INCIDENTAL PAPER

Seminar on Command, Control, Communications, and Intelligence

The Convergence of C^3I Techniques and Technology
William O. Baker

Guest Presentations, Spring 1981
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THE CONVERGENCE OF C³I TECHNIQUES AND TECHNOLOGY

William O. Baker

Chairman, Bell Laboratories, Inc. (Ret.)

Dr. Baker rose to his present eminence via responsibility for Bell Labs' renowned research capability, whose discoveries have led to some fundamental modern technology: transistors, superconductors, lasers. As a technologist, he shares the view that the very existence of technology — the digital computer, for example — inevitably dictates new ways of doing things, in C³I as elsewhere.

Baker. The notions I will propose today are pretty well summarized in an old Yankee story. The election campaign in Vermont was underway; the candidates were flowing with rhetoric about what they would do and what the issues were. After a particularly flowery and obscure session one observer turned to the other and said, "What's he talking about?" The other said, "He don't say." And that, of course, is exactly what is happening in our government command, control and intelligence arena.

We've struggled with this for a long time. Tony Oettinger has been a co-conspirator in the many movements of the past three to five years that have enhanced and advanced, modestly, our ability to deal with the keen questions of national security involved in this arena you are probing. It was President Eisenhower who brought many of us into this matter, following his experience with the episodes in Lebanon. On the one hand, it was believed (in a fashion which is now rather familiar in external crises) that it would be necessary to land the Marines. On the other hand it was found that the diplomatic corps had created a rapport which made it unnecessary to mount an actual invasion. The information contributing to these conflicting assessments was buzzing around the President's environs, but was sorted out so poorly, and communicated so crudely, that eventually the ambassador ran down on the beach waving his handkerchief and imploring the Marines not to land. This had a profound effect upon General Eisenhower, who had had quite a lot to do with landings, and he believed, rightly, that we ought to do something about it.

One of the early therapies applied to this problem was the evolution and revision of the Criticoms — the signals, based on current intelligence, that govern worldwide action. An able captain, Howard Enderlin, committed much of the last years of his distinguished career to creating a Criticom regime for the United States which could react in a few minutes at the most, at best in less than a minute; and that was one of the happy experiences in the ongoing process of trying to communicate and process the crucial command/control intelligence messages. The torn tape techniques that had previously dominated the Criticom process meant that committed individuals around the globe had to tear off pieces of teletype tapes, run across the room to another machine and somehow convey them to the Commander-in-Chief or his delegate.

Now that is a poignant reminder of the theme Professor Oettinger has developed so skillfully: that eventually there ought to be some kind of unity, some kind of coherence, some kind of common meaning to C^3I in the broad sense. In terms of current affairs, he was noting that the development process, the acquisition of systems, the guidance of command/control intelligence through the Pentagon, which is primarily focused in DDR&E (Director, Defense Research and Engineering), is in a fragile state. Indeed, he is right.

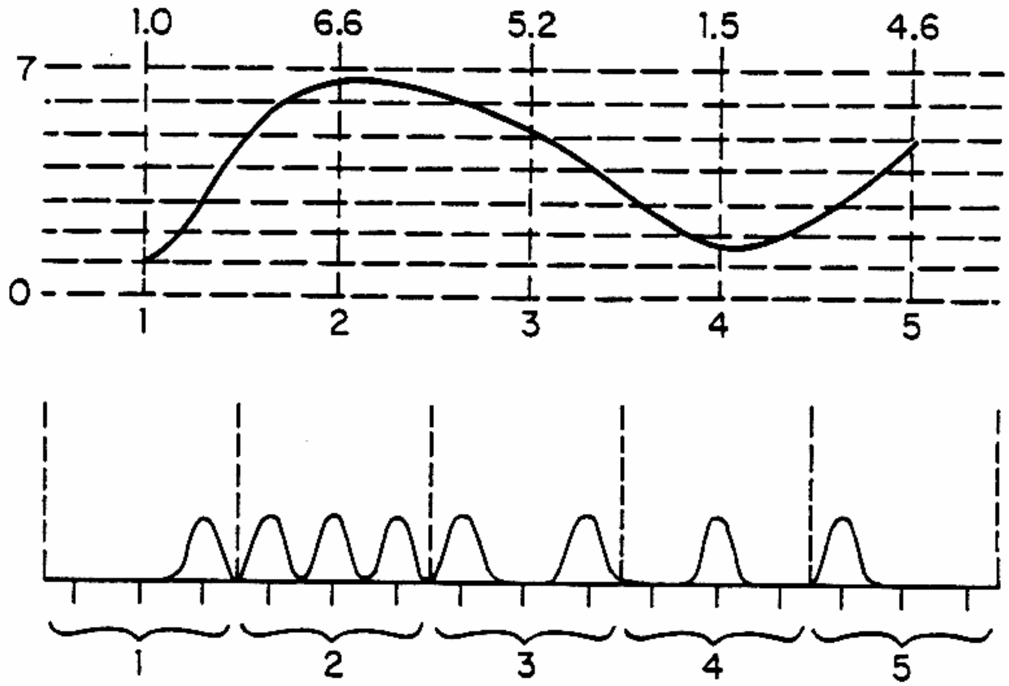
The ironies of the DDR&E method of development procurement are many. Some of you, or your predecessors in this seminar, have pointed them out very neatly in your essays, which I greatly enjoyed reading. For instance, you have pointed out that the secretaries of the Services have no command responsibility. That's true, and it leads to problems. The National Command System, which many of us worked on, particularly in the late 1950s and early 60s, does structure the situation as the 1947 act suggested, through the Secretary of Defense and the unified and specified commands and other commanders. But the Service secretaries and their staffs have a great deal to do with procurement, technology, and the ways systems are acquired, quite outside the direct operations of the DDR&E. DDR&E suggests how it is done overall; but then a charming contest ensues to see how it can be done differently — because the worst experience for any Service is, of course, to find some other Service doing it the same way.

This reluctance to interchange is known to you all, I'm sure, in many forms; but in command/control intelligence it is a fatal malady when the very important actions of the Services do not get interwoven. We have had many dismal experiences with that in recent years in Southeast Asia, Korea and other places. So let's look at how technology, operations and science can affect this situation, and how our proven resources and proven capabilities in intelligence and command/control communications and computers can be brought to bear.

The approach can be twofold. One aspect is to see what we can do to supplement and augment human capabilities, and how these systems, of which there are dozens and dozens in the military and throughout the government establishment, can be brought together. The other is what relationship this capability should have to the human exercise of command/control intelligence. The human exercise, of course, is primarily that of perception and language — the two sometimes are not closely connected, but ideally there should be a relationship. Perception occurs pretty often in the mind, but there may be sensors involved; it may be vision, it may be some sense of what is going on in hearing and vision. The technological capabilities, in the meantime, are coming to couple more and more closely with perception. To get a sense of dimension, we might remark that the linkage of human activities with machines, with computers and communications — in short, software, which is the linkage between what you want the system to do and what the machines are able to do — is now about 5% of the DOD budget, no less than $6.7 billion a year. By 1985 it is almost certain, conservatively, to be about $12 to $15 billion, or something over 6%. Now that is a huge fraction, just too much money for what we're getting. It does represent a huge commitment to do things much better, and to do them so that they work. But what we get for those billions doesn't work; the software is just nonfunctional. You've all read about WWMCCS and the other failures.

Intelligence is disrupted and dispersed in the defense/intelligence arena. This is a post-Schlesinger period, so the situation now is a little worse. Just operating systems in the present circumstances is rather hopeless. That gives us a good place to start. In the communications area alone, all kinds of uncontrolled sections are likely to work badly or not at all as emergencies arise. So there's little doubt that our command, control, communications and intelligence system physically, and our structure organizationally, are both ready for change and improvement.

Fortunately nature is with us. You all recognize that it's now possible — as observed by Hartley and Nyquist many years ago and elegantly construed by Shannon, Weaver and Wiener and their collaborators — to represent all knowledge, all perception, signals and information in electromagnetic form not only by analog waves, as at the top of Figure 1, which shows your regular telephone voice message. For this can be done equally well by the digital signal shown at the bottom. It's this that gives us our extraordinary confidence that the Department of Defense, and the nation generally, can now move into a stage of skill in command/control and intelligence which is both unprecedented and suitable to our needs. It would be nice to think that something like this also goes on in people's brains, and that we have a continuum between Shannon's theorem that digital representation is virtually complete, so that you can represent anything by electromagnetic pulses or electromagnetic waves, and the extraordinary ability of living matter to exhibit intelligence. But we don't find such a continuum, and we've not found the connections. The neurons are a very rugged system; they do a wonderful lot of processing. We know there are things like analog waves that move around in the nervous system, and we know there are pulses which don't act like those digital waves. What we've got to do is find flexible ways to couple this kind of resource in nature with the human elements in usage, despite not quite knowing how all this gets connected in the mind.



Amplitude	Code
0	000
1	001
2	010
3	011
4	100
5	101
6	110
7	111

It's been confirmed, I think, that only about 40 bits per second of these digital pulses can get into the human channels. It's not that one knows how to define those bits, for this is a purely empirical thing, but when you consider the number of them that could be processed per second (easily a billion now), clearly that disparity is something we've got to remember every minute: 40 bits per second out of the available billion are about the most any observer, any listener, writer, maker of marks, reader of print, can absorb.

Figure 2 will help us get these parameters more firmly in mind. Here is a million-billion-bit pulse, one of the picosecond pulses which are very easy to produce now using lasers, and which are being applied extensively for digital communication in our laboratories and elsewhere. These pulses are separated by a million-billionth of a second (we get them even a little faster than that), and the mechanisms of processing, detecting and transmitting through light guides (fibers) are all very easy. Integrated optics form the circuitry that handles these pulses.

So the opportunities are extensive. The thing to remember is that these pulses — which are a form of open-coded knowledge — are handled in the familiar modes by the ordinary terminals and transmission media (Figure 3); there's nothing special about it. It all functions with great efficiency in the telephones, Picturephones®, computers, TV cameras and receivers which are so much the center of our modern culture. It is carried by satellites, cables, microwaves, and all the rest. So we've got the established capabilities, we've got the ways of processing and handling these things, based on integrated circuits and on electronic ones. Figure 4 shows a MAC8 processor which has a few thousand systems on it, Figure 5 one of our MAC4s. They bring out my point: that this is all so cheap, so effective, so convenient that we are now really pressed to come up with software, with processes for using these things, so that we'll be in balance with the potential of the facility itself. This MAC4 has 18,000 transistors, about 5000 bits of memory, it'll handle 43 instructions, and it's rather small and typical of the great generations coming on. We'll see in a few minutes that these things will handle the digital manipulation of intelligence, of commands, of text, in ways that are versatile and powerful. They will enable us to close in on the goal of coherence in the national command and control system by requiring the human expression, the language, to be machined into a coherent and intelligible form. And these machines are so convenient, so numerous, so efficient that there's no excuse for failing to do it that way.

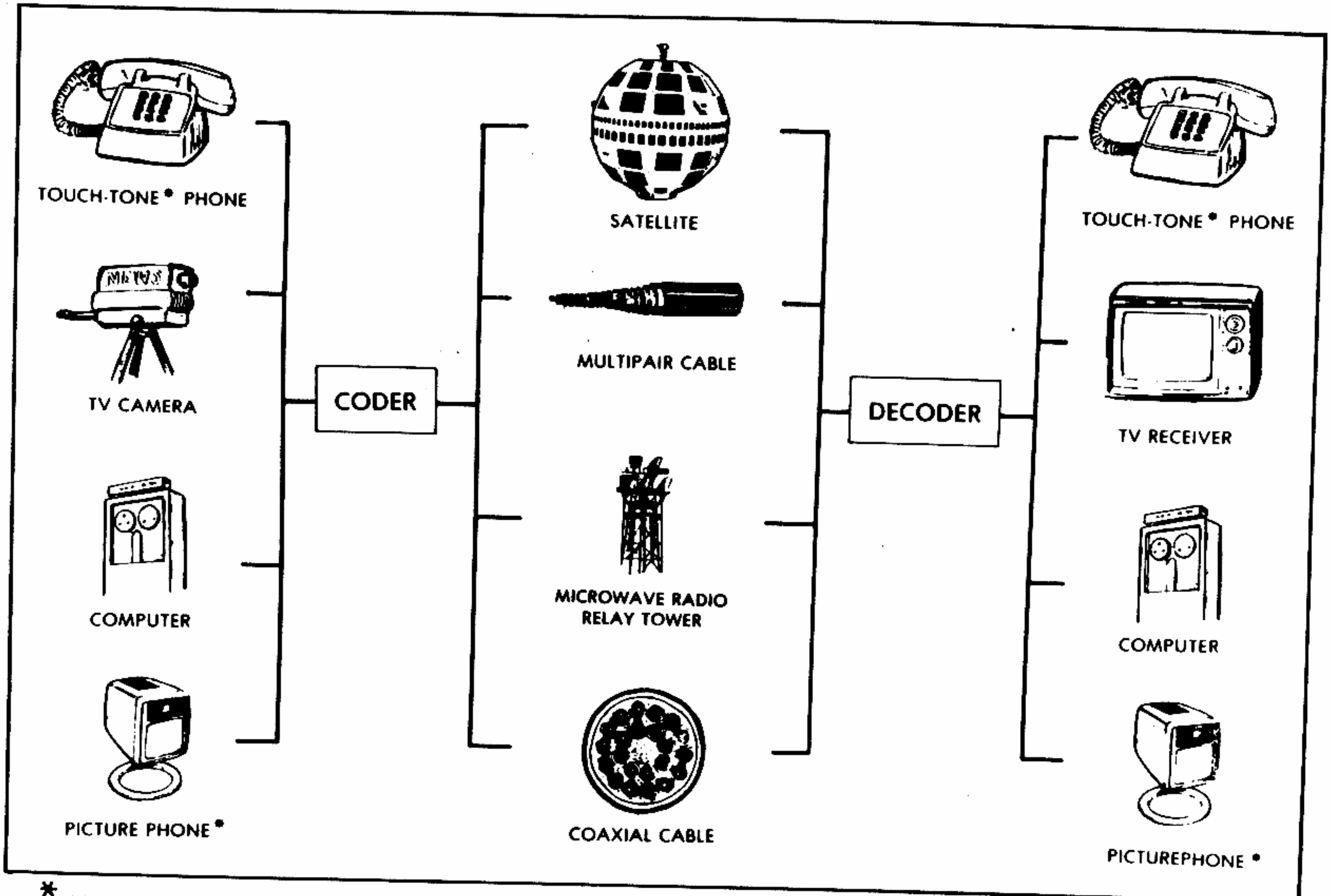
Student. Is the Picturephone® a viable commercial product?

Baker. Yes, conferences are sensibly and quite effectively based on it. There are conference centers in major cities. It is still too expensive for individual subscribers (but does not exclude them by any means) because not enough subscribers have Picturephones® yet to make the switching efficient in a particular area. But they are quite extensively used in the conference centers.

Now, the cost per circuit, as you see (Figure 6), has dropped to 10^{-5} of the original level. In fact, it's down even better than we show for 1981; that curve is coming down a little more steeply. So you can afford to spread around large quantities of these circuits. In

Figure 2. A Picosecond Pulse

TRANSMISSION MEDIA



*TRADEMARK OF THE AT&T CO

Figure 3. Transmission Media

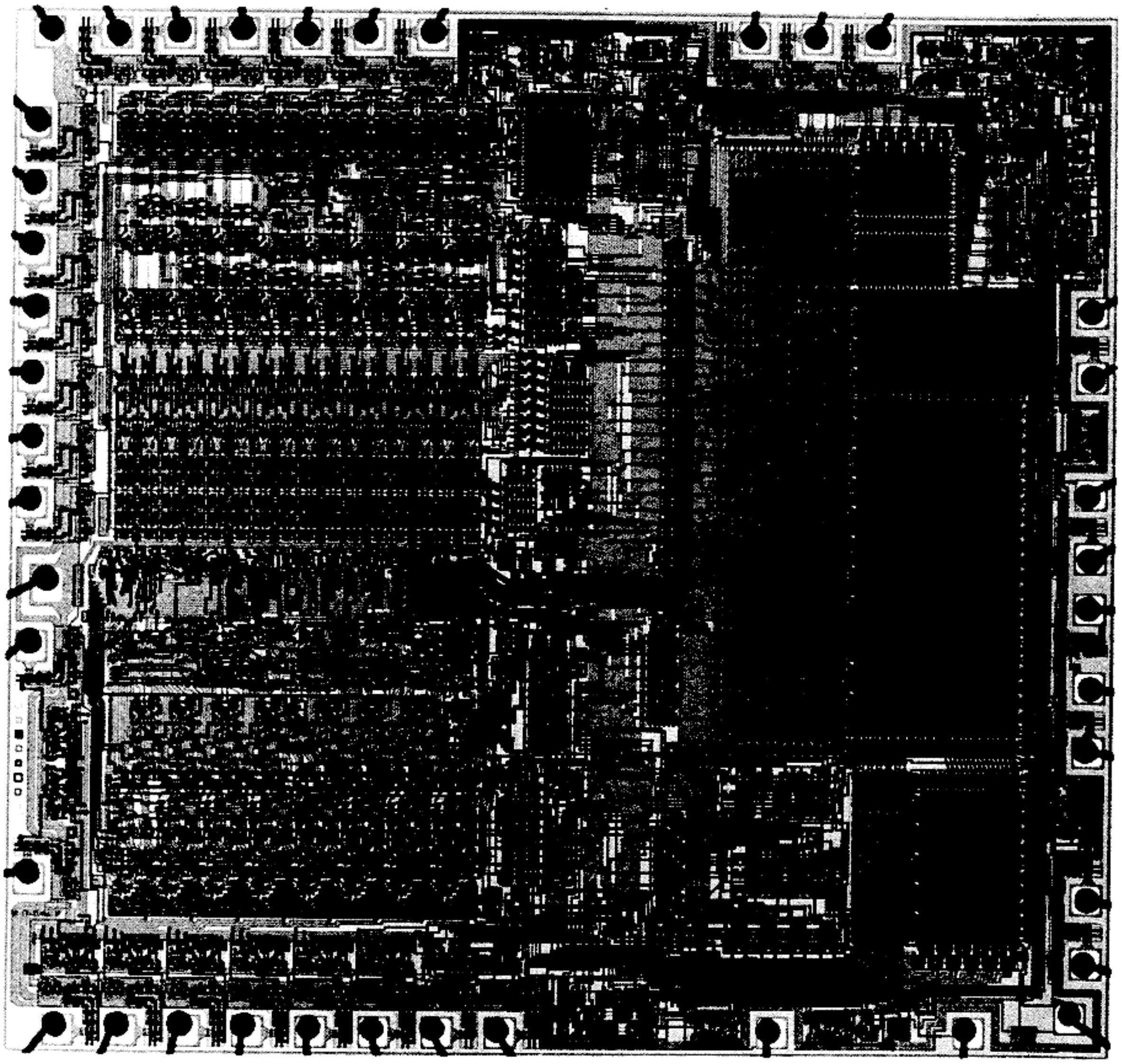


Figure 4. MAC8 Processor

INTEGRATED CIRCUITS

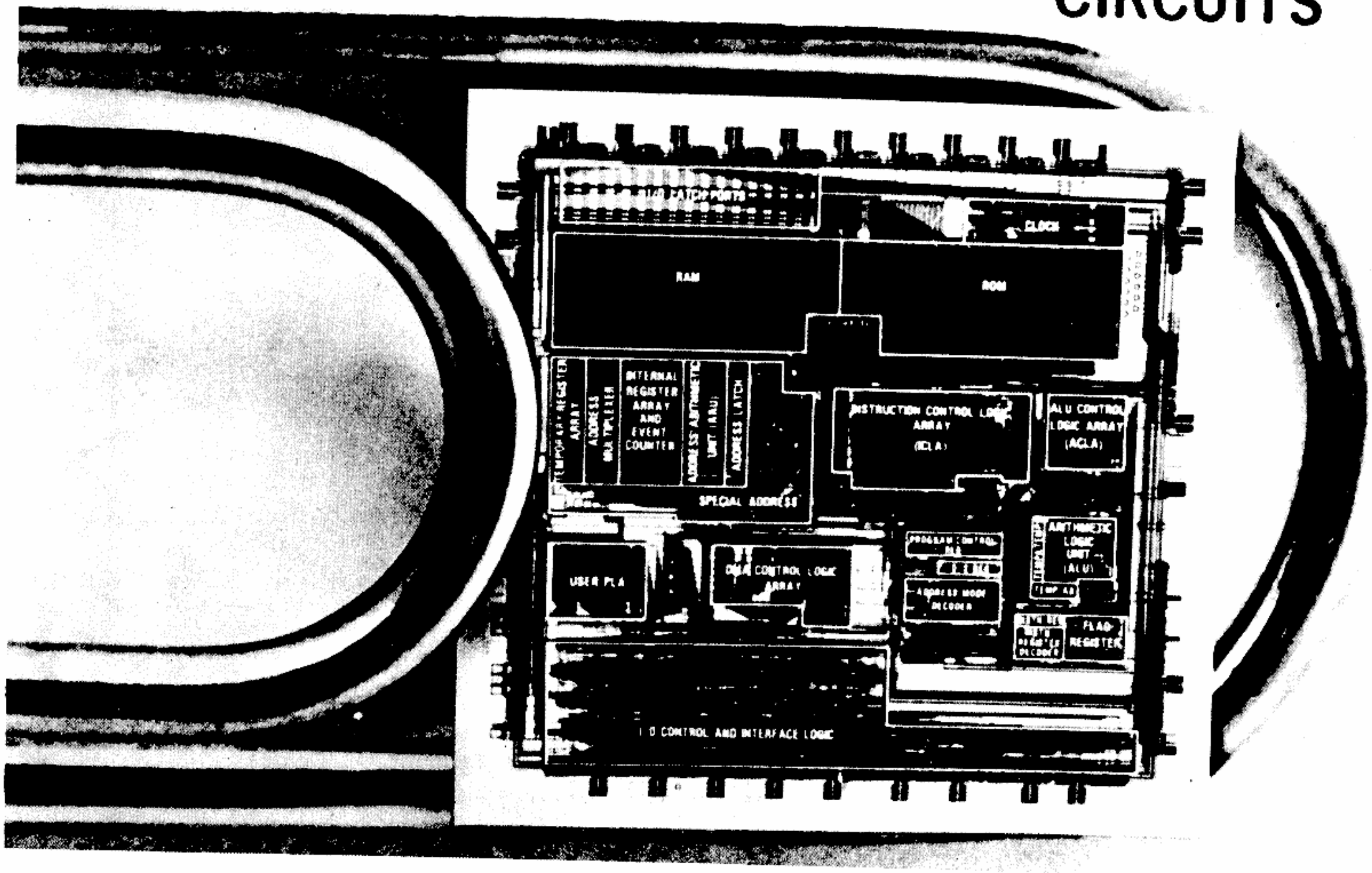


Figure 5. MAC4 Processor

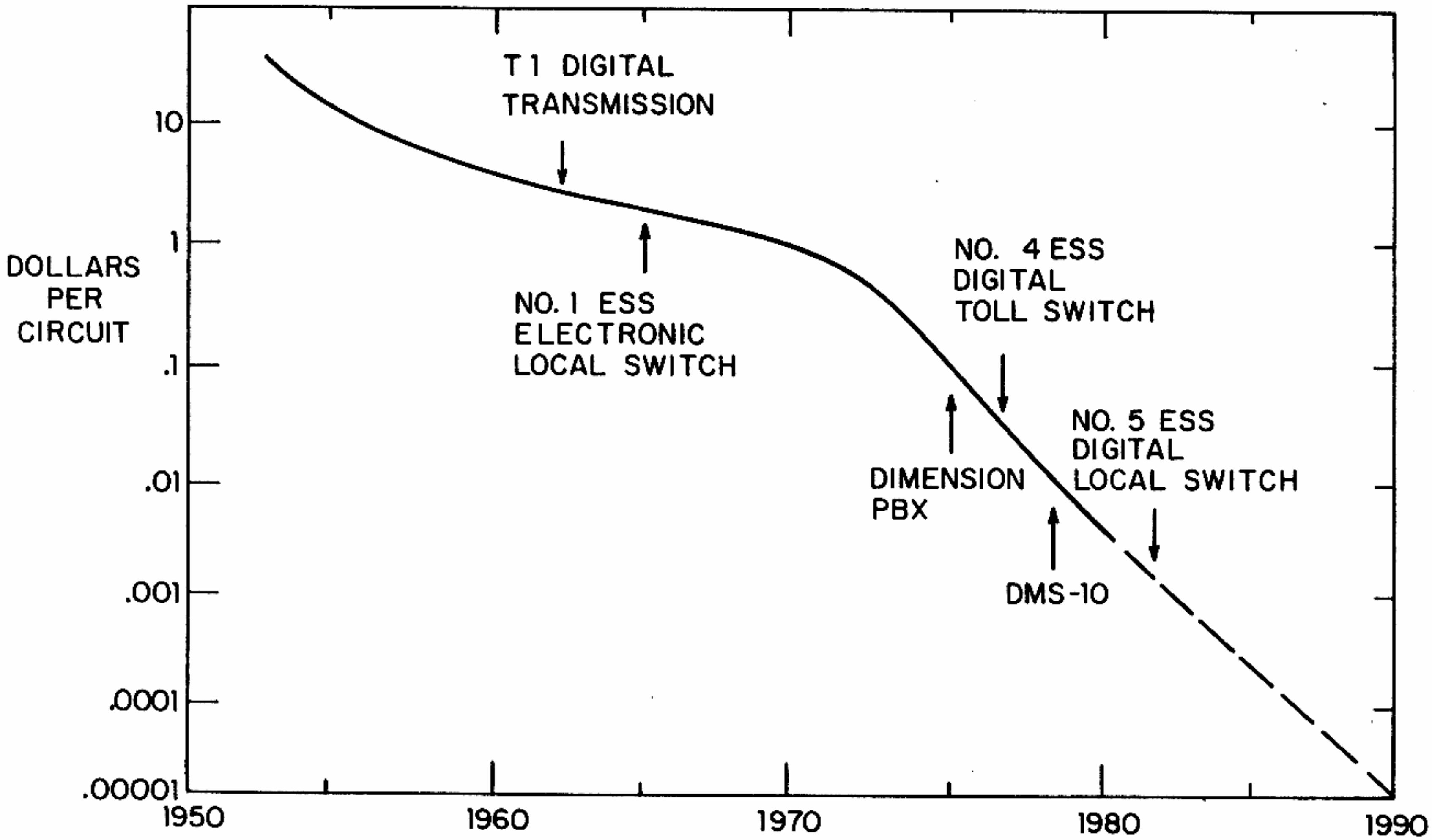


Figure 6. Trend in Digital Integrated Circuits

command and control the economy leaders are exemplified by the T-1 digital transmis- sion, which is the first large digital capability beyond the telegraph. It runs at very high speeds, and was the first real coherence introduced into Washington's command and control intelligence community. Computation cost, which involves both the power and the actual apparatus of computing on machines, is down too (Figure 7), very much lower than was ever imagined when the command/control systems that are still conventional were set up. Meanwhile the power in relative terms is rising, also exponentially (Figure 8), so there's little problem in doing what I am going to propose to you today. The machine, the language, the actions of intelligence and command/control: the implications of this for all kinds of technologies and business and other affairs, of course, are enormous. And these can be distributed. There's no problem of having either overlocalization or overcentrali- zation. We and others are already operating extensively in this manner, using hierarchical systems whose remote processors can be connected to module processors connected to central processors (Figure 9). This is just made to order for the highly hierarchical systems typical in command and control and, using persuasion, we have already introduced a few such structures into the intelligence networks.

The other theme Professor Oettinger has cited is startlingly evident — that you don't want to fragment the whole national structure in introducing these technologies. On the contrary, you want to take advantage of the hierarchy and bring our forces and our capabilities together through it. That requires commonality of software as well as of transmission modes. Both those things are entirely practical and, in fact, economical. These systems can be managed by qualified, competent people without having to disrupt the applications, and the operating systems, which are the essence of the software, have a coherence and a sense of purpose these days which can be controlled, updated by the facilities shown in Figure 10 — arithmetic unit and so forth — so that the applications can be assured the best resources available. You don't have to have narrow specializa- tions. The field is entirely served by an organization of operating systems. This is a relatively new capability, but it's ready.

In business (which, perhaps because of its economic desperation, is likely to get to these things a little faster than the military) these capabilities are all being put to use (Figure 11); and this center at Harvard is one of the pioneers in showing business leadership and the community what this sort of resource can mean to them. It means the difference, of course, between profit and loss, between survival and decay in the face of present world competition. I could give you an earful about our experiences with the Japanese automo- bile business, and how they are trying to use some of these systems; about the ways in which America can maintain much of its commercial and business leadership if it does move to these systems; about how they are spreading throughout very farsighted busi- nesses; but that isn't the subject this afternoon. The point is that there is a precise equivalence between what these systems are established to do in the world of commerce and what they can do in the military and government spheres if they are allowed to.

Student. What's retarding dissemination of such systems in industry? If costs are going down so rapidly, it must be economical. Why have businesses not been more quick to adapt?

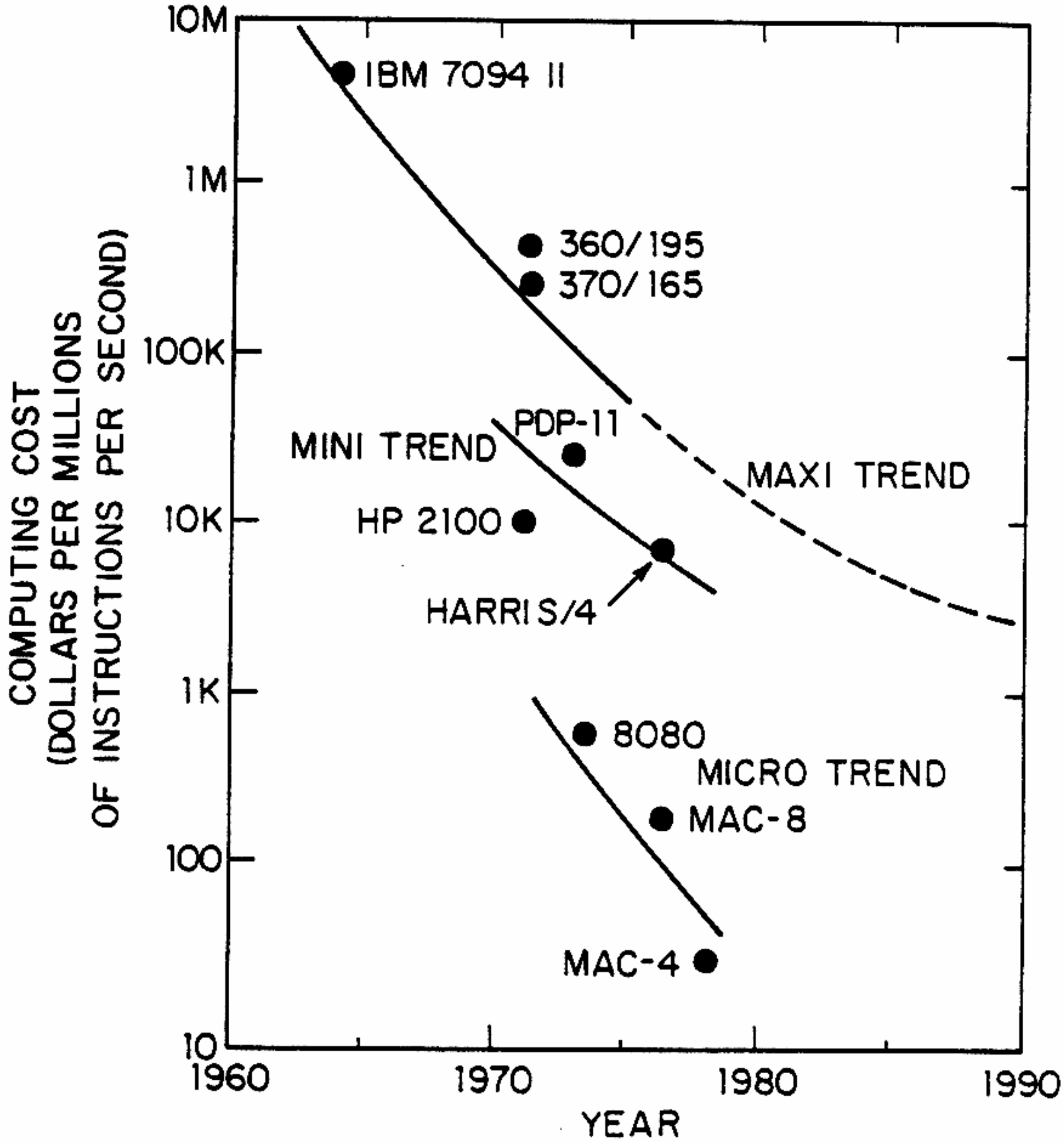


Figure 7. Computation Cost Trend

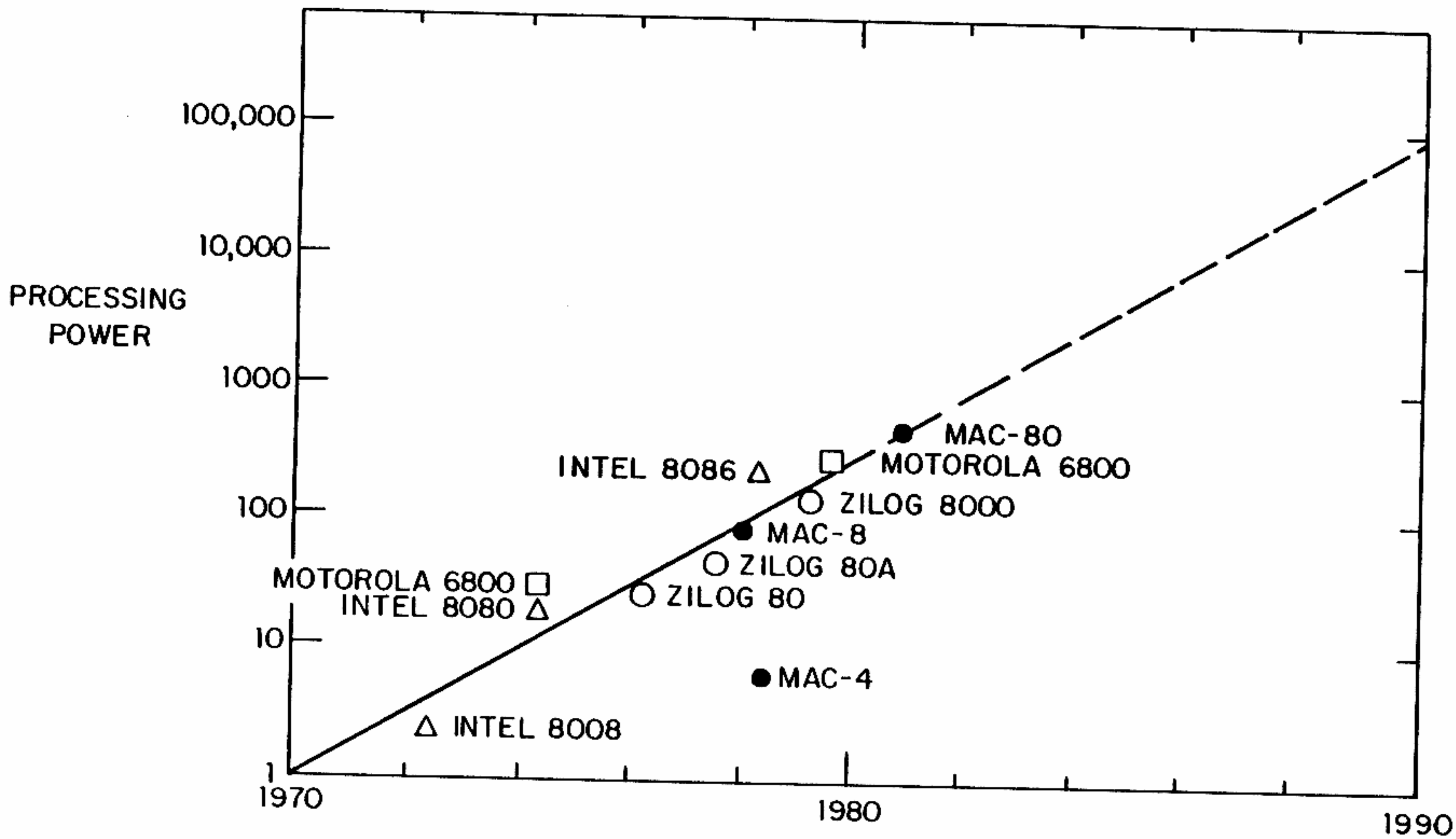


Figure 8. Trend in Microcomputer Processing Power

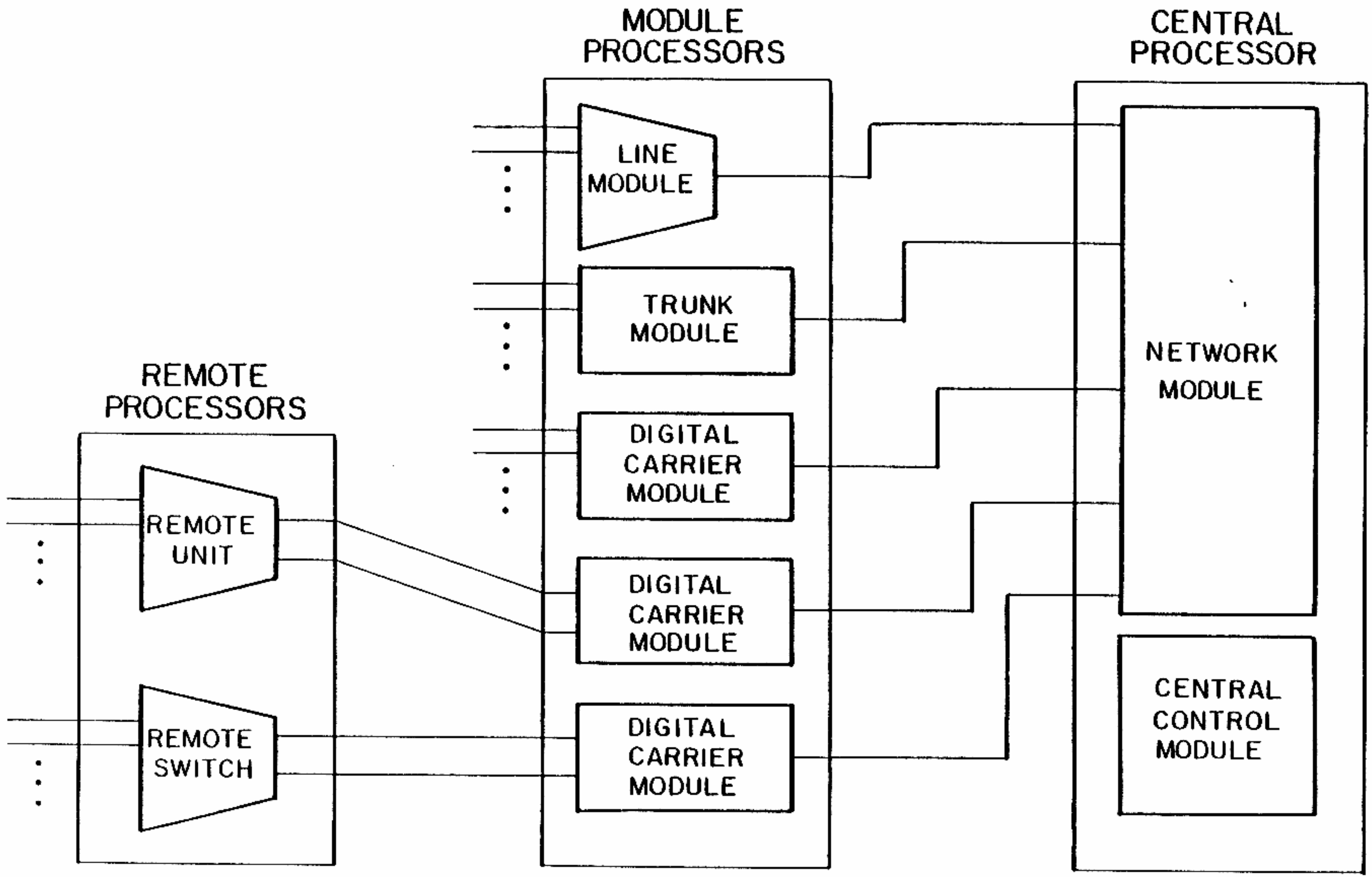


Figure 9. System Architecture

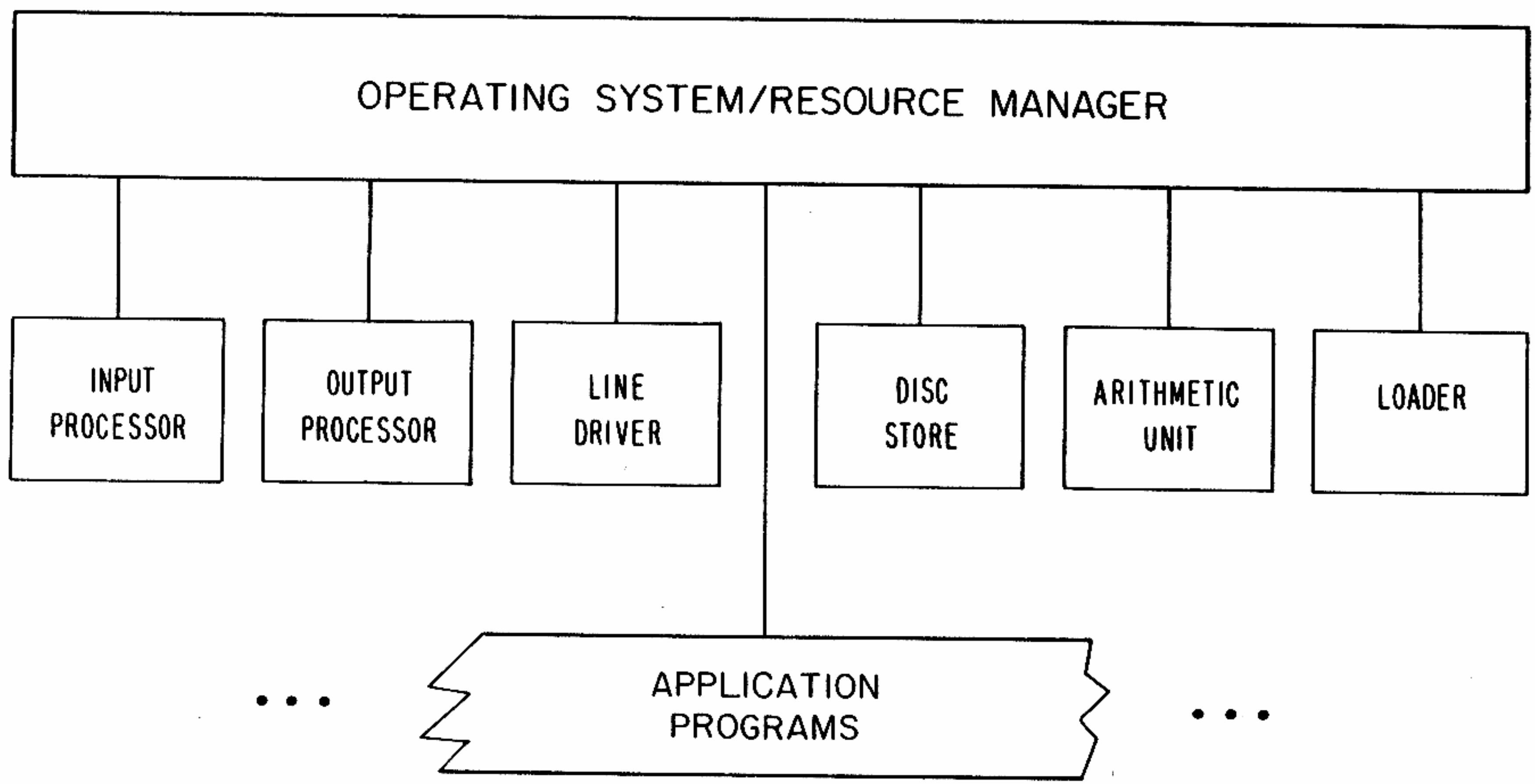


Figure 10. Operating System

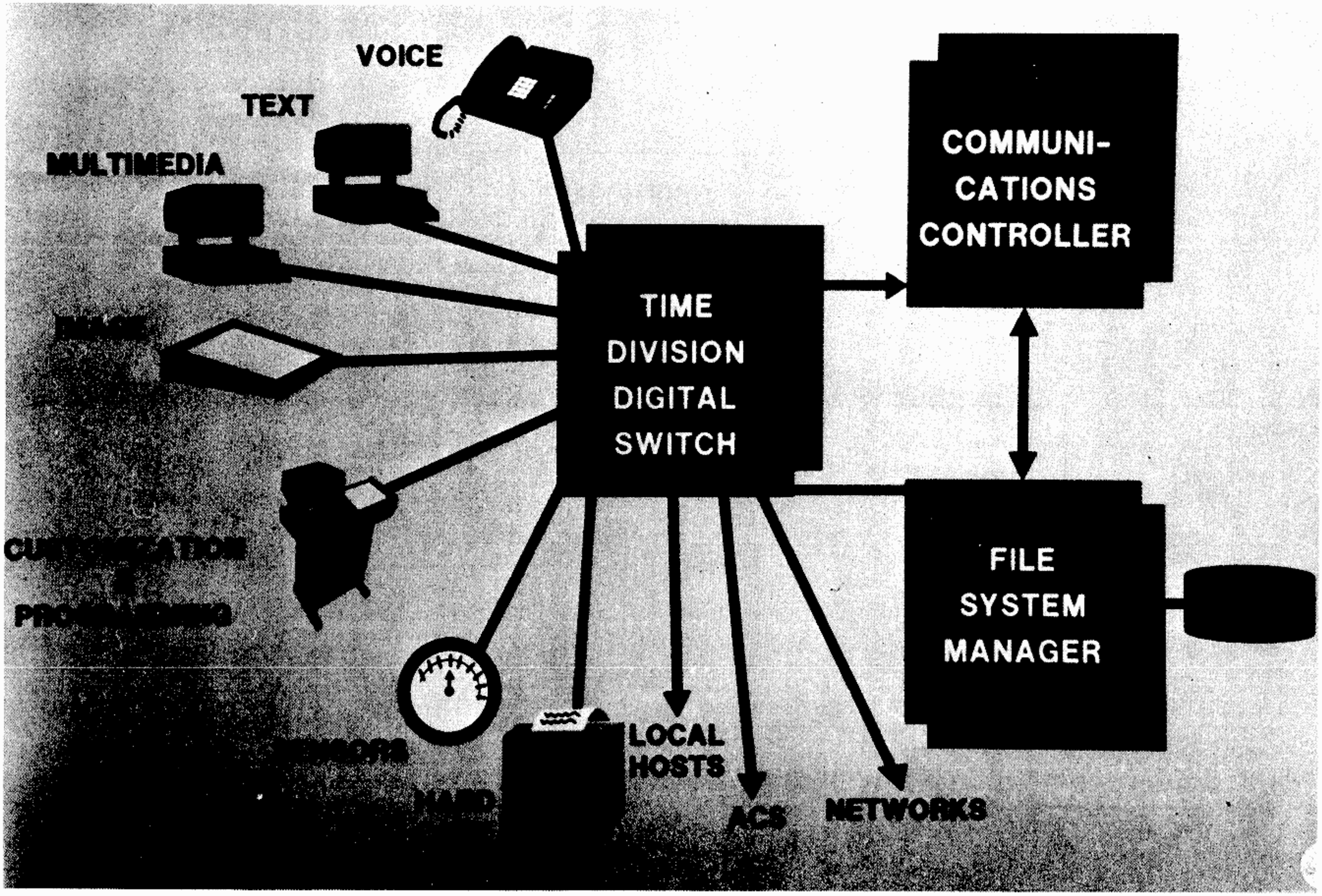


Figure 11. Advanced Business System

Baker. They don't have the courage or, in most cases, the knowledge. It's as if someone had been manufacturing buggies before the invention of the wheel. To appreciate what it can do for him, he has to know something about it, and this involves comprehending what these capabilities are and how they will fit into his business enterprise.

Student. How about the salesmen of the systems? Aren't they capable of the educational function?

Baker. Salesmen are trained this way now by the thousands in the private sector. There's nothing more elegant than the traveling salesman doing the sales job in his automobile. But the United States government has denied the American people that opportunity in mobile systems for nearly a decade. There is a version of our telephone system called a cellular mobile system which is ready and equipped that would have enormous significance for the military. If I were a Chinese general beginning to establish a system on mainland China, I think I'd build it entirely on this cellular principle. But for a decade it has been denied to the American people by arguments and petty bickering in Washington. So I can only answer your point by saying that, on the one hand, it does take a lot of knowledge to understand the advantages of such systems; on the other hand, it takes the results of (I hope) the election held on November 4, 1980, to open up some opportunities. Your point about the salesman is well taken. It is just an unconscionable restriction on national capabilities to cut this kind of system off. It is exactly what the defense community can use and needs.

I'll say again that the crucial factor about it is that the programming, the software, must be done so that it fits all the functions the users believe are part of their business. It may turn out, though, that when you do program them, the functions aren't part of your business, who knows? I say this with tongue in cheek. In our own industry we're very amateurish; we're probably the worst salesmen in the country. We're beginning to learn, a little bit; and what we are learning is that a lot of what they teach you about being a salesman is unnecessary these days, and that when you begin to program a system like this carefully — simply to do a selling job, or an inventory or manufacturing job — you can learn things about the job itself that nobody ever imagined before. That's going to be true of the military and of national security affairs, too. So this business of devoted and thoughtful people sitting down and programming and creating software technology is a major step we are facing, and it is what that $12 or $13 billion from the Defense Department will be devoted to in the early 1980s.

Now this simply demonstrates how rapidly we are learning in this activity — or, if you will, how stupidly we began. We at Bell Systems have spent a few billion dollars ourselves in arranging things in the telephone network, such as call forwarding, which is terribly important in command and control.

Of course, you want the thing to develop to the point where the person who is going to use it needs it. We had to go through a number of languages and programming systems (Figure 12), for example. But I'm just reporting that anything you're confronted with in programming shouldn't be taken as an absolute barrier. People say, "Don't take too long or you can't do it," or "It's uneconomical" — well, just don't believe it. It takes learning

1965 NO. 1 ESS

```
WL       MASK(CALLFWDINUSE)
MK       DATA
CWK      1
TKAZ     EQUAL
MCBAM    COUNT,Z
T        OUT
EQUAL    EQU*
WL       MASK(CALLFWDINUSE)
MCII     DATA,F
MB       DATA,F
BM       DATA,F,ES
T        OUT
```

1980 NO. 5 ESS

```
IF(DATA(LINE)→CALLFWDINUSE)
BUSY.CALLFWD;
ELSE DATA(LINE)→CALLFWDINUSE=YES
```

Figure 12. Trend in Programming Languages

and progress and the military is in the learning stages. For instance — and this is really part of the essence of my talk today — we believe that natural language, English, is most amenable to the detailed machine processing I've been talking about, and you learn a lot from the functioning of the machine. Command and control has its classic commitment to natural language. After years of fumbling around with it, we believe we've got to machine the language of command/control: shape the English text (text is not a very adequate term) so that it fits our artificial systems, networks, instruments, sensors, weapons and command/control centers as comfortably as it fits the speaker and the listener. That's rather a lot of work but, to make for mutual comfort, that's what we've got to do; and the happy news is, we are now convinced we can do it.

On an elementary level, consider text processing. The UNIX® system (Figure 13) is one that reacts elegantly to the natural language theme. It's not just a matter of phototypesetting or laying out text (that is an illusion if one stops there). It's characterizing the text by various kinds of studies so that one reaps the greatest advantage from having a machined bit. And the advantages are just overwhelming. Readability, for example — over the last several years, using local computers, we have carried out detailed studies among our 600,000 employees on how readability varies and what it means economically. Simple parameters can probably be applied, and we think it means the difference between having an actionable instruction or message and having one which fails. The United States talks about productivity, and there is concern about our fractional gains in the past decade, perhaps one percent a year. It is not unrelated to the disadvantage of the complex kind of instruction: the ones that can't be understood aren't followed, even in simple matters, like spelling words that can be mechanized (Figure 14). This is now done routinely in a great deal of our own command/control work by UNIX®. Misspelling, misplacing or even invention of words that are unreal or unintelligible (Figure 15) can be taken care of by machine and, of course, difficult graphics or particular symbols are also readily done.

Now when you impose all these features on a command and control system, picking whatever type forms you want and whatever sort of emphasis you want, you are certainly well along toward being able to devote attention to the content. But that is just what hasn't happened. We are now in the course of publishing directories which are machine-assembled (Figure 16); Figures 17 through 20 show some of the basic building blocks. You can do colors and shapes and positions routinely, and when you do that, you have greatly shifted the emphasis from format and composition to the content itself. And that's what one is after. In the course of doing that you can use photographic and other graphic displays interchangeably with the small processors we've talked about. You can use your fingers on the keyboard and your voice on the telephone quite interchangeably (Figure 21). This kind of duplication of options, we find, also heightens perception, heightens the human confidence we spoke about at the beginning, and apparently makes people feel immersed in the information process.

But again, you see, you don't try to connect all these things by some kind of elaborate hardwiring, which is very crude and requires all sorts of special switching. You do it by this wonderful digital commonality, which permits you to run the things through with a small computer any way you want. Run them so that you can pick letters or symbols

Document Preparation

- Text formatters
- Global document layout
- Mathematical equations and tables
- Phototypesetting

Statistical Studies of Text

- "Typo" program
- File compression
- Readability studies

Figure 13. Text Processing on UNIX

Strip out all punctuation (tr)

Change all upper case to lower (tr)

Place all words one on a line (tr)

Alphabetize the words (sort)

Cast out duplicates (uniq)

Cast out those in dictionary (comm)

4-column printout (pr)

Figure 14. A Program for Finding "Spelling Errors"

Statistically Unlikely Words from a 100-Page Typescript

☛	17	nd		16	disagreement
	17	heretofore	☛	16	bwirte
☛	17	erroronously		15	violating
☛	16	suer		15	unaffected
	16	seized		15	tape
☛	16	poiter		15	swapped
	16	lengthy		15	shortly
	16	inaccessible	☛	15	mutiliated

Figure 15. "Typo" Program

- Document preparation software under UNIX; *ROFF, NROFF, TROFF, EQN, TBL,* macros
- Phototypesetting of Bell System documents, technical papers, and books
- American Physical Society experiment; composition costs for Physical Review and Physical Review Letters \$10-\$20 per page vs. \$25-\$30 for typewriter composition and \$40-\$50 for monotype

Figure 16. Computer Typesetting of Technical Papers

An electronic system drew, then set in words, sentences, and justified columns the letters you are now reading.

Figure 17. Text

File : FONT Standard Record : BASKERVILLE III GALLEY

Characters in the font

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
a b c d e f g h i j k l m n o p q r s t u v w x y z
& ff fi fl ffi ffl ? ! ( ) . , ; : " ' [ ] % / ¢ @
$ 1 2 3 4 5 6 7 8 9 0 # • ° + = _

$c_{ij} = a_{ij} + b_{ij}$
A quick brown fox jumps over the lazy dog.
Fill my box with ten dozen jugs.

GENERAL DESCRIPTION

This memorandum describes a system for the digital control of a high quality oscilloscope for the purpose of generating graphic arts quality images such as are needed for printing text and line drawings.

In general the images will be photographed and the resulting pictures reproduced by the standard methods of offset printing. The input information which specifies the image will come from a digital magnetic tape or computer.

Figure 18. Type

Figure 19. Advertising Page Layout

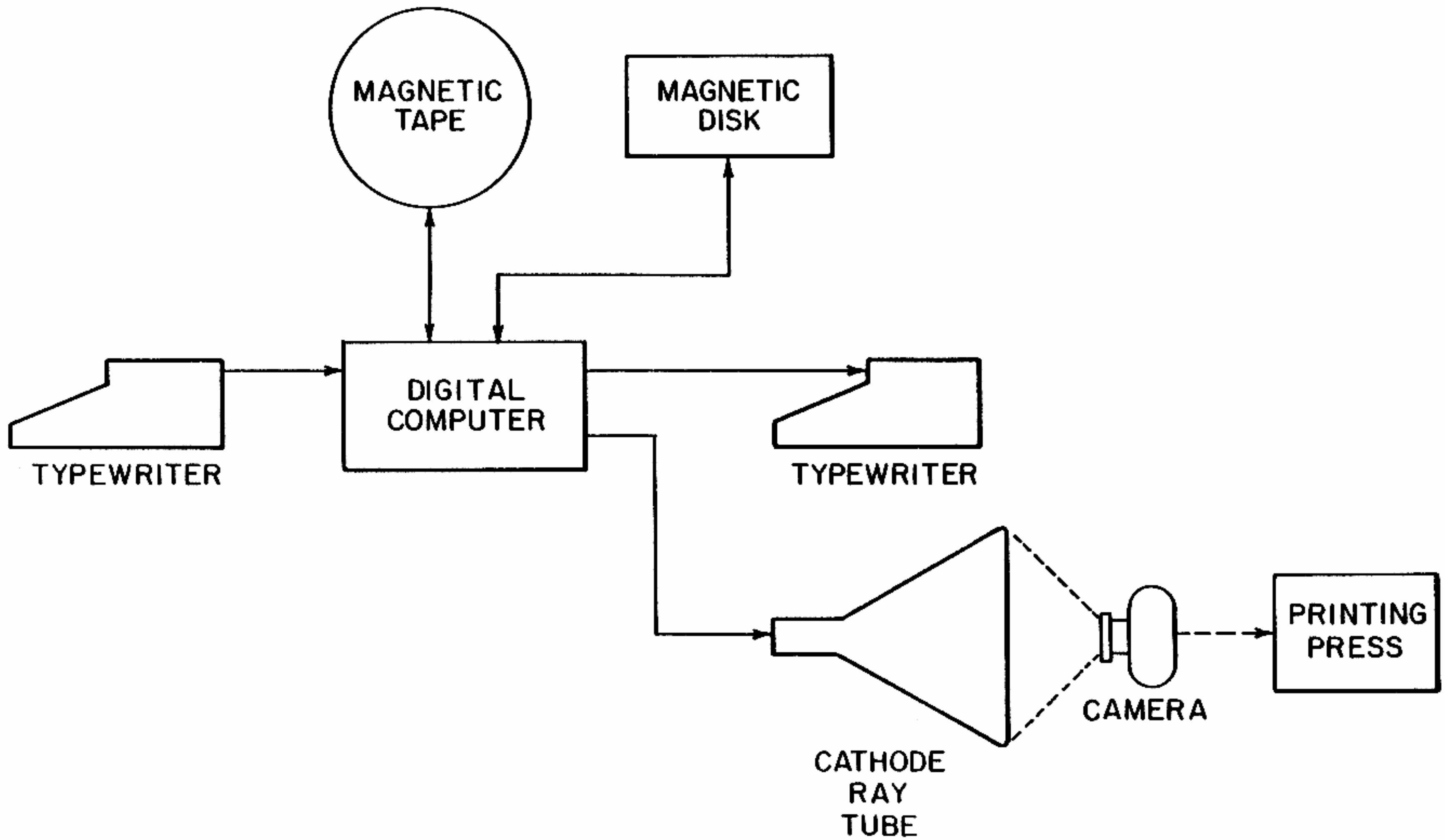


Figure 20. Editing Program

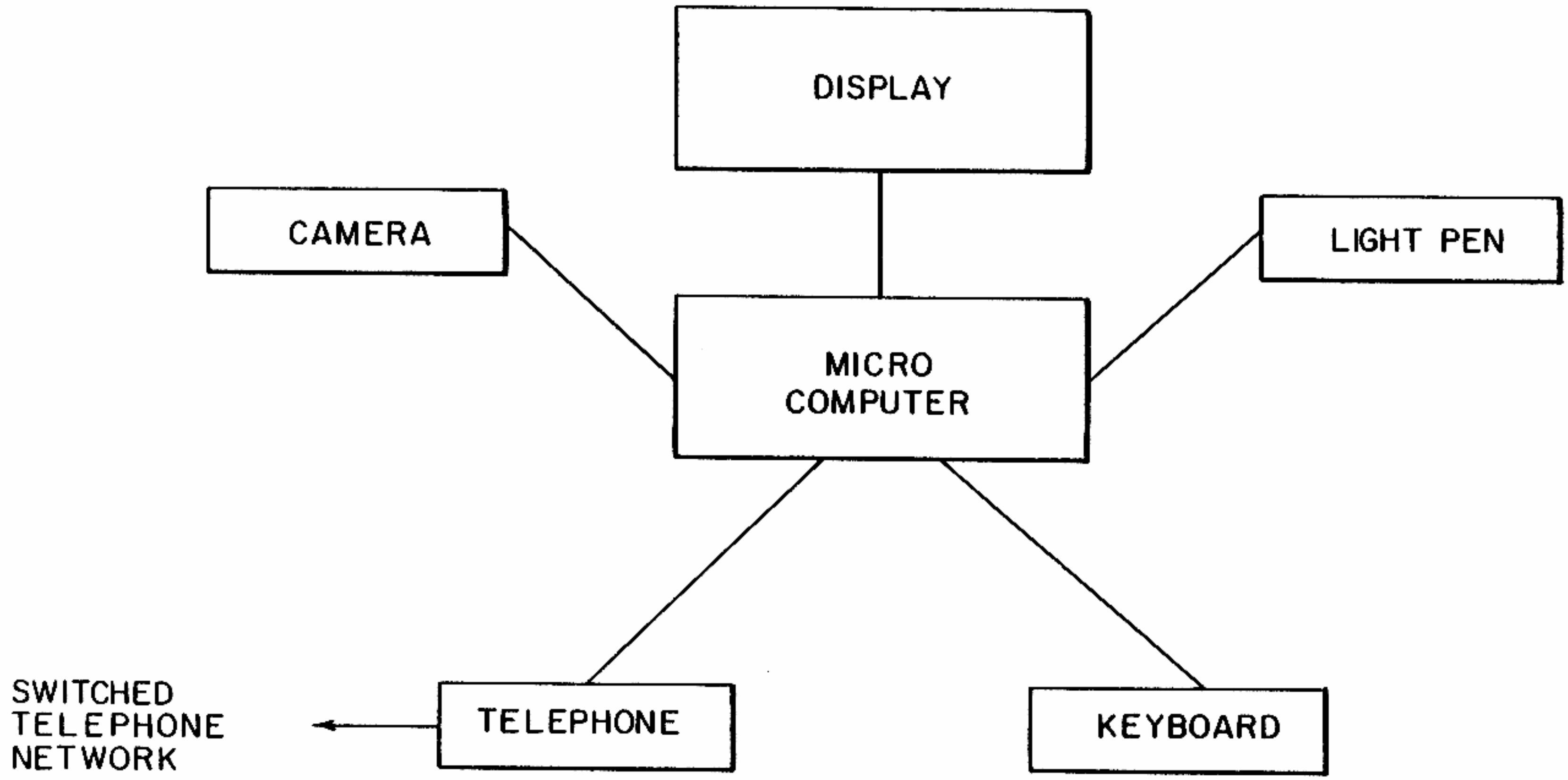


Figure 21. The Shared Visual Space

(Figure 22), so that you can toy with the notion of having a text description of a scene or a person come out in graphic form. Now, it's perfectly conceivable (we've done crude experiments with it, and it'll be developed, I think, in the next few years) that you can write out a description of a person derived from intelligence, an account of a viewed individual, say, going into the command headquarters in Gdansk, and you should then be able to generate a replica of that person's face by synthesizing the available data digitally, if it is complete enough. That kind of interchangeability of intelligence from text, from writing, from description into graphics can be expected to spread. We have seen the same sorts of things happening in the audio as well as the visual form — and, of course, command, control and intelligence remain very heavily voice-oriented activities. But this digital exchangeability and capability, if appropriately understood, can greatly extend those voiced and heard activities.

The physiological or human elements (Figure 23) involve muscular actions as well as mental performance, and since this is about a 40 bit per second deal, we can use some of the rest of the billion bits to do an enormous amount of arranging, machine processing and rearranging outside the human element. It also means that we ought to be using that huge surplus digital processing for things which will improve the kinds of actions that are diagrammed in Figure 24. Correspondingly, the DIMENSION system (Figure 25) is not just a coding assembly, but is also capable of direct simulation of speech generation by the vocal cords. In command and control there is the possibility of machine responses and machine inputs. We use this in the factory as a command system, and it is very well received by the workers at the benches. The workers are particularly fond of instructions generated in words by the machines, because they have learned that they are consistent and very precise. And that is an element which we need in military applications, especially in weapons control.

In the other facet, machine speech recognition, we are doing less well at the moment. The cases that you all are acquainted with are as far as we've been able to go; they're quite awkward, but they do work and we expect continuing improvement. So, again, the possibility of enhancing the reliability of human response by means of machines recognizing speech and by augmenting what the human recognizes is very real, very promising.

Student. How confident are you of the system's ability to handle noise injected from the environment — channel noise, for example? Your model was conspicuously void of any noise injection.

Baker. These digital systems are relatively rugged compared to any kinds of analog schemes and to conventional signaling, and they can be made more and more so. I think it's possible, however, to disrupt any one of them by the proper sort of jamming, just as you would jam conventional signals.

There's a direct digital conversion earphone which is philosophically as well as physiologically intriguing. I said earlier that we don't know how to get direct coupling into the process of neural cognition by means of digital encoding and processing, but in this case, at least, the signal comes in digitally and is converted to mechanical waves, which the ear makes very good use of. And, of course, we are pursuing the symmetrical

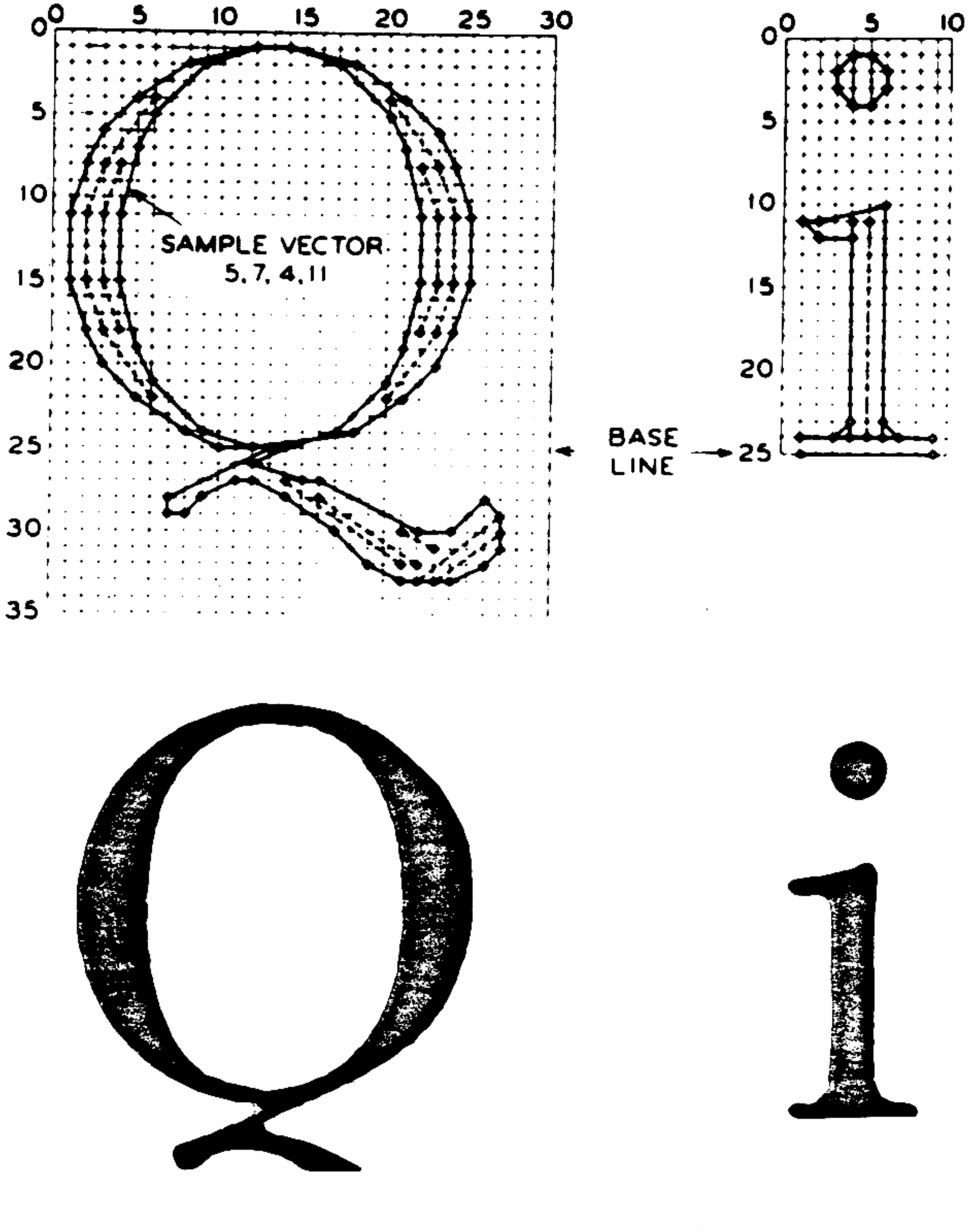


Figure 22. Digital Production of Letters and Symbols

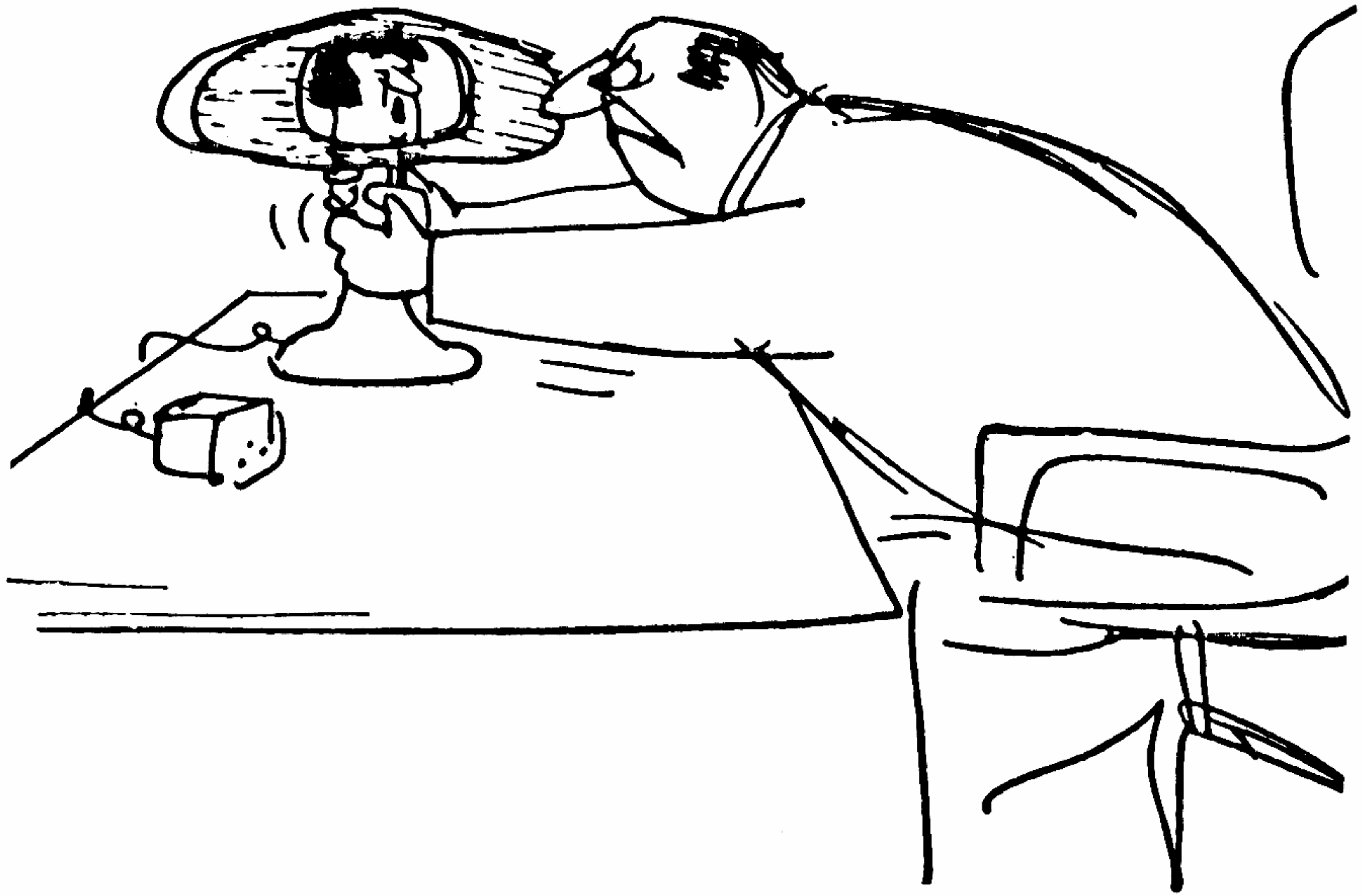


Figure 23. The Human Element

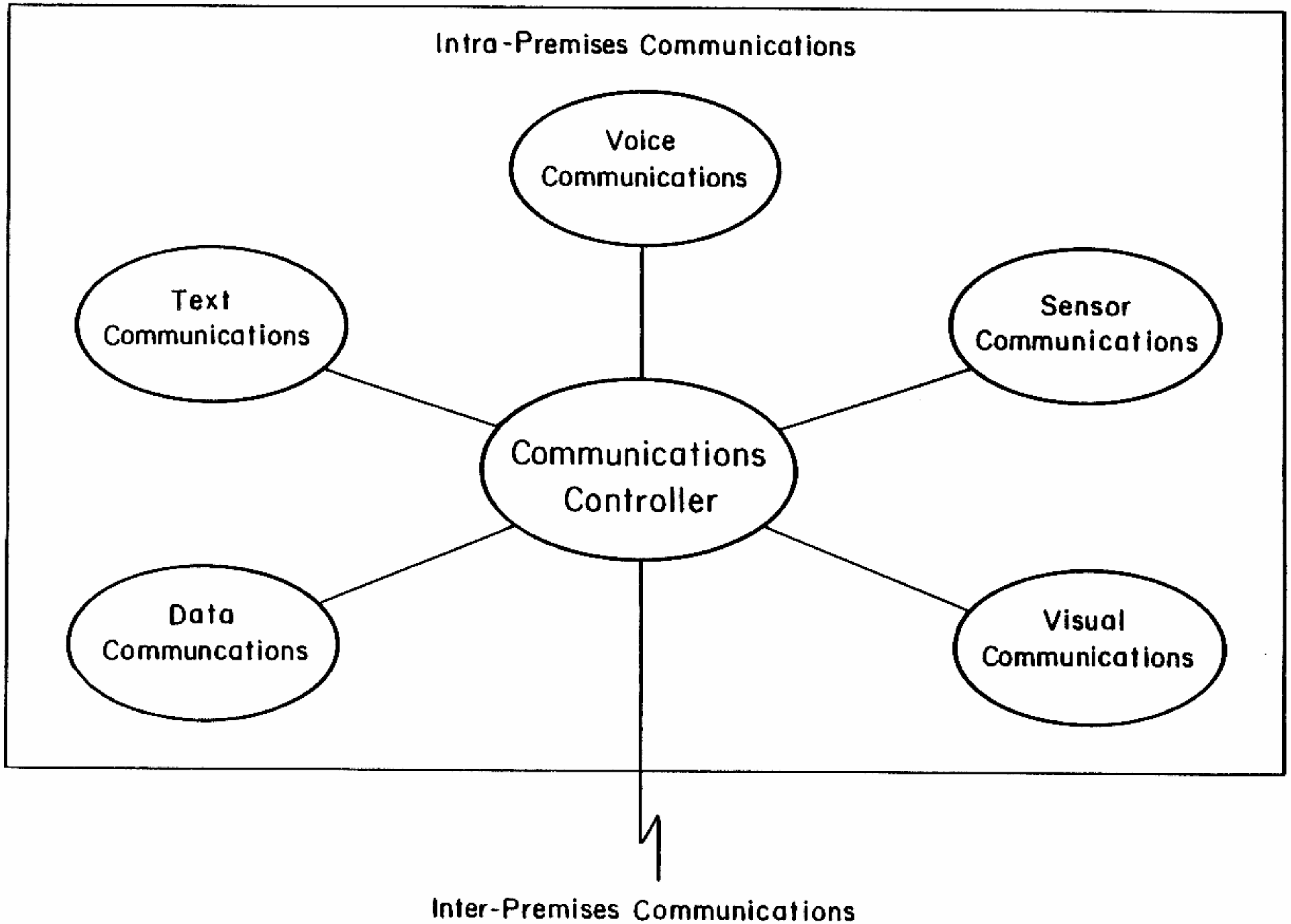


Figure 24. Communications Opportunities

A new dimension. Pictured here are the major components of the DCTS. The new multibutton electronic telephones are available in desk and wall models.

The electronic telephone controller can be installed in a separate apparatus closet or in the DIMENSION PBX cabinet.

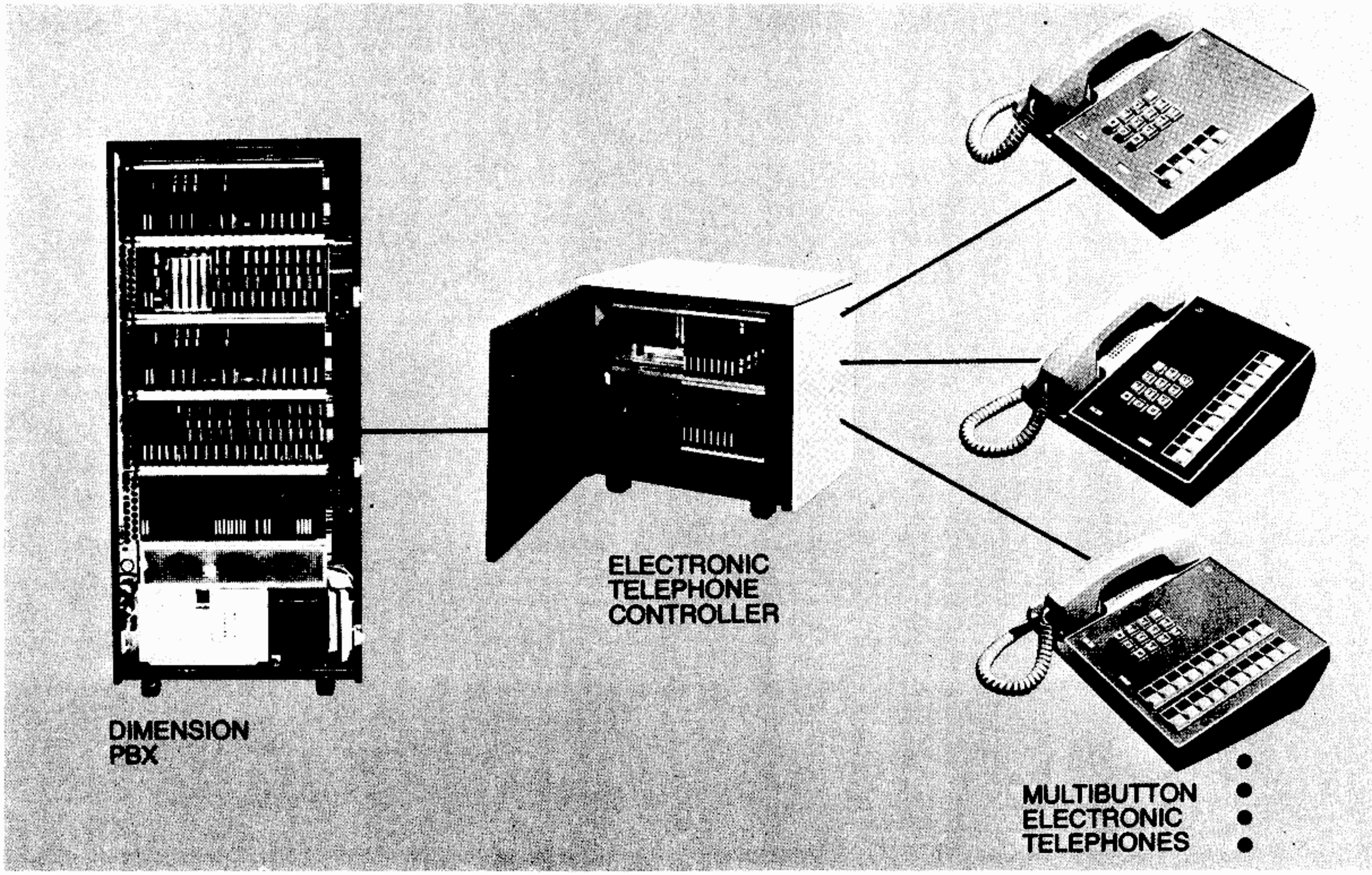


Figure 25. The DIMENSION System

case: the digital microphone needing no electrical analog-to-digital conversion. I said that you can carry this through from text, from a dictionary, into a message and then through a speech synthesizer. That is very promising for the kinds of field controls that the military will more and more depend on. An emotional element may be lacking in the reproduced speech as yet, but we may be able to make some sort of compensation for that.

Student. I wonder how much the technology (apart from the hardware) has advanced in the last ten or fifteen years. This sounds very similar to what we were doing ten or fifteen years ago, and there were fundamental problems — for instance, context switching when you change speakers, the number of speakers you could handle, speaker recognition, emotional content, that sort of thing. Have we come any distance in the last ten years on fundamental understanding? We proposed an experiment, for instance, for the Manned Orbiting Laboratory, using a vocabulary of 200 words, spoken in isolation by one of five people who were pretrained on the system. That was about the state of the art then. By 1985 we could probably handle 2000 words —

Baker. Well, I don't know. But I know we can handle 2000 words now.

Student. But whatever the numbers are, we're still talking about words in isolation without context, which is not continuous speech.

Baker. No. The whole point is that the system assembles the words in context with inflections, and makes sentences out of them.

Student. So it does work on continuous speech then.

Baker. Right, that's what it creates. Now the recognition sytems also depend on sentence structure and inflection, and they don't always do it adequately. But what I'm talking about now is a heavily, almost wholly content-based system — not isolated speech elements.

Student. Well, how far have we come in ten or fifteen years?

Baker. Oh, a long distance, but not perhaps as far as we will go in the next few years.

Now, you can interchange and combine these functions, as I've been pointing out, and what is most needed and most useful in programming to augment the human element is the communications controller function. The case that is most appealing now is machine processed language and the coherence it is going to bring to command and control. Does construction of understandable prose depend on a running assessment of text coherence, for example by analyzing the proximity of associated words in a text? You bring that out using a small processor to screen word concurrence data and establish a reasonable topical description of the content. On the one hand that may give you a kind of machine identification of content, which we're already starting to see some intelligence applications for, but on the other hand, it gives you an ongoing reflection of whether the person writing or speaking really has a message, whether he is optimizing the use of the system, and that's the way we think considerable gains can be made: by being willing to train people and give them steady practice in showing them how their language is able to work in these machine systems or, correspondingly, how their ordinary language looks sloppy and ineffective in these systems. One can, we find from early experiments, drastically improve the editing and indeed composition of messages that way. The computers can help bring out, conveniently and easily to the operator, the relationship between text features and the cognitive process those text features are supposed to bring into play. Keenan and her associates have recently studied 60 texts of varying readability and identified a variety of format changes and word construction and distribution changes. We believe this kind of interplay among the digital processing system, the sensor, the communications, the storage, the message maker and the message receiver will lead to a progressive sharpening and improvement of meaning, and thus greater efficacy of intelligence in command and control.

Oettinger. You almost make it sound as if there is no way to go but up. But a couple of months ago I ran into an admiral who told me that systems perhaps more primitive than this, but nonetheless the kind of systems you describe, had led in his milieu to increased message length and frequency that, he found, essentially clogged all his communication circuits, fostered sloppiness and verbosity and so on. He said he yearned for the days when folks could speak telegraphese and get their point across fairly quickly with much less fanciness, and he was wondering where he might get some way of controlling this logorrhea so as to get more signal through the human-generated noise factor.

Baker. Well, I think he was illustrating exactly what we're worried about in present circumstances — that widespread use of abundant communications without the machine discipline I've been describing will do just what he found. We believe on the other hand that machining the qualities of the prose will swing it drastically the other way.

Some years ago, Herb Simon identified "chunks" — reasonably accessible groupings of information, with a premium on strong word thrift and word discipline. These machine systems permit you to describe those chunks, process them and put them through, discarding the verbosity, the excess word usage, the unrelated words you're talking about. Much of this can be done by very simple keyboard operation. (I keep referring to the kind of machine accessories you need to have, and I just want to emphasize that digital systems don't exclude one's fingers.) The keyboard in Figure 26 will operate under the circumstances we've just been noting — all kinds of interchangeable message formats. A slightly larger system is being proven in the field, including the military — some of the large bases are now being equipped with these systems that involve message distribution, but they will also accommodate the kind of processing I've been talking about. The point (Figure 27) is to make the machine itself generate the appropriate keyboard image. You see that the image is appearing on top of the operator's hand. It was found that you can generate the appropriate keyboard for the program you need to use, and just project it onto a blank set of keys.

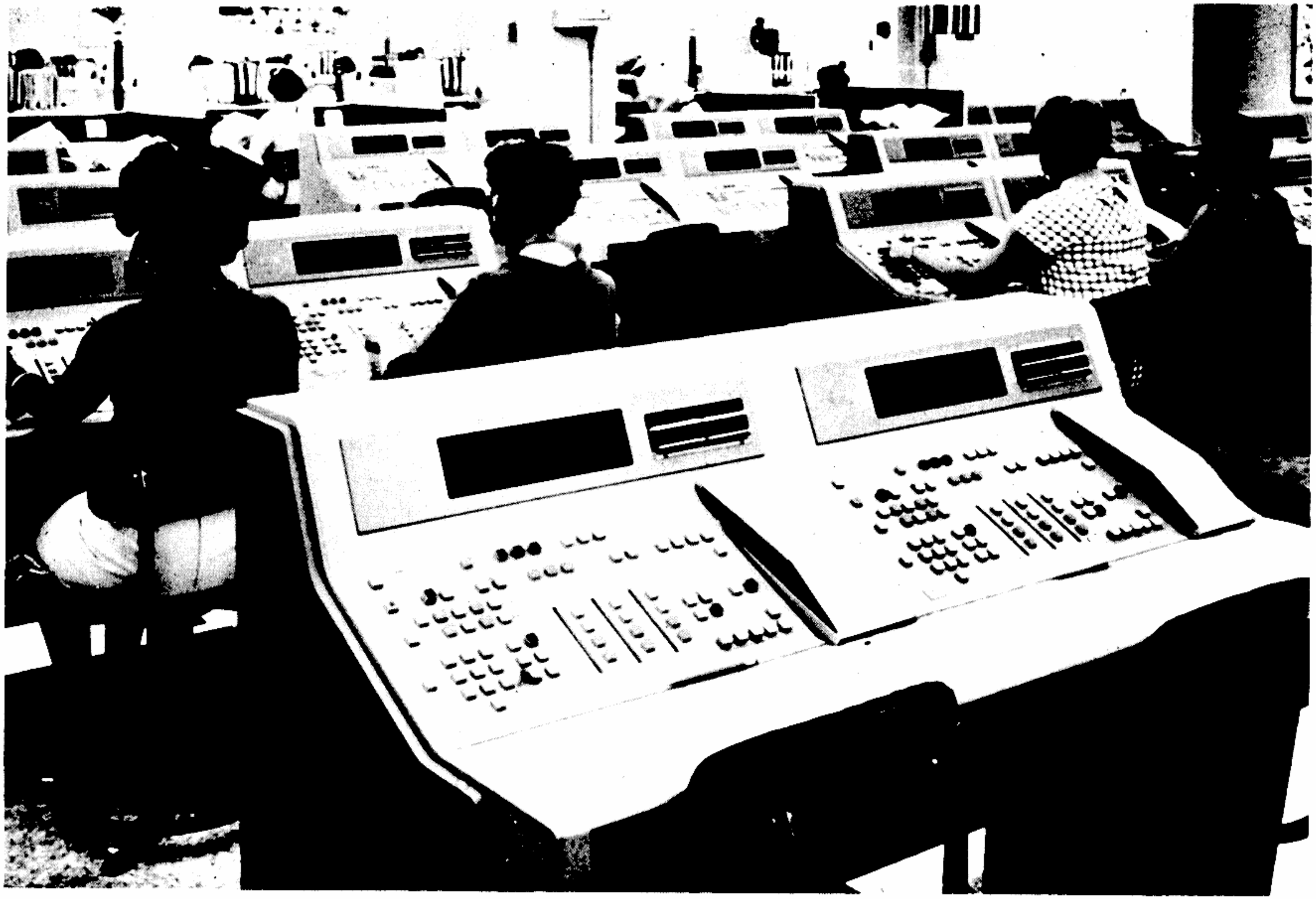


Figure 26. A Language Processing System Keyboard

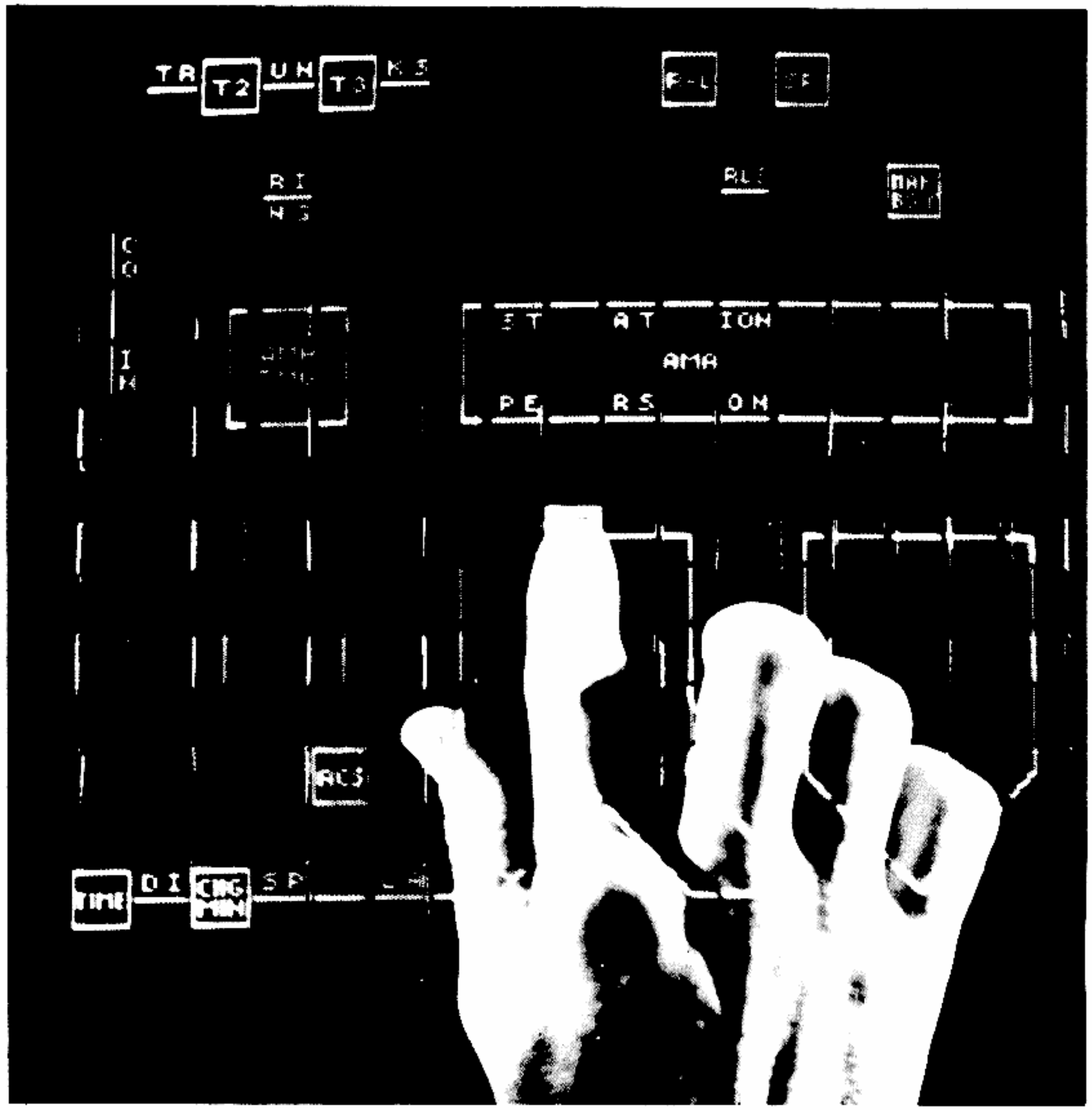


Figure 27. Keyboard (Detail)

Oettinger. But that is being projected from above! That's remarkable. It brings to mind some work I was doing a decade ago, and the horror of having redefinable keyboards which, of course, you hadn't memorized, and of course your fingers always covered them up, and you never knew what the hell you were doing. The notion of projecting the keyboard definition from above is one of those magnificently simple ideas that solves a very nasty problem. Ten years ago it was unthinkable, and now here it is.

Baker. Yes, we're working with the most deeply imbedded traditions and practices information handling has, namely: you've got a keyboard. It's a sacred sort of thing, it has all those keys on it. If you cover some of them up because you don't want to use them, well, that disrupts your concept of what was there and what you did want to use. You all know about the great debate whether the typewriter keyboard should be changed or not, and whether QWERT is built into people's nervous systems — well, you're not bound by all that. You can change it. Just as you're not bound by the classical principles of printing and editing and shifting words around. You can switch that off and go into a different kind of prose combination. You can leave out words; you can find out very quickly what kind of words you've overused. The kind of functions we're seeing take place now (Figure 28) are simply methods of going from conventional voice and keyboard through graphics into the whole voice-data-image commonality. And I'm reporting that it's here. We don't have all those non-voice kinds of terminals in place yet; but it is definitely time to start planning our whole advanced military and commercial structure along these lines.

Student. It seems to me that an awful lot of software is involved in integrating that stuff into an effective environment to do something; and that's usually not been done by the time you build the prototypes. Isn't a great big up-front job of software development necessary to make all that take place?

Baker. Yes. We have a lot of the software begun and (from a primitive functional point of view) even done; but it is not yet ready or capable of doing the mission, machining the human use of language composition so that the writer and the reader, or the speaker and the listener, will quickly get a good reflection of how much sense they're making. That machining involves a lot of things like word proximities, word reusage, word chunk frequency and density — all psychological parameters which nevertheless, in our experience so far, determine the intelligence and efficiency of communication, the degree to which the message is understood. The software has progressively got to bring out to the user, the writer, the reader, the speaker, the listener what the machine is saying and is able to reveal about the composition. It's going to reveal things which you can learn, by a lifetime of study or inspiration, about sentence lengths, adjectives and verbs and all the rest, but which increasingly we're not learning by conventional means. We believe the human user will benefit, and that this will dramatically advance the efficiency of command and control.

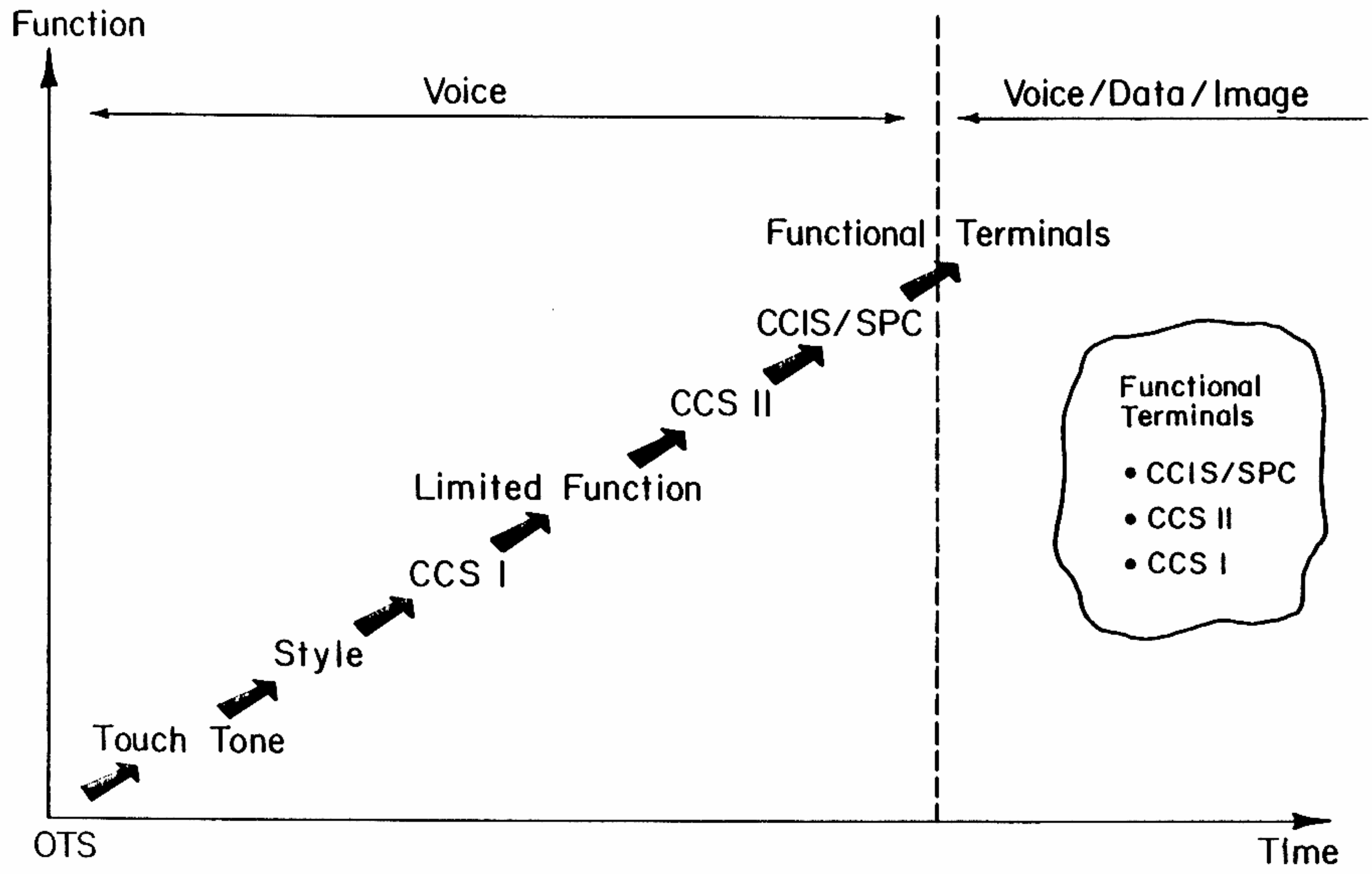


Figure 28. Voice-Data-Image Commonality

Oettinger. It might have helped the Argentinian pilot who misunderstood the instructions to stay at 2700 feet, went down to 1500 feet, and nearly hit the New York World Trade Center.

Baker. That kind of thing is happening all over the world all the time, and our military exercises show that it's happening more and more in the field. It is happening in diplomatic affairs. In the case of Israel in the early 1970s, we were trying to help specify the surface-to-air missile sites and the movements of forces in the area. It was found that the simplest sorts of status descriptions were misunderstood and in many cases mistranslated, and on translation they were not reconstructed in precise forms. The kind of programs we're talking about, which have to be machined to go through these systems, simply wouldn't permit that. There is a consistency which has to be maintained.

Student. You were saying at the outset that $12 billion of software isn't really buying the Defense Department what it's paying for.

Baker. Oh yes, it's buying very little capability at the moment, and that's been true since 1960, when some of the big software efforts got started — for example, the 400L system series. And it's buying very little because it's programming some very specialized function. A sensor may display a number of missile launchings, or count a set of radars, but it doesn't correlate this in a form or language that can be associated with orders to attack or otherwise react to the information that will inevitably be forthcoming. We believe that such a commonality of phrasing, of communicating can now be achieved.

Oettinger. I think one point to emphasize is that this is all happening extremely fast. You might realistically assume it could be run by personnel who have a lifetime of training, but it's an unrealistic assumption to depend, as you must in today's military, on the decision power under stress of a continuous stream of folks who don't understand what's going on. It puts a high premium, it seems to me, on the kinds of capabilities Bill was describing, that can couple with less heavily trained human beings and still function effectively.

Baker. That's exactly right. We don't know what levels of training we'll be able to have in the military — in the field forces particularly. We know our literacy levels are generally very modest anyway throughout the country, and perhaps more modest in the Army than elsewhere. Now what I've described today is a system which will refine a highly sophisticated input of intelligence to tell a person with a rocket launcher in the field, "Shoot", and that word "Shoot" will correspond to pages and pages of very precise instructions about the target, about the decision to attack that target, about the relevance of that decision to a whole range of other things. This can all be going on, and it'll come out as the command "Shoot". We simply find that this is a very compelling kind of goal.

Student. So investments in software may lead to savings in manpower?

Baker. Not only savings in manpower — also actions which we do not have the manpower to do, but don't need manpower to do. And what I'm reporting to you is that those actions, which were goals some time ago, are now realities.

Student. Are you arguing that you can take the man out of the loop, so to speak, or just that you narrow and define his role? In the broadest sense the commander still pushes the button, but instead of the rocket going off, the word "Shoot" is said to somebody out in the field, so he pulls the trigger. That doesn't seem to be a big improvement, unless there's also an integrated function that's supporting the commander's ability to make that decision somehow.

Baker. Well, we would want to do that too. Perhaps I am naive, but I think even the "Shoot" commonality is a fabulous improvement. I don't think the people who do the shooting now have a finished background in this. In Southeast Asia nobody got the information to them, nobody told them how to do it, nobody told them what was behind an order to shoot or a need for some shooting. This at least would be done by the new kind of system.

Student. I guess I'm not really clear what the scenario is.

Baker. Well, the scenario is that the field instructions for operations, which may be launchings of airplanes, rockets, a single mortar-like field weapon, can in all cases come from intelligence and command/control processing which is thousands or millions of times more detailed and comprehensive than is presently possible or has been possible in the past. By "more detailed" I mean that it just involves that much more knowledge.

Student. If I follow your line of argument to its ultimate conclusion, it would seem to me that every single individual could be wired to a command system. So that if we're asking where the individual fits in, the individual would be the part that's got the machine attached to him somehow, or that is carrying it somehow.

Baker. A telephone!

Student. Yes, but not every individual would carry a telephone; that's still much too large. So I guess the point is that, with transistorization, it will be possible in the very near future for each individual to have, maybe, a little earplug or something of that size.

Oettinger. Let me try something that takes off on both of your comments, because I think there may be a missing middle here. I hear in what Dr. Baker's saying an implicit assumption that I would articulate as follows: it is possible now, indeed it was the case in Southeast Asia, that the commander is not short of information, but is so deluged with a vast amount of stuff that neither he nor any of his subordinates can process it in time to act — even assuming that it has gotten to them. I hear what you're saying as the provision of more sophisticated processing devices that would filter out a lot of this — make it more compressed, more intelligible and provide the commander with that more intelligible integrated picture. If he says go ahead, it would also interpret that go-ahead by picking out of the massive picture certain bits and pieces (including some that would go to one place and say Shoot!) — instead of saying nothing while the commander scratches his head and tries to figure out, "What is all this garbage on my screen, what does it mean?" Is that a reasonable model of what you mean?

Baker. Yes. The distribution can occur just as you are saying, even based on just a single message from the commander, though it has previously had to go through a complicated chain, getting modified as it went. The commander's decision can be disintegrated into the desired series of actions.

Student. It sounds to me like you're describing an immense centralization of intelligence analysis. Wouldn't an alternative model be to decentralize the processing capability? If indeed the commander is deluged with information, then rather than send the information to some centralized point and come back down to him with what's relevant, could you not (with technology the way it is) come up with a model which would give him the ability to synthesize it, analyze it at a much lower level?

Baker. What I've been describing permits decentralization above all. Indeed it fosters decentralization of action and, conversely, decentralization of information gathering. On the other hand it permits concentration of information at the same time. We believe this is essential in the command and control domain, because there are big weapons, large systems, major decisions in diplomacy and policy which require such centralization. What this kind of system really does is foster a hierarchical system in both directions, so that you don't have to have one to the exclusion of the other.

Student. At the state of the art in command, control and intelligence we are just now coming to grips with the fusion center. We have a proliferation of sensors, we are processing with fifteen different computer systems, and the obvious thing to do is put them together — one computer against one data base — so it can be interrogated in an integrated way. But isn't that slightly beyond us right now?

Baker. Not really; the COINS system is a very good approach to it and shows that it'll work. The challenge beyond this is the decision, the courage to do it, and perhaps the unselfishness — in the sense that agencies love their machines and their capabilities. We are saying that the art, the science must now do what you're describing, do it on a very large scale, and at the same time link individuals with it at every level.

Student. A lot of values are involved in that kind of system; it's not merely technology. That sort of centralization of decisionmaking, or even just the intelligence-gathering function, implies a certain value system. I would think that that's the most difficult thing to overcome. If you're going to have checks and balances, how can you have a centralized decisionmaking authority?

Baker. Well, you can't form many checks and balances during an actual command and control operation, can you? On the other hand, you're quite right about the intelligence side, and here I think our stress on language machining, on the establishment of precision, is especially helpful. Ambiguity in intelligence is just where the system gets vulnerable to overreaction, to loss of checks and balances, and to lots of other troubles. How do you deal with the ambiguity? How do you deal with the uncertainty and vagueness? Well, what we're suggesting is that the language machining that we are now learning about works in these systems, and that the systems are so cheap you can afford to have them all over the place. That will lead to an authentication of information which will give you checks and balances. At the same time they're going to be able to give you direct and unambiguous action when you have to have it.

Student. So the numerous systems will ensure that all the different power centers have the same information?

Oettinger. Yes, but that image is fraught with problems. You're now threatening everybody's livelihood and bureaucratic independence; I mean, you have just said an enormous mouthful, and indicated why it takes so long to persuade people that it may be of some value to do this.

Baker. Yes, exactly. And what I hope I've done is show that these are realisms, that you can indeed spread the same kind of information around, deal with natural language, have worldwide networks that will very quickly produce this kind of knowledge base. That is something new, and it is what I hope our national system can adapt to.

Oettinger. I'd like you to comment on another aspect. I have two nightmares. One is that the sort of thing you are describing will *not* come to pass, and the reason that's a nightmare is now, I think, fairly obvious from your discussion. The other nightmare is that it *will* come to pass, and that's a slightly different dimension. What if people get so used to having this kind of sophisticated backup that when push comes to shove, if there is a minor electrical failure someplace, the ability to function in a more modest realm will be completely gone?

Baker. We've had to worry about that a lot. The systems we are talking about are full of junction devices — 18,000 in one system. Those junction devices can be put out of action by a few beta rays, alpha particles or other nuclear byproducts. We're putting in a lot of redundancy and a certain amount of survivability, but still it could happen. We believe we'll cope with this by having a small part of all local processors service individuals all around the nation — on the ground, in the air — and pare down the knowledge they can expect to get in case of disruption. We expect that they will have been sufficiently practiced in the disrupted system to be able to make good use of the local processors (which, by the way, can do astonishingly well; what the TI language processors or voice machines can do now is only the beginning). That is the advantage of the digital universe: background noise and jamming and disruption may affect a system during hostilities or during a catastrophe and it would seem to be preempted, but the individual self-contained portable processors are rugged, and have so much redundancy that they keep on giving you knowledge and a basis for action.