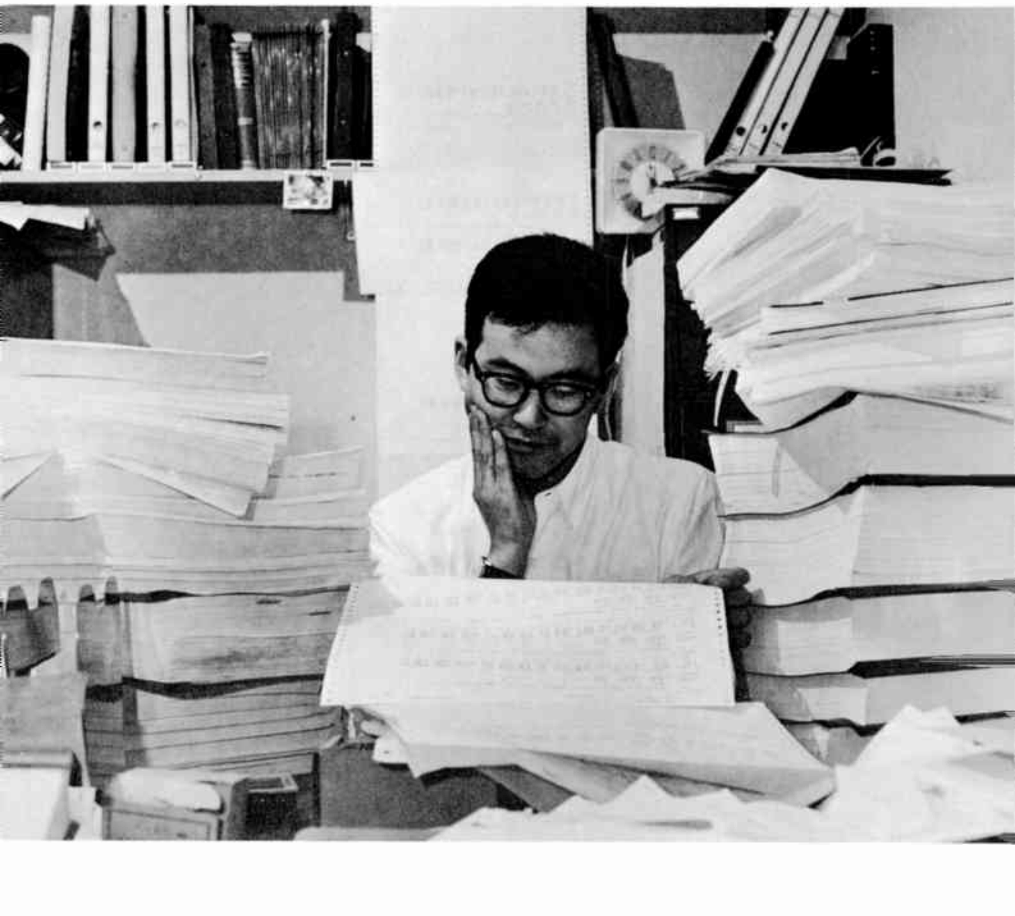
One of the more basic instruments for studying speech is the speech spectrograph, or sonagraph. This device "spreads out" the voice on a chart as shown, so that it can be studied more carefully. The principle is similar to the way a prism spreads out white lights into colors; however, in this case the vertical axis represents the frequency and the horizontal axis represents time.

Another way the computer can answer back is by means of some kind of visual display, such as a television or Picturephone set. We will learn of some surprising developments in this area later in the chapter.

In the meantime, let us look back momentarily at the beginnings of man/machine communication. This will help us see how far we have come since then. Initially, the data with which we humans are used to dealing were not compatible with the data analysis tool, the computer. The information—letters, numbers, mathematical symbols—had to be hand-transcribed (key-punched) into machine language. This was usually done on IBM cards, and run through the key-punch verifier to find errors. At the other end, the chart recordings and data runoffs that resulted piled up to the point that warehousing became a problem, for it was very difficult at first even to get a program to run right.

In other words, the man/machine interface—the input and output equipment—had lagged, and still lags, far behind the processing and memory (storage) capabilities of the computer.

The printed output from computer programs used to present work-space problems.



The reason, to put it simply, is that man and machine are just plain different. They don't look alike, they don't think alike, and they don't act alike. Let us look a little more closely at these differences.

Language

Even with the biggest, fanciest, most expensive computer in the world, you would still be helpless unless you could speak its language, or it knew yours. So the first great gap that must be bridged is one of language. We speak English and use Arabic numerals in the decimal system. The computer "speaks" a foreign tongue, more foreign than any found in the remotest parts of the earth—the language of bits and binary coded instructions.

A translator is needed, something or someone who knows both languages. This need has called forth an entirely new profession—programming. Of all men, the programmer comes closest to thinking in the language of the computer. At the very least he knows it well enough to be able to convert your language (numbers, letters, equations, words, sentences) into a form which is understandable to the computer.

In the early days of computers all programming was done in machine language. Thus not only was the programmer confined to those kinds of instructions which the designers had built into the machine's comprehension, but also he had to work in the numeric symbology which the machine accepted. For example, the instruction "add" was not acceptable to the machine. It would only respond to such numeric symbols as "010," the machine-language equivalent.

The drudgery of programming and the manifold opportunities for clerical blunders stimulated the development of automatic coding, which is a scheme to make the computer itself take over the drudgery. In other words, intermediary languages were developed which could be understood by both the operator (who might or might not be a programmer) and the computer. Thus the process of entering, "debugging," and using the program was immeasurably simplified.

The resulting languages, sometimes called "compilers," are "problem oriented" in the sense that they are geared to the human language and operations of a particular class of problem. Examples are COBOL (Common Business Oriented Language), PLANIT (Programming Language for Interactive Teaching) and FORTRAN (Formula Translation). FORTRAN, for instance, accepts the symbology and operations of ordinary algebra, such symbols as: ., +, —, ( ), superscript. It is a language for problems which can be stated in algebraic terms.

Naturally, users in various fields—business, science, medicine, industry, manufacturing, education, engineering, transportation, communications—would like to "converse" with the computer in their own intermediary languages. But because the computer has become indispensable in so many different applications, and because many of the computers have their own peculiarities and requirements, the number of languages has multiplied alarmingly: ALGOL, MAD, CLIP, JOVIAL, SHADOW III, MADCAP, MATHEMATIC, LOGLAN, and so on. RCA Chairman David Sarnoff said recently that the American computer industry now functions in a "Technological Tower of Babel." There are, he points out, more than 1,000 programming languages. There are even languages within languages—in one instance there are 26 "dialects," and in another, 35.

And the worst of it is that new tongues continue to proliferate; some are offshoots of dominant languages such as COBOL, FORTRAN, and ALGOL. One harried computer man has even suggested the formation of ALGOLICS Anonymous.

Input/Output

A second major difference between man and machine is a physical one. We are sensitive to pressures on our eardrums, light rays on our retinas, and so on. We respond with complex motions of our bodies and sounds from our larynxes. We cannot, perhaps unfortunately, generate electric currents or flashes of light as some other living species can.

On the other hand, an electronic computer, versatile as it appears to be, is really much more limited. It can only respond to stimuli of electrical currents by producing additional currents. Therefore, to communicate with the computer (the processing portion) we must convert muscular activities into electrical currents, and the computer must transform its signals into visible, audible, or otherwise tangible stimuli so that we can sense them. This is the function of the input/output devices.

At the beginning, computer prices were astronomical. One factor in bringing the prices down was the elimination, for scientific purposes, of the costly equipment that accepted conventional punched card or tape input and produced line printer output. Scientific and engineering applications, plus some

Computer installation with disk packs in foreground and tape drives at left.

Cathode-ray tube is used to display data.

others, did not need the masses of output data that business-oriented computer systems produced.

Several companies stressed direct, immediate access to the computer, plus concise results, presented as a print-out on console typewriters, or at times on cathode-ray tube displays.

These smaller, less powerful devices were developed for use as a complete computer or, more likely, as the control element in larger information-processing systems. The operator could watch his answers appearing on the tube face or on the same paper he was typing on, giving an unmatched sense of immediacy in the program he was running. He could intervene to pose new questions or to organize his data in new formats. This close contact with his program let the user make changes as soon as they were needed, not days or weeks afterward, as had been the case when he had to study his results from a line printer.

Keyboards are now frequently used for setting up programs, as well as testing and alteration of the program, and information retrieval. In applications that require frequent access to large files, such as airline reservations or savings bank accounting, special-purpose desk sets have been designed for speed and accuracy.

The airlines, with their need for fast, efficient reservation systems, have led the development of *on-line*, or while-you-wait, data processing. American Airlines, for instance, receives an average of 70,000 calls daily and has to provide information for some 900 flights. Prior to the installation of their SABRE system, processing a passenger reservation took over forty-five minutes. Now it takes seconds. This is accomplished by direct communication between nearly 1,000 reservation agents throughout the country and a central processing unit in Briarcliff Manor, New York. The system automatically controls seat inventory, notifies agents when special action is required, maintains standby passenger lists, and provides arrival and departure times for all the day's flights.

In the SABRE system the desk-size electronic console is equipped with buttons, display lights, and a keyboard. Coded cards, each listing American's flights between specific cities, are used to interrogate the computer's file about seat availability. The computer's response is indicated instantaneously by lights which show all flights that are available. The agent presses the buttons of the console to indicate number of seats needed and date requested.

The keyboard is used to transmit information to the computer about the passenger—name, telephone number—and any other special requests such as automobile rental, package vacation tours, or air taxi service. The printer records messages and replies from the computer. Some airlines use a system based on an electronic display rather than lights and print-out.

But because people type too slowly and are prone to make mistakes, keyboard input is a very poor risk when large gobs of printed data must be transferred into the computer's memory. Examples of such applications are information storage and retrieval systems, and scores of government and industrial applications like the census bureau and poll takers.

What is needed here is an input device which can rapidly "read" our language and translate it into machine language. In the last chapter we mentioned a print reader which can convert type into computer language at 1,500 characters (roughly 10,000 bits) a second. This unit could convert the 2,720-page *Unabridged Webster's Third New International*

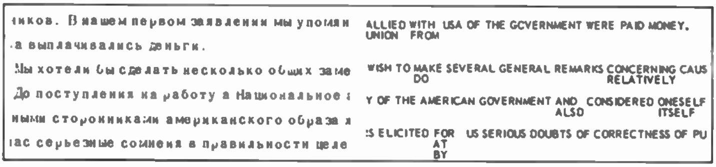
Dictionary of the English Language into computer language in about fifteen hours. Pretty good. But the computer could accept the data at the rate of several *million* bits per second. At this rate the same dictionary could be read into the computer's memory in a few minutes.

New ways of "inputting" are being studied which will also exert strong effects on the input and retrieval of graphical images—drawings and photographs—as well. Ultimately it will be possible for the computer to search entire pages of copy or entire photographs at one time. Individual characters or figures won't have to be scanned serially as they are now, just as you needn't read every number on a phone-book page to find the one you want. Specific patterns, characters, or words will be located in as many places as they appear, all in a single look. A useful application would be the searching of photographs of nuclear or astronomical events which, when done by eye, is extremely tedious and time-consuming.

Within ten years computers will also be able to act on voice commands. As we mentioned earlier, it may someday even be possible to "dial" a number by simply speaking it into the mouthpiece. One might think that such a development would go hand in hand with the voice synthesis we mentioned earlier. This is not so. Although there are some common aspects, it is considerably harder to make a computer understand speech than it is to make it speak intelligibly. Speaking machines have

American Airlines SABRE reservation system; on the right side of each desk-size console the bottons are used to tie in to computer center. Display lights on left side are flashed on to indicate alternate-flight possibilities. Agents can "talk" directly to electronic reservations center with typewriter. When request has been filled, a verification message from computer is printed out.

already produced reasonably intelligible speech and have even been made to sing. But the difference between "a name" and "an aim" is after all very small; distinguishing between the two, as is necessary in language translation, depends largely on understanding the context in which they are used.



Trial translation of English/Russian before alternative meanings and problems of syntax are resolved. When displayed on console, linguist selects proper meanings and feeds them back to computer for a better translation.

Nevertheless, some progress has been made. If the vocabulary to be recognized is held to a minimum, and ambiguous words excluded, then we can say that voice input to computers has already arrived. A voice control unit that will enable an astronaut to maneuver himself in space while leaving his hands free for work is being developed for the Air Force by RCA. That is, the unit will respond to a specific set of commands such as "Left," "Right," and so on.

Draw Me a Picture

Although computers were first applied in business, it quickly became apparent that they would provide immense advantages in scientific fields as well. However, the two had somewhat different requirements. In the business field words and numbers were the major factors. But many of the scientific problems being tackled, such as trajectory calculations, design of structures, and hydrodynamic problems, involved some form of visual image. At the Murray Hill branch of Bell Telephone Labs, for example, computers generate over half a million graphical plots a year. This is fully 30 per cent of the total annual output of the computers.

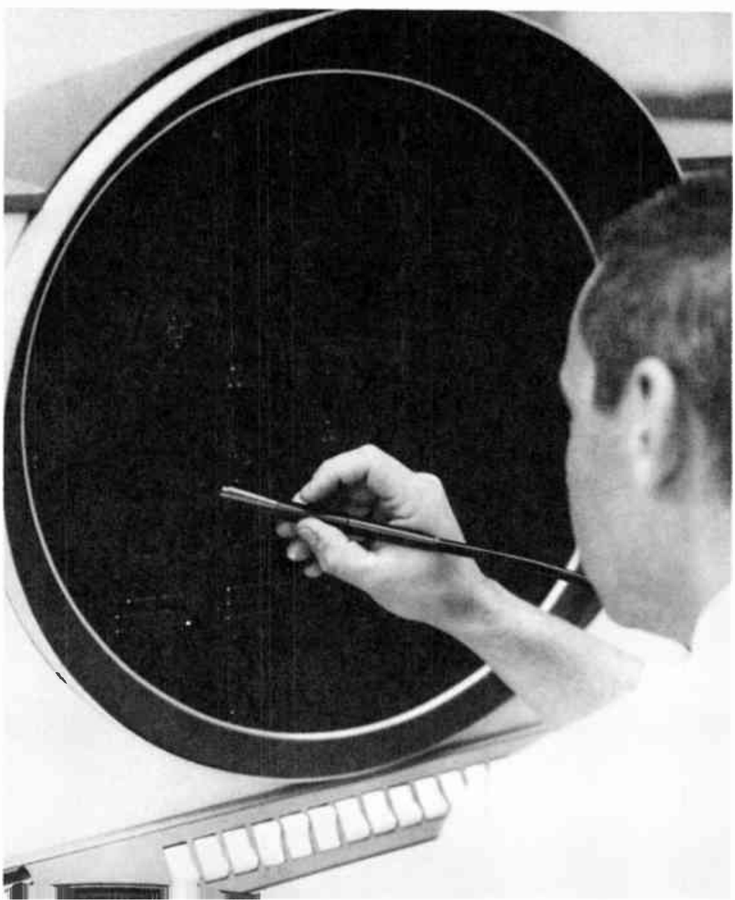
A common form of visual display is the cathode-ray tube (crt), an electronic device similar to a television set. We saw an example of its use a few pages back. For graphical displays, however, the tube face is usually thought of as an X-Y grid like graph paper. The crt is widely used by radio repair men, scientists, and engineers as a rapid and automatic way of plotting graphs, such as the output voltage of an amplifier as a function of frequency. When combined with the required electronic equipment for these purposes, the crt is also often called an oscilloscope.

During all of the first period of automated computation (roughly 1946–1952), it was evident that graphical display of a large percentage of the scientific work then being done on computers (such as the trajectory of a space vehicle) would be of great value. Hence a milestone was reached when a crt was first linked with a computer so that the circuitry which controlled the display could be controlled in turn by computer programming. In other words, the results of any calculation could be graphically portrayed. Almost always, a graph will show a result or trend more clearly than a table of numbers.

For some time now, computers have been linked with such crt displays, as well as standard or modified high-speed printers, and X-Y plotters. These have been used to produce missile and rocket trajectories, engineering layouts, topological (weather) maps, and so on. However, input of graphical data had required tedious hours of assigning coordinate positions (as in plotting a curve on graph paper), punching data onto cards, and then feeding them into the computer.

This has all been changed. With a system recently introduced by IBM, and now similar ones by a number of other companies, the engineer is able to directly transfer the graph-

An engineer uses his "light pen" to modify a circuit design. The computer alters its stored data and produces final design for use in manufacturing microelectronic circuitry.



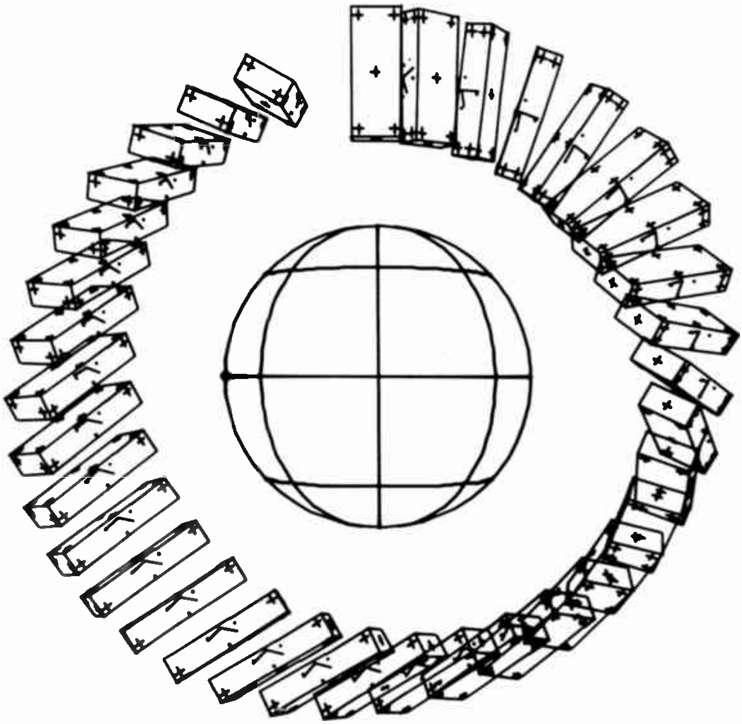
ical data onto tape in a matter of minutes. He does this by "writing" directly on the tube face with an electronic "light pen."

Thus, for example, it is no longer necessary for someone to key-punch the data. The operator, who is now the engineer or scientist himself, simply touches the tube face with the light pen at the proper spot; the computer makes the measurement and automatically inserts the coordinates into its memory as well. These can then be used for further processing, such as curve fitting.

Alternatively, the operator can draw circuits on the crt and have the computer plot the response characteristics of the circuit. It is then also a simple matter to change one of the components, or its value, and have the computer display the new performance characteristics. The new and the old curves can even be called up simultaneously, side by side or one on top of the other, to make comparison easier. The possibilities are almost unlimited.

What we have then is a man/machine interface that makes real-time or then-and-there trial and error solutions a reality for every conceivable design problem. Even movies can be created which can help scientific workers to visualize complex motions.

Designer and computer at General Motors have been "mated" in this way. The programmer can, with a minimum of fuss and bother, use the console's crt for the output of letters, numbers. drawings, or requests for operator action. He can use the light pen for the input positional information, the keyboard for input of alphanumeric (alphabetic and numeric) data, and the program control keys for the input of data. This combination gives him tremendous flexibility.



A computer-made "movie" to help scientists visualize comsats making orbit of the earth.

Actually, of course, it doesn't matter whether the operator is working in graphics, words, or mathematics; the main thing is that with direct access to a computer he can insert a newly thought-out approach directly into the computer as he is working. If he is not sure it is a good approach, he can try it out then and there. If it is good, he puts it into the program permanently or as long as he needs it. If not, he sends a command to the computer to wipe it out and that's that.

At the end of the session he tells the computer to take his program out of its high-speed memory and put it back into storage where it remains on tap. In this way room is made for others' work.

Slow Motion?

There is a third major difference between man and machine: speed. How do we understand somebody who talks thousands of times faster than we do—like a wildly speeded up phonograph? On the other hand, from the standpoint of the computer, imagine listening to someone talking at the maddeningly slow human rate. It would be like seeing a suspense movie in weekly installments of one frame each.

But we must tread very carefully here. Man is indeed a much slower worker than the computer—but only in those

Automotive design by computer at General Motors. At any design level the designer can request a permanent photographic copy of a new drawing.

areas he willingly gives over to the machine: repetitive computation; remembering and fiddling with a multitude of names and numbers; and complicated mathematical analysis where the programmer knows exactly what has to be done and can program the computer in advance to do it.

But where the procedure is not clearly defined, as in language translation, man still has it all over the computer. As a matter of fact, when you instantly recognize a face you haven't seen in years, you are accomplishing something the computer won't be able to do for a long time to come; and perhaps never.

Still, in those areas where the computer is strong, it is very strong indeed—capable, for example, of performing thousands of computations per second—and far surpasses our capability.

But since the computer does operate, in its domain, so much faster than we do, it would be ridiculous if it had to wait until we finally got around to answering it. By an ingenious process called *time-sharing* it has already moved on and handled ten or twenty other customers while the typewriter or other display unit is still presenting its answer to us. There are computers already in operation that can handle forty different inputs simultaneously.

In time-sharing the mode of communication is called "conversational," as opposed to "batch," which is used in the usual data processing system. This is because the basic unit of input is the individual statement rather than an entire program (a "batch" of IBM cards), and every communication by one of the participants is acknowledged by the other.

The form of the program is also significant. Each statement is given a number by the computer, so that it can be easily identified in case of trouble or if necessay to call it back or change it. The computer also prints a "status" word which informs or cues the user; for instance, the cue word READY invites the user to enter his next statement, and ERROR tells him that he has done something wrong or used a word not understood by the computer. This will normally be followed by an explanatory or "diagnostic" message. Suppose you typed in, "What is squire root of 93?" The computer might come back with: ERROR. DO YOU MEAN SQUARE ROOT?

While newcomers to the field are often astounded by the seemingly intelligent reply, the old-timers are well aware that somewhere along the line someone has programmed in the comment.

But one mathematician at the Rand Corporation, who is an erratic typist, received a real shock when, after he had made several mistakes in a row, the computer shot back, CAN'T YOU GET ANYTHING RIGHT?

It took a while before he was able to determine for sure that some practical jokers in the computer sciences department had programmed in this special one-time "comment" which had been keyed to his initials!

Computer Utility

We have seen that a computer can knock out in minutes what it might take us months to do, and also that a "conversational terminal" provides great flexibility and convenience in programming and use of the computer. But suppose our company or institution doesn't have such a computer? After all, these are very expensive and complicated devices. Not many firms can afford them. Must the potential user then travel to a firm that has a conversational terminal, or send his problem to a processing firm by mail? In the latter case, each change in the program, and there can be many, might take a week. Making a highly paid scientist or manager wait is expensive as well as frustrating for him.

I'm sure you see what we are leading up to. If we combine the possibilities for remote communication with the new time-sharing capability, we come up with a "computer utilty," a company that supples computer time to those who need it just as a water company supplies water to those who need it.

The firm would need only a terminal on the premises. The operator dials the computer's number on a built-in phone, establishing a connection over regular telephone lines. The computer acknowledges, assuming it has an opening, and asks for a prearranged password to be sure that an unauthorized person is not stealing some of its very valuable time. (Eventually voice-print identification might be used.)

M.I.T. has done experimental work on a time-sharing system for several years, and IBM, ITT, G.E., and several other companies have recently announced the opening of computer utilities. Clients are charged about $10 an hour, but only for the time actually used.

The use of time-sharing has increased rapidly. The first commercial system "went on the air" in 1965. By the end of 1967, G.E. alone had twenty-five systems in operation. Further, it is no longer even necessary to have a terminal on the premises; terminal offices are being opened at convenient lo-

High School students learn use of teletypewriter which is linked by telephone lines to outside computer. Computerized calculations save time in problem-solving.

cations across the country where one pays for his time just as he would on a pay telephone.

As computer use grows, more and more separate computers (many of which may be "specialists" in certain fields) will be linked together into larger and larger networks. Then the problem of communication between computers will be felt more strongly. This problem has already been confronted with the planned network of large time-shared computers by the Advanced Research Projects Agency (ARPA) at the U.S. Department of Defense. Due to gigantic computer requirements at the Pentagon for military operations, ARPA has been a major force in the push toward networking. The experimental network will eventually include some 1,500 remote consoles tied to thirty-five computers at sixteen locations across the country.

The use of computers in communications systems is increasing rapidly. Russell W. McFall, president of Western Union, points out that only one per cent of the computers in service in mid-1966 were linked in communications systems, but says that more than half of the computers expected to be in operation ten years from now will be in such systems.

Further, while the data processing or computer specialist has traditionally been in charge, Mr. McFall believes this will change, and that the communications specialist will eventually become responsible for the management and direction of the merged information and communications systems.

In any case, we will surely see the emergence of national and global information processing utilities, serving hundreds of thousands, perhaps millions of subscribers on a time-sharing basis. These utilities will accommodate the specialized needs of researchers and engineers, lawyers, medical men, sociolo-

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TUTØRI    14:14   MØN.   07/08/68

   CØPYRIGHT 1966 FØRD MØTØR CØMPANY - ENGINEERING STAFF
WELCØME TØ THE FØRD TIME SHARING SERVICE. WE WILL TRY TØ TEACH YØU
ENØUGH ABØUT THE SYSTEM IN THIS SITTING SØ THAT YØU WILL BE ABLE
TØ WRITE YØUR ØWN CØMPUTER PRØGRAMS.

BEFØRE WE CAN WRITE A PRØGRAM WE NEED TØ REVIEW THE SYMBØLS
AVAILABLE:

  [1] +
  [2]  -
  [3]   /
  [4]    *
  [5]     [ ]
  [6]      ↑

AFTER THE ? BELØW TYPE THE NUMBER ØF YØUR ANSWER

WHICH ØF THE ABØVE SYMBØLS IS USED FØR ADDITIØN?1
GØØD.
WHICH SYMBØL IS USED FØR SUBTRACTIØN?2
RIGHT
WHICH SYMBØL IS USED FØR DIVISIØN?3
GØØD FØR YØU. NØW THE NEXT ØNE IS TRICKY:
WHICH SYMBØL IS USED FØR MULTIPLICATIØN?4
VERY GØØD. IF'X' WERE USED FØR MULTIPLY, IT CØULD BE CØNFUSED
WITH THE VARIABLE X. LET'S PRACTICE A LITTLE:
HØW MUCH IS 2*3?6
SURE
HØW MUCH IS 3*4+7 ?19
RIGHT YØU ARE.
HØW MUCH IS 3*[1+5]/2 ?9
GØØD
THAT LEAVES ↑ WHICH IS ØUR WAY TØ INDICATE SQUARES, CUBES,ETC.
SUCH AS X↑2 FØR 'X SQUARED' ØR X*X, Y↑3 FØR Y*Y*Y, ETC.
WE ALSØ CAN USE FUNCTIØNS SUCH AS SINE, CØSINE, ETC., AND
YØU CAN EVEN DEFINE YØUR ØWN, BUT \HESE WILL BE CØVERED IN
ANØTHER LESSØN.  WE'LL USE SQR [SQUARE RØØT] IN ØUR CØMING
EXAMPLE TØ GIVE YØU THE IDEA. LET'S ASSUME YØU WANT TØ CØMPØSE
A PRØGRAM TØ CØMPUTE RADIUS VECTØRS [THE SQUARE RØØT ØF THE
SUM ØF THE SQUARES ØF THREE CØMPØNENTS.]  THIS PRØGRAM WILL
BE A SEQUENCE ØF STATEMENTS TØ TELL THE CØMPUTER WHAT TØ DØ.
DØ YØU THINK THESE STATEMENTS SHØULD BE NUMBERED:
 [1] CØNSECUTIVELY [1, 2, 3, ETC. ]
 [2] INCREMENTALLY [10, 20, 30, ETC.]
 [3] ANY SEQUENCE FØR IT DØESN'T MATTER
[TYPE NØ. ØF ANSWER]
?2
RIGHT.
```

The Ford Motor Company's reinforced-learning computer program is a teach-yourself guide to program-writing for nonprofessionals.

gists, psychologists, students, or even the general needs of the public.

In the not-too-distant future, for a few dollars a month, the individual will have a vast complex of computer services at his fingertips. Communication with the machine may even be by means of natural language, but this is an ambitious goal. More likely is the design of an artificial language that approximates the way the user would describe his problem in natural language. It has already been shown that the computer can teach such an approximation to the nonexpert in relatively short time.

On the other hand, there are those who maintain that a major result of ever increasing man/machine communication will be that our language will be forced to become more logical!

We shall see in the next chapter some additional areas in which logical language is an absolute requirement.

9

Machine/Machine Communication

IN ADDITION TO comsats, the United States alone has hundreds of other satellites—weather, navigation, astronomical observatories—whizzing around in space and gathering all kinds of data. Many are intricate laboratories sent up by scientists determined to unravel the mysteries surrounding the earth.

These devices extend man's senses into outer space. But the information obtained is useless unless and until it is returned to the men waiting below.

Electronic tracking, telemetry, command, and control provide the critical links that tie the spacecraft to the earth. Without these links the electronic explorers would be no more than so many pieces of junk.

Tracking provides information on the location of a launch vehicle, a satellite, or a deep-space probe. It is clearly important for the launching people to know where the craft is at all times. But if the craft contains scientific experiments, as is often the case, this knowledge becomes twice as important. Suppose, for example, the experimenter is interested in measuring the number of electrons in a particular part of the earth's atmosphere. The numbers collected by the craft's sensors would be useless if he did not know the position and altitude of the vehicle when the measurements were made.

Telemetry is the process of getting the information obtained and recorded back to earth. As the flight instruments or sensors react to an event, they produce a coded electrical signal which is either recorded and held for "interrogation" (questioning), or it is returned directly to earth. There the signals must be received, recorded, and decoded. And, finally, the information must be made available to the experimenter in charts or tabulations of data.

Command is the process whereby a coded signal is sent by the ground transmitter; it causes the satellite or spacecraft to change position, turn an instrument on or off, or perform any one of a hundred different operations involved in this complex business.

Control is the ability to direct the operations of a spacecraft and of the entire network of ground stations in a flexible and responsive way to carry out the desired mission successfully.

All of these functions, you may have noted, are communications functions, involving transfer of information from one point to another.

Another point worth noting is that these satellites have much to say; and they must say it quickly, before they pass out of range of the acquisition antennas. Hence they cannot "speak" at the leisurely pace we are used to. The data must be sent via wide-band transmission channels, generally multiplexed, and often in PCM or various other digital techniques. Only in this way is it possible for well over thirty satellites a day to be interrogated, and for the resulting forty or fifty *miles* of tape per day to be handled.

The Weak Link

Clearly man has no place in this process until the data are processed, translated, and delivered to him in a form—and in amounts—he can handle.

But man must stay out of the process as much as possible for another reason. As we mentioned earlier, he is very prone to making mistakes. This was illustrated in a humorous way when a Bell Labs scientist was demonstrating the wonders of tomorrow's technology to an audience of seven hundred graduates of Ohio State University's College of Engineering. He asked the members of the audience to pretend they were owners of a hardware store and that they were going to order a certain number of bolts by Touch-Tone phone. A computer at the Holmdel, N.J. branch of Bell Labs had been programmed to receive the order and, he went on, would automatically fill it.

He solemnly dialed the computer at Holmdel. It rang once. No answer. It rang again. Still no answer. On the third ring a tiny voice piped, "Hello, my mommy isn't here right now, she's over at Mrs. Durkin's house."

The scientist had dialed a wrong number. All of which goes to show, as he blushingly admitted to his audience, that modern technology goes out the window when man makes a mistake.

In the "old days" a certain amount of carelessness could be tolerated. Today, when large manufacturing and chemical processing plants depend on automatic machinery, absolute accuracy is essential in the instructions. In one case, a multi-million-dollar missile was lost because a hyphen had been left out in the program instructions.

Man has traditionally been the weak link in the chain that supports computer technology. For example, every one of the 76 million income tax returns filed by individuals for 1967 is being gone over by computer. This could never be done by human labor in any practical sense. Nevertheless, every piece of information contained therein must first be key-punched by fallible humans.

We have seen how optical readers may soon be able to overcome this bottleneck, at least for typewritten forms. But wouldn't it make more sense if the data could be entered directly into the computer? Suppose the taxpayer had a typewriter with a simple tape punch attached. As he typed out his tax or any other kind of form, the information would be punched onto the paper tape. Naturally, magnetic tape or punched cards could also be used.

In order to get the information to the Internal Revenue Service (I.R.S.), he could mail the tape in. But that's so old-fashioned. What he needs is some kind of device that will convert the data into a form suitable for electronic transmission to the central computer. Normally the transmission channel will be the telephone. In this case, a device called a data set or acoustic coupler, already widely available, will do the job. The taxpayer simply places the tape into the equipment, dials the I.R.S., and, once a connection is made, places the phone into a special cradle in the acoustic coupler. The in-

An acoustic coupler converts data to electronic impulses for transmission through telephone lines.

formation is converted to electronic impulses by the equipment and sent on its way.

Alternatively, the data might be sent to the I.R.S. via a direct, two-way connection. That is, the taxpayer might dial the I.R.S. and then use his Touch-Tone buttons or type or speak answers to questions presented on his TV tube face, his printer, or even voice recording over his telephone.

Which of these two general approaches, if either, will ever come to pass (for the private taxpayer, particularly) will depend on the relative costs of input/output equipment *versus* communications. If the latter are very cheap, it might pay to keep a line in operation for the time required to complete the two-way transaction. If not, it would be more economical for the taxpayer to "batch" his data and send it all at once, consecutively. Every firm dealing with data transmission faces this decision even today.

Data Rates

A simple data set will transmit up to 300 bits per second (bps). For the income tax form, this of course is quite sufficient. Where larger amounts of data must be sent, other equipment is available. A slightly better data set will send up to 600 bps. Another type will handle four times this amount.

Experiments have shown that it is possible to send anywhere up to about 10,000 bps over a telephone. However, such transmission requires highly sophisticated techniques, including error-correcting codes and equipment which adjusts to the characteristics of the particular circuit.

For many applications, even these rates are not high enough. Special data sets are available that will pool up to 60 voice channels and transmit up to 230,400 bps. A few years ago Bell Labs used an experimental data set in test transmissions at the rate of 875,000 bps, or 1,460,000 words per minute. At this speed the entire King James version of the Bible could be sent in less than ¾ of a minute. It is worth noting that these test transmissions were transatlantic, and were relayed across the ocean by the Bell System's Telstar comsat.

Actually, communications channels are often classified by the rate at which they will transmit data. Teletype is low capacity; telephone is intermediate; microwave and a service called Telpak are high capacity. All three, in reality, are related. A single high-capacity microwave circuit might be used in place of several Telpak channels, several hundred telephone channels, several thousand teletype channels, or some combination thereof.

As points of comparison, we might mention that the maximum rate of data transmission via teletype is 150 bps, while the high-capacity microwave channels we have already mentioned transmit at the rate of several million bps. (A rough conversion rate is ten bits per character and five characters per word.)

Considered as a field of its own, data communications is a relatively new one. Yet so rapidly is this branch of the communications industry expanding that within a few years the volume of data transmitted will exceed that of spoken language, if it has not already done so. (We refer to the quantity of information being transmitted, not to the time spent "talking.") One estimate puts the rate of growth at 42 per cent a year, as opposed to 20 to 25 per cent for the communications industry as a whole.

Every industry, every institution, is involved in the taking, storing, and eventual retrieval and use of various kinds of data. And more and more these data are being sent over communications lines, public and private—from branch offices to central plants, from one computer to another.

One type of transmission which is not included in the growth figure given above is interesting nonetheless. We refer to communication *within* a computer. After all, a computer is not a single entity, a thing like a stone or a ruler. Rather it is made up of parts: control unit, processing unit, memory, and input/output devices. And, like all "intelligent" things, the different parts must "talk" to one another. But the switching or operating speeds of the very large and powerful computers have increased to such an extent that one of the obstacles holding them back is the time it takes for the various signals to get from place to place. For although the speed at which signals travel through a wire is fast, it simply is not fast enough. This problem is being attacked in a number of ways, of which we shall mention only two.

One, advances in microelectronics have enabled computer manufacturers to shrink the size of components and subsystems; as a result the different parts of the computer can be situated closer together and the signals take less time to go from place to place.

Two, the possibilities of optical computers are being looked into. That is, the various parts of the computer would communicate with each other through optical channels, most probably beams of light. Thus signals would move at the speed of light (186,000 miles per second, or about 1 foot per billionth of a second), rather than at the slower speed of wire communications. This latter speed can vary from 99 all the way down to 40 per cent of the speed of light. The figure depends on a number of conditions, such as the type of components in the circuit and the type of insulation used. It is worth noting that light beams would also provide the advantage of large bandwidth capacity, which might prove useful.

On Line

Until now we have spoken of situations where data are collected at the source and then sent rapidly or slowly at a given time. (Many firms do this at night when the lines are more likely to be free and the rates are cheaper.) The giant memories of modern computers make them ideal for this kind of thing.

But computers work so quickly that another kind of operation can take place. They can be used for split-second decisions in a fast-breaking situation. Monitoring and anticipating events as they happen is what we have already called a real-time operation (page 135). That is, the computers are operating in the here and now, rather than "after the fact," as they used to. In high-energy physics experiments, for example, time on the big accelerators (atom smashers) is extremely limited. After the experimenter takes his set of data, he must remove his apparatus and make way for the next man.

The introduction of computers made it possible for much more complex experiments to be run, but very often the data showed later on that something was missing or wrong. But by then it was too late. For a long time an often-heard comment was "Now I know how I should have done the experiment." This is heard less often now, for computers are attached directly to the experimental apparatus and work the data over as they are taken. Hence any necessary changes or additions can be made immediately. Human taking, plotting, and analysis of data are on the way out.

Some of the older generation will shake their heads and mourn what they think is loss of control by the human. But this is not the case at all. He is still in control. More important, however, is the fact that computers have freed him from long hours of mental drudgery. It is the planning, the theory, and the results that count. Computers and modern communications make it possible for a creative scientist to do ten times the work he could do before.

Another real-time use of computers and communications permits a range-safety officer to follow the flight of a rocket from its launch pad, compare what is happening with a flight plan prepared beforehand, and then blow up the vehicle if it begins to deviate a specified amount from the plan.

This sort of operation, namely, computers working in real time and warning of tendencies that need correction, is one of the foundation stones of all modern oil refineries, chemical plants, and automatic factories. But fully automatic operation requires yet another part to the foundation. When the computer is connected to automatic control devices so that it runs a whole system without human intervention, it is said to be operating not only in real time, but "on line." The communication lines are the nerves of the system, and sensing devices at the ends of the lines are the eyes, ears, and perhaps fingers and nose. (When man converses directly with the computer, as we had him doing in the last chapter, the machine is also said to be on line.)

Advances in communications have made it possible for controlled systems to be quite widespread. In a large electric power system a microwave communications network might handle four jobs:

1) Send information on power use to the central computer.
2) Transmit computer-prepared instructions to the generators.
3) Carry data from smaller computers at several locations to the master computer for automatic customer billing.
4) Provide private multichannel telephone communications.

Information Systems

Before this kind of thing could become practical, several major events had to take place. Powerful computers and highly developed communications capability were necessary, especially in complex operations. And this in turn required developments in electronic miniaturization, reliability, and cost.

But there are still more required, namely, the communications theory that has made all this possible. For at the heart of communications theory lies the basic idea of information flow. And that, after all, is what our story is all about.

While we touched on the subject earlier in the book, there is lots more to it. For example, consider the question: "What do hands, antiaircraft guns, automatic factories, and the national economy have in common?"

If this had been put to us even thirty years ago, we would probably have been unable to give an answer. Today we unhesitatingly say, "They are all examples of self-regulating information systems."

They are information systems in the sense that their operation depends entirely on the amount and validity of information fed to them. An antiaircraft gun or an arm aimed in a punch is useless if the target cannot be seen or at least heard. The national economy is an information system in the sense that communication binds together its various parts no less than mortar cements together the bricks of a house. As Norbert Wiener put it, "Any organism is held together . . . by the possession of means for the acquisition, use, retention, and transmission of information."

Indeed, society itself may be regarded as a vast network of mutual agreements. Let us look more closely at this concept. Any large organization, such as a corporation, a school, or a city, can be viewed in terms of its physical structure—its buildings, its machines, the people who run the machines.

But more and more it has become useful and, thanks to computers, possible to view the organization as a dynamic or active, rather than static entity. Thus we can look at it as a communications network with a number of different channels. This helps us realize that the important thing about the organization is not its properties, but its range of activities and operations which are carried on through the communications channels. Management is learning how to plug directly into these communications channels; the resulting equipment and programs have come to be called Management Information Systems and are coming to be used more and more widely in business and industry.

In other words, any system can be thought of as an information system if it depends upon information flow for its functioning—and there are not many which do not.

Feedback

We turn now to the idea of self-regulation. Let us think again of an arm as an example of an information system. Suppose the eye has seen the target and relayed this information to the brain, and that the brain in turn has "told" the arm where and how fast to go. Is this the end of the information process?

Not at all. The muscle contraction stimulates sense organs in the muscle, which sends impulses *back* to the central nervous system, informing it of the degree of muscle action. Based on this information the central "control" system will vary the degree and rate of movement. If this part of your information system were to be damaged or destroyed, proper control of your movements would not be possible.

Similarly, *feedback* from the process being controlled in a factory is what makes automatic control possible. The heating system in a private house is a simple example of automatic control. The temperature of the house is sensed by the thermostat. When the temperature drops below a set temperature, let's say 70°, the thermostat instructs the furnace to go on. As the temperature rises above another set point, say 71°, the thermostat causes the furnace to shut off. In this way the temperature in the house is automatically controlled and stays within a "comfort range."

This, of course, is a crude example. Manufacturing plants depends upon the accurate sensing of many different factors, which may include temperature, rate of flow of materials, chemical composition, thickness, and many, many more. But in all cases it is the concept of feedback—sensing conditions in the area or process being controlled and sending this information back to where it is needed—that makes self-regulating control systems possible.

Your body is another case where this holds true. Your temperature, as you know, must stay within very narrow limits, otherwise you are in trouble. If it is too hot outside, your body will begin to gain heat; temperature sensors in various parts of your body will send signals to the brain which will initiate a series of responses, the best known of which is sweating. At the same time, you become conscious of the warmth and can take appropriate voluntary action (a swim, opening the window, and so on).

Conversely, when it gets cold, other sensors are activated and other activities take place.

We have been looking at the body as if it were a machine. And so, in a very real sense, it is. Due to your body's activities, it gives off signals. When you are seriously ill your body may no longer be able to regulate itself, and these signals must then be monitored externally in order to provide doctors and nurses with information on how you are doing.

As in the communications systems we discussed earlier, these signals are of two kinds, analogue and digital. Examples of the first are temperature and blood pressure. Examples of the second are pulse and breathing rate. With modern equipment it is possible to "wire" the body in such a way that both types of signals are automatically transferred into a computer-controlled system. The system can be programmed to alert the nurse on duty if any of the characteristics being monitored move out of a safe range.

The technique is not very different from the "wiring" of astronauts to enable ground personnel to keep tabs on their condition. Hence it should be no surprise that an experimental patient-care unit has been built by the Boeing Company in Huntsville, Alabama.

The prototype device is about the size of a package of cigarettes and is battery powered. It is strapped to the patient's arm or leg, and tiny wires extend to skin-surface sensors, which report on six physical conditions—three for the heart, two for temperature, and one for blood pressure. The unit also contains a miniaturized electronic-signal transmitter and receiver. Upon radio command from the central station, information on the patient is sent by the transmitter and printed out on the same kind of strip charts that physicians presently use, or displayed on an oscilloscope. The device could of course also be connected to a computer, and additional automatic measurements could be made if necessary.

Looking to the future, we can imagine everyone wearing wristwatches on the undersides of which are radio health monitors, and which in turn will be tied in with a computer at the doctor's office. One can almost imagine being called one day by the computer, who (which?) suggests, "Maybe you ought to drop in to see the doctor this afternoon. Your blood pressure is a little low."

10

Human Language

The word "infant" means "not able to speak," from the Latin *in* (not) plus *fari* (to speak).

What better demonstration could we ask for the close association between man and his language?

But this does not mean that the infant cannot communicate his wants. From the very first we can distinguish his gurgle of pleasure from a cry of pain. But such sounds are only communication in a very special sense. We might compare them to animal sounds, although animals can go even further. They can warn each other of danger; a mother hen can call her chicks; even bird song is now thought to be not an expression of well-being, but rather a warning to other birds to keep out of the singer's territory.

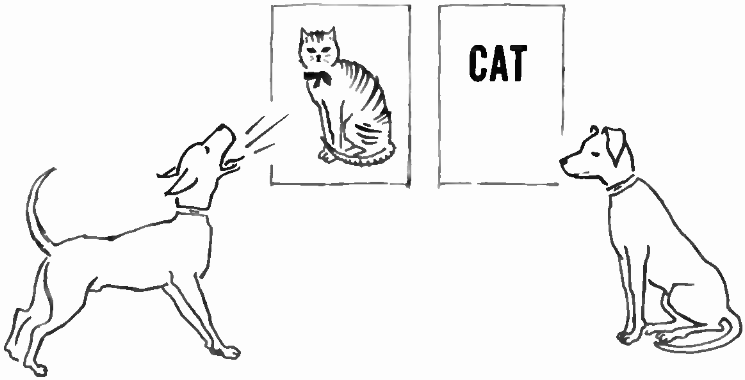
Still, these are very limited kinds of communication.

It was not until our ancestors developed speech that they really became men. Lewis Mumford, the distinguished historian and scholar, even suggests that the emphasis on early man as a tool-using animal is entirely misplaced. What has happened is that these tools have come down to us as evidence; man's early words are unrecorded. Mumford adds, "If the only clue to Shakespeare's achievement as a dramatist were his cradle, an Elizabethan mug, his lower jaw, and a few rotted planks from the Globe Theatre, one could not even dimly imagine the subject matter of his plays, still less guess in one's wildest moments what a poet he was."

But what, really, is the basic difference between the howl of a dog and the warning shout of a man when danger threatens? For one thing, communication implies intention. The face of an inexperienced poker player may tell his opponent all he needs to know about the first one's hand, but this is certainly not communication in the sense we mean it. Similarly, it is likely that the bleating of a sheep or even the trumpeting of an elephant is only a nervous response to the situation, rather than a deliberate warning to its fellows. (We cannot be certain of this since we cannot ask the animal.)

Second, animal communication consists of *signs,* not *symbols.* A sign is usually connected in some way with the thing it represents, while a symbol has an arbitrary meaning. A smile is a universal sign for pleasure, but the word "pleasure" is a symbol which has meaning only for those who have learned English.

By this definition, even the human infant's first words are signs. To him "bottle" means warm milk, not a glass container. But when a man shouts "Avalanche!" he is using a symbol for a particular activity or thing. Through prior training he has learned that the term means something specific, and the one who hears him has learned the same thing. If the latter has not, he may still realize there is danger from the urgent sound of the first man's voice, but he will not know just what the problem is. On the other hand, a dog may bark at a cat,



and he may bark at a picture of a cat (a sign), but the word "cat" (a symbol) leaves him unmoved.

Third, the sounds and expressions of animals are, for the most part, inborn rather than learned. This means that the animal is not likely to pass on to his offspring a more complicated world than that into which he was born.

Animals may have expressions that mean "Food!" "Run!" "Follow me!" "Fight!" "Look out!" "I give up!" "I love you!" But all of them, as you can see, are limited to the present. Thus the animals too are limited to the present. What they learn, they must acquire through direct experience. Man alone, thanks to language, can cut through space and time. And when we compare what we have learned by direct experience with what we have acquired by communication with others (via conversation, the printed word, and the visual image), we find that the scope of our direct experience is extremely limited.

We can carry this even a step further. It is commonly believed that thought preceded words. But just the reverse may be true! That is, not only do thoughts produce words, but words may produce thoughts. For example, in his fascinating though nightmarish book, *1984*, George Orwell described a government which has complete control of all modes of communication. It is a tyrannical, despotic government that is ruthless with those who cannot, or will not, conform. The worst crime one can commit is a political one, such as speaking against the "Party."

The government does not hesitate to alter the past by simply altering all references to a specific event. The past thus becomes whatever the Party wants to make it. The rise of electronic journalism in our own era (radio and TV), which leaves fewer and fewer written records, makes the idea even less fantastic than it was when the book was written in 1949.

But the ultimate aim of the Party is to *change the language* in such a way that even thinking about a political crime ("thoughtcrime") becomes impossible.

Unbelievable? We need go no further than the Russians' use of the words "liberty," "freedom," and "democracy," to which they have given meanings quite at variance with our own. The Communists know very well that each person both thinks and sees the world about him as his language conditions him to.

The impact of words on human life can show up in other ways. There are primitive societies even today in which the pronouncement of a spell by a witch doctor means certain death for the unfortunate victim. That it may be the victim's own fear that does him in is quite irrelevant. The point is that it works. Even among "civilized" people, rumors can ruin a man and even start panics.

Another difference between human and animal communication is that man's sounds are adaptable (as indicated by his many languages) as well as complex and repeatable. Indeed, speech has always been, and remains, the most practical and useful form of communication between individuals. It is conceivable that some new type of person-to-person communication may evolve out of present studies of language (involving perhaps smaller or larger thought units than our words), although at the moment this seems unlikely.

Thought Transference

Well, how about the claim made by some that the next great step in human communications will be one that is found under the general heading of ESP (extrasensory perception)? Other names for the process are telepathy, thought transference, and mind reading. The basic idea seems to be that there is some kind of unknown radiation which makes it possible to communicate without the use of any of the known means—sight, sound, and touch—and without regard to distance.

Many of these people claim that words are limiting and that communication by ESP will be more precise as well as more convenient and faster. The implication is that we will be able to probe directly into the communicator's mind.

Unfortunately, no one has ever been able to successfully demonstrate the process to the satisfaction of the scientific community, or to figure out what these radiations are. Invariably, when someone claiming to have powers of ESP is carefully investigated, these "powers" turn out to be based on trickery or coincidence. And we have already seen that words (or other symbologies such as that used in mathematics) appear to be fundamental to the thought process. What then would the mind reader be reading?

All the same problems would arise in ESP that we have already discussed for broadcasting in general. That is, if we have a jam in our electromagnetic spectrum, just imagine the chaos if several billion people begin to probe other people's minds with these radiations, or to project their thoughts or messages indiscriminately into the air.

You might object that the projections would not, or need not, be indiscriminate? Where, then, is the focusing apparatus that will permit "narrowcasting?"

Also, how will one handle and discriminate among the vast numbers of simultaneous signals impinging on his brain?

No, the whole idea is just too loose, too vague, to be given serious consideration for communication in the world of the future.

International Language

There are other, more likely possibilities for change in language, however. With the ever-increasing spread of instant communication, and the subsequent "shrinking" of the earth, the problem of international communication becomes more and more just that—a problem. Somewhere between three and four thousand different languages are spoken in various parts of the world. We mentioned in Chapter 1 the horrendous consequences of one little mistake in translation. It is not hard to imagine this kind of thing multiplied manyfold. What can be done?

One answer is an international language, that is, a single language that can be understood by everyone. This might take the form of worldwide use of one of the present languages, such as Russian, Chinese, French, or English. Obviously, if everyone on earth agreed to learn one of these the problem would be solved. However, even among those living in Russia today only about half speak Russian. And Chinese is really many different spoken languages. French was for a long time the language of international diplomacy, but it has been largely supplanted by English.

Today the most widely used single language in the world is English, with perhaps one in four people on earth speaking it with some level of proficiency. It has been predicted that within fifty years this figure will rise to half the world's population.

Still it seems highly unlikely that English will take hold worldwide. One can hardly imagine the Russians or Chinese agreeing to make English the official international language—either as a primary language, replacing their own, or even as a secondary one.

Another possibility is a completely new language. This would overcome the national objections that other nations would have in adopting our tongue. It would provide other possible benefits too. Our language and most others are extraordinarily illogical—both in construction and pronunciation.

The problem showed up clearly when computers became a reality. A man will accept an illogical or unclear statement. He may be smart enough to know what the speaker meant to say; or he may think he understands while really he does not. This has been the cause of many misunderstandings, even among friends. But a computer simply will not accept an illogical statement; it is quite stubborn about things like this, which is one of the reasons it is called "stupid." We are therefore learning to be more careful about how we speak to computers. And as a result some of us are learning to be more careful about how we speak to each other.

While man is to blame for most of the problems of misunderstandings, his language contributes to it. Consider the matter of pronunciation. If a language, such as English, is to become an international one, it should be relatively easy to learn. But English is one of the two most confusing languages in the world in terms of spelling, stress, and pronunciation (the other being Gaelic, spoken by the Irish). It was the English playwright George Bernard Shaw who showed that "fish," in our language, could legitimately be spelled "ghoti." We have "gh" as in tou*gh*, "o" as in women, and "ti" as in na*ti*on.

A number of artificial languages, which are usually simplified, "logicalized" combinations of existing languages, have been proposed over the years. Among the best known are Interlingua and Esperanto, in both of which international meetings have been held and publications printed. It has been stated that an advantage provided by such languages is that no one need feel a loss of national pride in using them. But this is not strictly true, for most of them are based on Western words and alphabets. The vocabulary of Esperanto, for instance, is derived from the Germanic, Greek, and Latin-Romance groups. The African and Asian languages are quite ignored.

A third approach would be what is called a *synthetic* (as against an artificial) language. Here we are really starting from scratch. The preparation of an "ideal" synthetic language would be even more complex and difficult than creation of an "ideal" artificial language. I use the quotation marks to emphasize that what might be "ideal" for one group may not be "ideal" for another. But perhaps a cleverly constructed language can get around this. At least there would not be the problem of nationalism.

As far back as the 1600's, and probably before, attempts were being made in this direction. In 1657 a man named Cave Beck proposed a system using a combination of both numbers and letters in writing. In speech, however, the numbers were replaced by spoken sounds. The admonition, "Honor thy father and thy mother," was written as *leb2314 p2477 pf2477*," but it was read *lebtoreonfo peetofosensen piftofosensen.*

As you can imagine, this attempt got no farther than did the vast majority of the seven hundred or so other constructions over the years. But the vogue for artificial and synthetic languages, which was high for a while, seems to have fallen off in recent years.

It would appear that lack of success of a world language may be due not so much to any theoretical impossibility as to absence of any real interest. Yet Lewis Mumford writes: "A world language is more important for mankind at the present moment than any conceivable advance in television or telephony."

It seems hard to dispute the point.

There are already virtually international "languages" for mathematics, music, chemistry, and even, to some extent, biology. That is, a musical score is readable and playable practically everywhere. Even score directions like *pianissimo* and *ritardando* are quite standardized.

But it must be remembered that an international notation for a specialized activity is a far cry from an international language covering a wide range of activities. Musicians and musicologists, after all, have much in common to begin with. This is hardly true of an American tourist passing through an African village.

Another problem is that in all cases the new language would have to be learned by adults as a second language. This can prove to be a major effort which relatively few people are willing to make.

However, Professor Mario Pei of Columbia University, a noted linguistics scholar, points out that two or more languages are easily learned by youngsters, and that all languages are spoken easily by their own nationals. That is, the Bantu language is no harder to the Bantu than English is to the Englishman, provided he is brought up with it. The *writing* of a language is another matter. English, with its strange spellings, is a perfect example.

Hence Pei makes the following suggestion. Let us give up on the idea of creating or adapting a universal language for the present generation. It is, he feels, quite hopeless. But with respect to future generations, we can see a far brighter picture.

Let us therefore, he suggests, appoint an international commission which will decide on some sensible choice. If they opt for an artificial language, fine. If an existing language is chosen, this too would be acceptable. But in this case there would be one proviso. The country whose language is chosen would have to agree to have its language given a phonetic spelling for international purposes. Thus, for example, the sound "f" would always be represented by *f* and not sometimes by *gh* as in trou*gh*, or *ph* as in *ph*iloso*ph*y.

Secondly, the language would be taught alongside the mother tongue to all youngsters beginning their education. It would not be "taught" as a subject, but would be used interchangeably with the primary language. Perhaps certain subjects would be taught in that language. There are a number of multilingual areas in the world today. In Switzerland children are often brought up with two and sometimes even three languages.

Pei writes:

> Within ten years, a new generation of interlinguists will crop up all over the world; within twenty, it will have grown to maturity; within thirty or forty, it will be ready to take its place at the helm of the world's affairs; within fifty or sixty, at least in civilized countries, the person that is not equipped with the interlanguage will be as rare as the illiterate is today.

Complex as this approach sounds, it is more likely to be "accomplishable" for spoken communications than automatic machine translation.

Assuming success is achieved in one way or another, would an international language eventually *replace* existing tongues? Very likely it would! (Recall Zipf's Principle of Least Effort.) However, I ask anyone who would cry over this loss to keep several things in mind:

1) We are talking in terms of centuries.

2) Languages are like living things. They change to suit the needs and desires of the people who speak them. To see how English has already changed, take a look at *The Canterbury Tales,* which were written by Geoffrey Chaucer at the end of the fourteenth century.

3) Hence the likelihood of English or any other language remaining as we know it today is very small no matter what

happens. In five hundred years, present-day English will be as much of a relic as Latin is today.

Spaceship Earth

Let us suppose a world language has indeed taken over. Will it then turn into a number of dialects, as Latin turned into Spanish, Italian, French, Portuguese, and a few others? This is very unlikely. Even though the transportation and communication of the Roman Empire was primitive compared to ours, the language remained substantially intact as long as the empire endured. It was only after the empire fell, and communications between the various parts ceased, that the isolated communities began to develop mutually incomprehensible dialects and, eventually, languages.

Today, with worldwide intercommunication already a reality, with movies and television and transistor radios, there is relatively little isolation.

Until the turn of the twentieth century, "English" English and "American" English were diverging, with very real difficulties in understanding cropping up here and there. But with the advent of modern communications and travel, the two languages have begun to grow together again. A sort of mid-Atlantic English is beginning to arise.

Perhaps, then, of all the remarkable advances we have described in this book, the accomplishment of a universal language would be the most important. For if earth is, in a very real sense, shrinking—becoming what communications professor Marshall McLuhan calls a "Global Village"—then we *must* be able to talk to one another.

The American economist Barbara Ward put it this way:

> Modern science and technology have created so close a network of communication, transport, economic interdependence—and perhaps nuclear destruction—that planet earth, on its journey through infinity, has acquired the intimacy, the fellowship, and the vulnerability of a spaceship.

Borrowing a concept from the architect/engineer R. Buckminster Fuller, she has called our world "Spaceship Earth." Imagine the navigator not being able to talk to the pilot.

11

The Printed Word

IN 1897 the Associated Press sent out a news story which was printed in many newspapers, announcing the death of Mark Twain. Shortly thereafter the writer and humorist, who was alive and well in London, sent them a telegram stating: "The reports of my death are greatly exaggerated."

Today many self-styled prophets are making what are, it seems to some people, similarly premature and unfounded announcements. We read, for example, that:

Newspapers will be a relic of the past in the world of 1984.

Letters will be left to the eccentrics who will enjoy them for themselves.

Libraries for books will have ceased to exist in the more advanced countries and most of the world's knowledge will be in machine-readable form. A few books will be preserved at museums.

Paper work will cease to exist in twenty years.

If challenged these "prophets" would probably say that they are not predicting the death of the printed word, but rather that we will see the end of the traditional form of the printed word, that is, on paper. Yet no one has really come up with anything superior.

It is true that as a medium for storage and organization, the printed page has its limitations and will need technical help. But for its basic function, a medium for the display of information, it is superb. It offers great flexibility in print style and format. It lets the reader control the rate of input. It presents enough information to occupy the reader for a convenient period of time. It is small, light, cuttable, clippable, pastable, movable, disposable, and inexpensive.

Another advantage to be claimed for the printed page is the simplicity of the system. The noted astronomer and writer Fred Hoyle has pointed out that human society is bound to become much more complex. Unfortunately, the more complex something becomes, the more likely it is that collapse will ensue—and the greater the hardship when it happens. One need only think back to the power failure that blacked out a large part of the northeastern section of the United States in 1965. Consider what would happen if all the information "owned" by society were in machines—and some disaster suddenly made all the information inaccessible.

Thus far, at least, the vast majority of our heritage of information is in printed form, making it fully accessible to anyone who can read the language it is written in.

Electronic communications have been with us now for more than half a century. The printed word may be sharing some of its importance with radio and television, but it certainly is not on its way out.

Even Marshall McLuhan, whom some call the "prophet of the electronic age," has chosen to put forth his ideas not via TV or the movies or radio or slide shows, but in books!

In the field of entertainment, too, there remains a solid place for the printed word. Books, magazines, and newspapers provide a wide range of material to choose from and are convenient to read and carry about. The novel can explore deep philosophical territory, mainly because the reader can move along at his own pace.

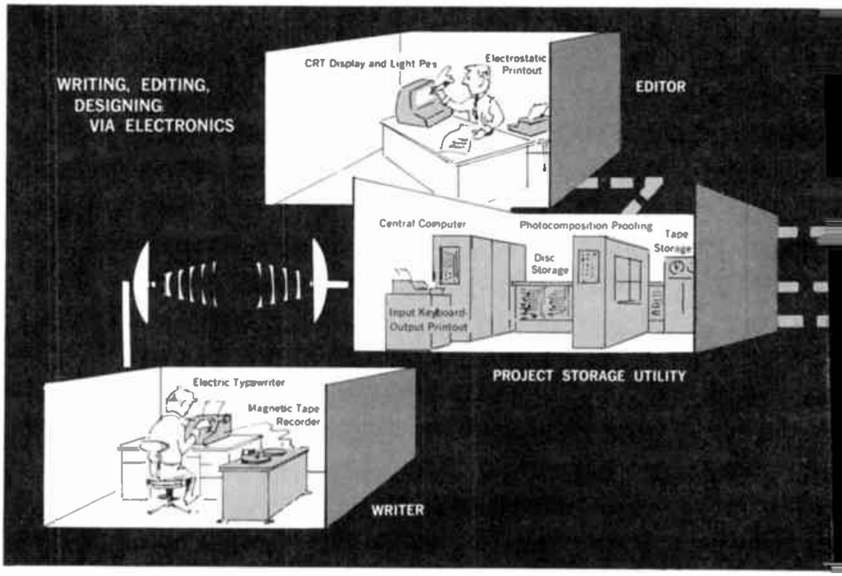
However, while the form of the printed word is not likely to change in the foreseeable future, the preparation and printing of the material will change radically, being profoundly influenced by some of the electronic technology we have already discussed. Let us take a look at some present and possible developments.

Electronics, Automation, and the Printed Word

Dr. J. R. Pierce of Bell Labs believes:

> In the future most papers, reports, books, and business correspondence will be put into machine-readable form at the first typing or keyboard operation. Such machine-readable text can be sent to distant points economically over phone lines. It can serve as computer input. It can be edited without retyping. The edited copy can be printed as a book or report without a further keyboard operation.

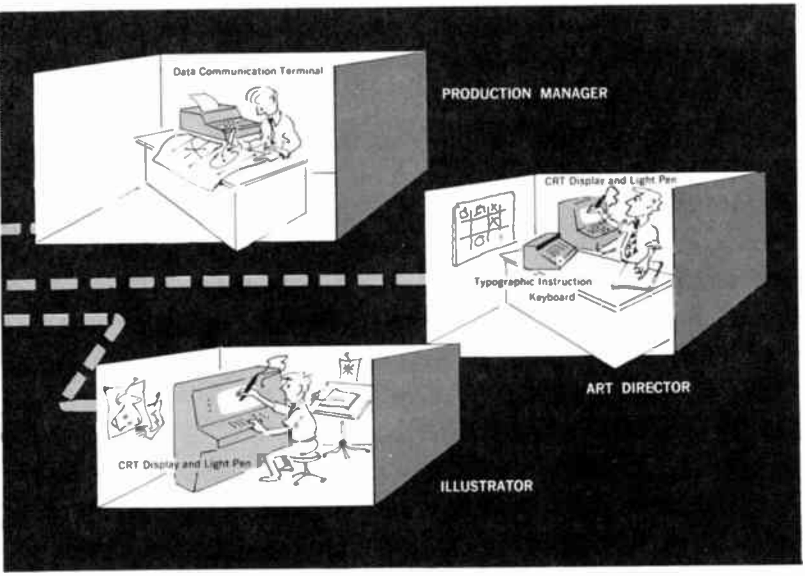
The illustration shows how such a publishing process might operate. Input/output devices such as cathode-ray tubes, light pens, and teletypewriter terminals are combined with a central computer. Due to convenient, flexible communications channels, each contributor can work in his own office, yet be an integral part of the group.



Publishing process of the future depicts information flow and storage facilities.

Another, even more important feature of such a system is the rapid response of the system to those working with it. The time-sharing operation of the computer makes it possible for everyone involved to have instant access to all that has been done up to the moment, since all of it is maintained in "Project Storage" (rather than, as sometimes happens, in someone's locked office, or even in his head when he is on vacation).

No longer need one wait a day for a draft to be retyped. With IBM's Magnetic Tape/Selectric Typewriter, one makes a magnetic tape as he types the first draft. As corrections are made on the manuscript, they are automatically entered on



the tape. Then, a push of a button produces a clean, final copy at the rate of 150 words per minute.

At the same time, this copy is entered in the computer memory, and perhaps printed out in the editor's office as well.

Or the copy could be presented to the editor on his crt terminal, on which he could do his editing by means of a light pen and keyboard unit (see Chapter 8). Changes would again be recorded simultaneously on the tape. Again a push of a button would bring forth clean, final copy; but this time hyphenation and justification (straight right as well as left margins) would also be automatically taken care of. In other words, with only a single typing operation we have produced copy ready for reproduction. Any of you who have been involved in producing a school or camp publication will understand what a tremendous advance this is.

The first draft on IBM's Selectric Typewriter has uneven right margins.

Other members of the team would also find the services very handy. The illustrator could ask the computer to search its memory for pertinent illustrative material. Illustrations not in the computer's memory could be called in from a different library source. The computer could even be used, as discussed in Chapter 8, to produce some of the required drawings. This would save the artist precious hours in measuring, drawing, and redrawing diagrams, thus leaving him free to apply his artistic talents where the computer is less capable.

Although the artist may well prepare final artwork by conventional means—ink or paint on paper or board—preliminary sketches and layouts could be displayed in several offices at once for discussion and review. Tentative changes could be made on the spot for all to see and judge. If acceptable they are put into storage; if not they are discarded. Final artwork could be entered into the system via an optical scanner.

The final copy is "justified" at both margins, and then stored on magnetic tape.

The art director could insert specifications and find out immediately how much room is available for artwork, and where and how it might best be placed. He could call for a sample page to be set in a particular typeface to see how it would look. This could be done on the crt, or he could get a "hard copy," a paper print.

The editor could instruct the machine to prepare an index, abstract, and table of contents, as well as charts or tables of numbers using data in the text.

The production manager would have all the materials at his fingertips. Estimating prices and cost projections would be easy. Automatic accounting, purchasing, billing, and scheduling would all be an integral part of the system.

Such a system would permit these members of a team to concentrate on the creative aspects of their jobs. Large amounts of nonproductive time would be saved which are now wasted on retyping several times, setting type, collecting material for conferences, and so on. Presently, with each operation in the development of text and artwork, new errors tend to creep in, and authors, editors, and proofreaders all spend unnecessary time in rereading and correcting the inevitable mistakes that occur with each stage of the process.

Hot and Cold Type

The process of putting the information into reproducible form is a remarkable one in itself. This used to be done by hand. That is, someone actually placed every single character —one small piece of type at a time—into a form. The development of the well-known Linotype machine permitted this to be done automatically as someone typed out the information on a keyboard. As each line is completed, molten metal is forced against the characters, thus forming a "line o' type." Other "hot type" machines have been devised with various advantages, but all operate on the same basic principle.

A quite different approach, developed in the 1940's, does away with the need for hot type; naturally, it is called a cold-type process. These machines operate on photographic principles and are called photocomposers. They are faster than hot-type machines and have found wide use in the typesetting industry.

The most recent development is the application of electronics to the cold-type process. These machines operate at incredible speeds. Standard Linotypes, a vast number of which are still in use, can set up newspaper lines at the rate of about 12 a minute. By contrast, an RCA machine, the Videocomp, can set up an entire magazine page in 3.5 *seconds*. These new machines are finding use in many fields, such as telephone directories, newspapers, and magazines.

The system is useful in the book field as well. The first novel to be set into type entirely by electronic composition was published in April, 1968. The advantage of the new system showed up early. When the first typesetting came out with fewer pages than anticipated, the width of the lines was reduced and the whole book was reset into a narrower format. The change, said the production editor, made a more attractive, readable book. Under normal typesetting procedure, making a change at this stage of the game would have been economically unfeasible.

The process begins as the editor marks the manuscript with the normal copy symbols and typesetting directions. Both copy and instructions are put onto tape. The tape is then run through a computer system that supplies correct hyphenation, composes proper page lengths, inserts the space breaks for the openings of chapters, and so on. Then the tape is run through an RCA Videocomp, which "reads" it and "writes" with an electronic beam on the face of a high-resolution crt at speeds of up to 600 characters a second. The fastest book composition by an earlier method was about 10 characters a second.

The characters displayed on the tube face are exposed through a lens directly onto sensitized film. For the book under discussion, it took less than ten minutes from the time the first punched tape was fed into the computer until the first page was produced by the machine. From then on pages were produced at less than ten-second intervals.

Such equipment is perhaps even more useful in high-gear operations such as newspapers. Naturally, only the larger operations can afford the necessary equipment. Unfortunately, this ties in very logically with a trend that has been all too apparent over the last number of years: fewer but larger newspapers. There used to be 500 cities with more than one newspaper; now there are only about 75.

Transmitting Newspapers by Radio

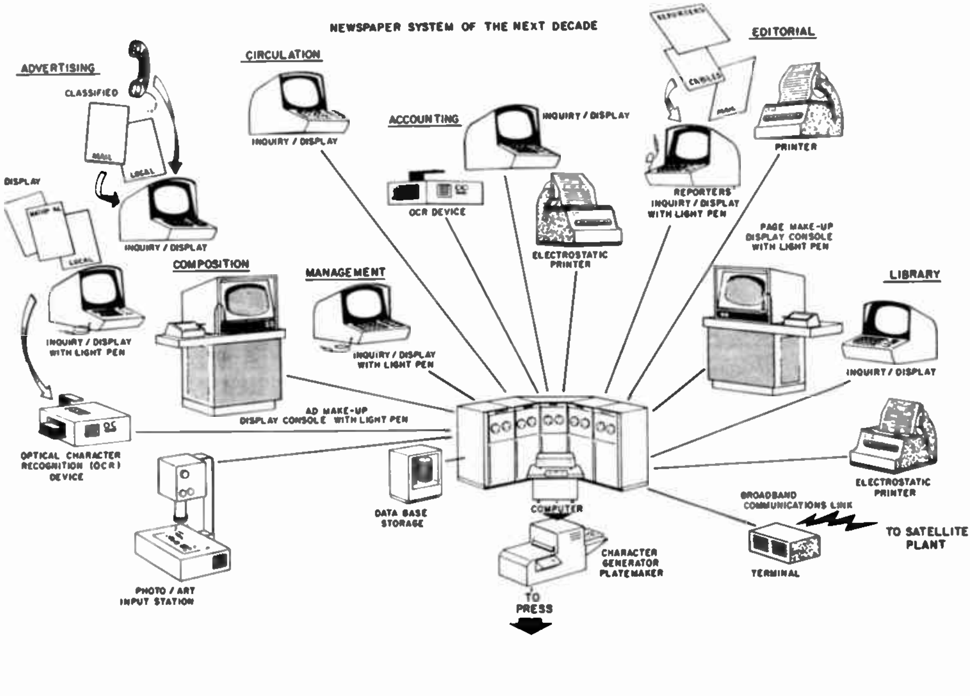
A big problem faced by many newspapers, which are of necessity "city" papers, is that of trying to distribute the finished papers through traffic-choked streets from the plant, normally located in the city center, to the outlying areas. Planes and trains are often missed; tempers are lost, and so are sales.

A further problem is increasing competition from so-called "shopper" papers. These contain local news, are distributed free, and exist on advertising revenues.

Both of these problems can be, and are being, met by setting up and using "satellite" printing plants in strategic locations. All or most of the composition facilities are located in the main plant. The finished (fully composed) paper is "transmitted" via leased lines or microwave facilities to the satellite plants, where it is printed and then distributed. This is done, for instance, with the West Coast edition of the *Wall Street Journal*, which is transmitted in facsimile form from San Francisco to Riverside, California.

With the increasing amount of international business and travel, there are more and more people away from home. One way to keep them in touch with developments at home is to have their favorite paper available to them. This can be accomplished by having it mailed, which is often done.

The flow of information, controls, and commands is illustrated in this newspaper system of the 1970's.

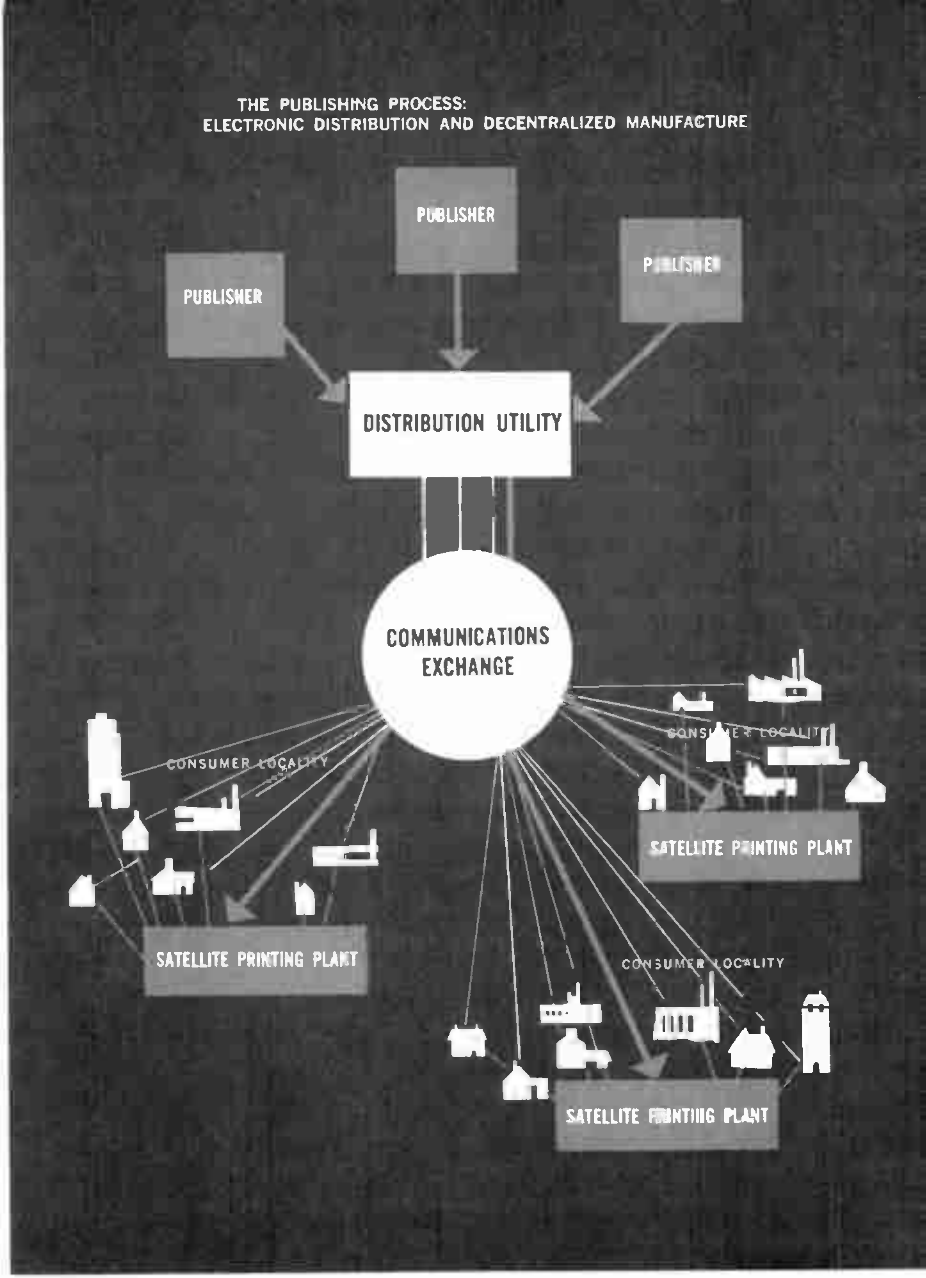


Another approach is to put together and print an overseas edition of the paper in some of the larger capitals of the world (utilizing text transmitted by the home plant), from which it can be distributed as needed. These papers can now be composed in the United States and still be published simultaneously with the mainland editions! An experimental transmission of this sort took place when the entire front page of the October 17, 1967, issue of the *London Daily Express* was sent via satellite to San Juan, Puerto Rico. Signals representing the page were sent by means of the London newspaper's facsimile transmitter (normally used to send photos) to the British Post Office's satellite ground station at Goonhilly Downs over the equivalent of twelve telephone channels. From there the signals traveled up to the Early Bird satellite stationed over the Atlantic, then down again to a Canadian ground station in Nova Scotia, and then by Canadian Overseas Telecommunications Corporation circuits to the United States border, where they were picked up by A T & T and sent by land line to West Palm Beach, Florida, and finally on to San Juan by submarine cable. Total distance was about 50,000 miles.

This was the first time a full-size newspaper page had been transmitted between continents and the first time a communications satellite had been used for such a purpose. The transmission took less than 15 minutes. With wider band facilities, transmission can be accomplished even faster; with multiplexing, several pages can be sent at the same time.

But how about the second problem mentioned earlier, namely that of the local competition? One approach is to print local news in the various satellite plants. Thus the paper has the advantage of providing local, regional, and national news.

Carrying this still further, we have the idea of supplying



Satellite printing plants depicted for the future to speed up communication networks.

people with only the information they are particularly interested in. The idea is similar to the information retrieval systems we discussed in Chapter 7, but here it is applied to newspapers. The result is a combination of the advantages of custom and mass communication. Corporations like IBM and Bell Telephone have already developed prototypes of such systems in which new material is matched by machine to user interest. Users identify themselves to the machine by means of an "interest profile," a form listing areas of information in which they are primarily interested. When information is received in a central clearing house it is automatically printed in the proper numbers and distributed to those who have indicated that they would be interested in seeing it.

Perhaps in the future you will receive a morning newspaper containing information only on sports, education, science, or whatever your interests are. It could be a supplement to the regular newspaper, or it could take the form of a series of abstracts only, with some sort of provision whereby you could then request the full text of those stories in which you are interested.

It might be possible to receive this information (or even the whole newspaper) electronically. RCA, for instance, has developed a television facsimile system which could accomplish this. Printed copy scanned at the transmitter is slipped into the outgoing television signal during the vertical blanking period—that time interval when the beam in the TV tube is returning from the lower right portion of the screen to the upper left. Thus no additional spectrum space is necessary and the TV picture being transmitted is not affected. An electrostatic printer (similar to the well known Xerox copier) produces the equivalent of a paperback page every ten seconds.

RCA's facsimile television system is used to transmit printed material.

However, it would add roughly the price of another TV set to the system.

Dr. James Hillier of RCA suggests that such a system would be especially useful for printed news briefs, sports, scores, stock market reports, charts—indeed, anything that would usefully require a hard copy.

The idea of the facsimile newspaper page coming out of the TV set is not a new one. Some researchers feel, however, that it does not offer anything that cannot presently be done more economically and efficiently in other ways. As a news medium, for example, it serves no real purpose. Indeed, the "hotter" the news the less there is to be said about it. We can already get the latest news on a convenient five-minute roundup on radio every half hour, and many stations broadcast nothing but news.

As for stock market reports, one can already purchase or rent a system in which a button input brings an immediate voice-answer (or some type of display) quotation for any stock on the market. CATV often has a channel devoted to stock quotations.

Nevertheless, there are cases, as we have seen, where hard copy is useful. Perhaps this is the way we will receive the full text of news stories in which we are particularly interested. And, as part of a larger home system, this may well come to pass.

Books to Order

In the meantime, there is another area of the printed communications field where electronics may very well answer a more pressing need. Except in some special areas, book publishers really have no practical way to get their product to potential customers. The present method is slow, cumbersome, unreliable in terms of demand, and expensive. It can safely be said that the biggest problems are not in the creation of the book, but in the printing and particularly the distribution of the end product.

Current methods of distribution rely on the mails, jobbers, wholesalers, distributors, retailers, and shipping systems. All depend entirely on the physical handling of thousands of tons of materials over long distances. As Paul D. Doebler and Jules S. Tewlowe point out in an article in the trade magazine *Book Production Industry*,

> Much of publishing's operational pattern has been determined by the fact that we create a physical product at the first possible opportunity . . . Warehousing of finished books has become a major activity because large manufacturing lots must be broken down and reassembled into small orders, usually over long periods of time. And it has given rise to complex systems of shipping and billing.

Because there is simply no way to predict in advance how well a book will sell at a particular outlet, stocks are invariably too large or too small. This leads either to frantic scrambling for rush orders, or a complex and costly system of returns because small retailers cannot afford the cost of unsold products. No single outlet can possibly stock all books published (some 30,000 each year in the United States alone) and in quantities that would ensure a copy for every person who wants one. Every customer has been told many times, "No, I'm sorry, we don't have that in stock, but we can order it for you. It will take about two weeks to get it in."

Is it possible that, except perhaps for the very few best sellers, the distribution process will be reversed? How about a completely automated printing plant in your local area? You could call the shop the night before you want to go down to pick it up. At closing time the printer would call into a regional or national information distribution facility and ask for transmission of the required books. The final product could then be picked up the next day, or even delivered as newspapers are today.

If you are in a rush and are willing to pay a little extra, the shop owner could make a special call and have the book for you in minutes. He might even have tapes of some of the more popular books on hand.

This arrangement would eliminate problems of multiple warehousing (for the retailer, wholesaler, and publisher). And it would eliminate returns of out-of-date or otherwise unsold items.

It would apparently also eliminate browsing and being able to look through a book to see if it is what you want. But perhaps this could be taken care of by providing viewing screens and access to the central distribution tapes.

The hypothetical system shown consists essentially of three main sections:

1) The electronic receiving system; coded signals would contain, in addition to the text and illustrations, information on the size of the pages, kind of type, any color used.

2) Some form of printing machinery.

3) An adhesive binder of the familiar paperback type, although hard covers and sewn bindings are not out of the question.

We have already covered the electronics involved in 1).

Here we will make some comments on 2) and 3). Tackling the last section first, we find that paperback books have already wrought a·major change in the book industry since their introduction about thirty years ago. Sales of paperbacks have risen to something like a million a day. It may well be that this will be carried even further than it has been. Science, for example, is moving so fast that original publication in soft cover might be a good idea. Such books are cheaper and easier to produce than the traditional hard-bound type, especially in terms of some of the new equipment we have already discussed.

Textbooks tend to go out of date equally quickly. Paperbacks have been used with great success in many schools. Another approach is the use of such devices as "do-it-yourself anthologies"—that is, making the various readings in a field available as separate items which can be bound in varying combinations. As some items go out of date, they can easily be replaced by new ones.

Turning now to the printing portion of our new system, we recognize that printers can only produce economically if they run thousands of the same page at a time. Thanks to new methods of printing, this won't be necessary. In a certain sense the "copying revolution," sparked by the Xerox electrostatic copier, has shown this to be true. It is already often easier and cheaper to make copies of chapters, articles, even whole books, than to try to purchase the original.

But even newer methods of printing are on tap. An "ink-jet printer" is available which sprays electrically charged drops of ink; these are deflected into the desired shapes by an electric field. Information can be printed at up to 72,000 characters per minute. At this rate a 48,000 word book (roughly two hundred pages) would take only about four minutes to print. This would be done in continuous fashion, on both sides of a continuous sheet which is then fan-folded, cut, and bound.

Such a system would be particularly useful in the field of educational materials, where obtaining timely and up-to-date information has traditionally been a problem. In the new method, the revised editions or other materials would be available within hours after the revisions have been made.

Edward E. Booher, Chairman of the McGraw-Hill Book Company, feels that the familiar textbook will be supplemented, and possibly replaced, by many kinds of other printed materials, such as "manuals, pamphlets, paperbacks, and, I suspect, some forms that haven't yet been invented."

Epilogue

WE NOW have four "pipes" coming into our homes: water, gas, electricity, and telephone. Perhaps we will one day have a fifth—an information pipe. A vast range of information and entertainment would then be at our fingertips. The computer would be no farther from us than a plug in the wall. And the most incredible realism would be present in both mass and person-to-person communications.

As exciting as all of this sounds, its greatest promise lies elsewhere—in man's search for world peace and understanding.

This millennium may never come. But if it does, improved communications will certainly have played a major role.

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