

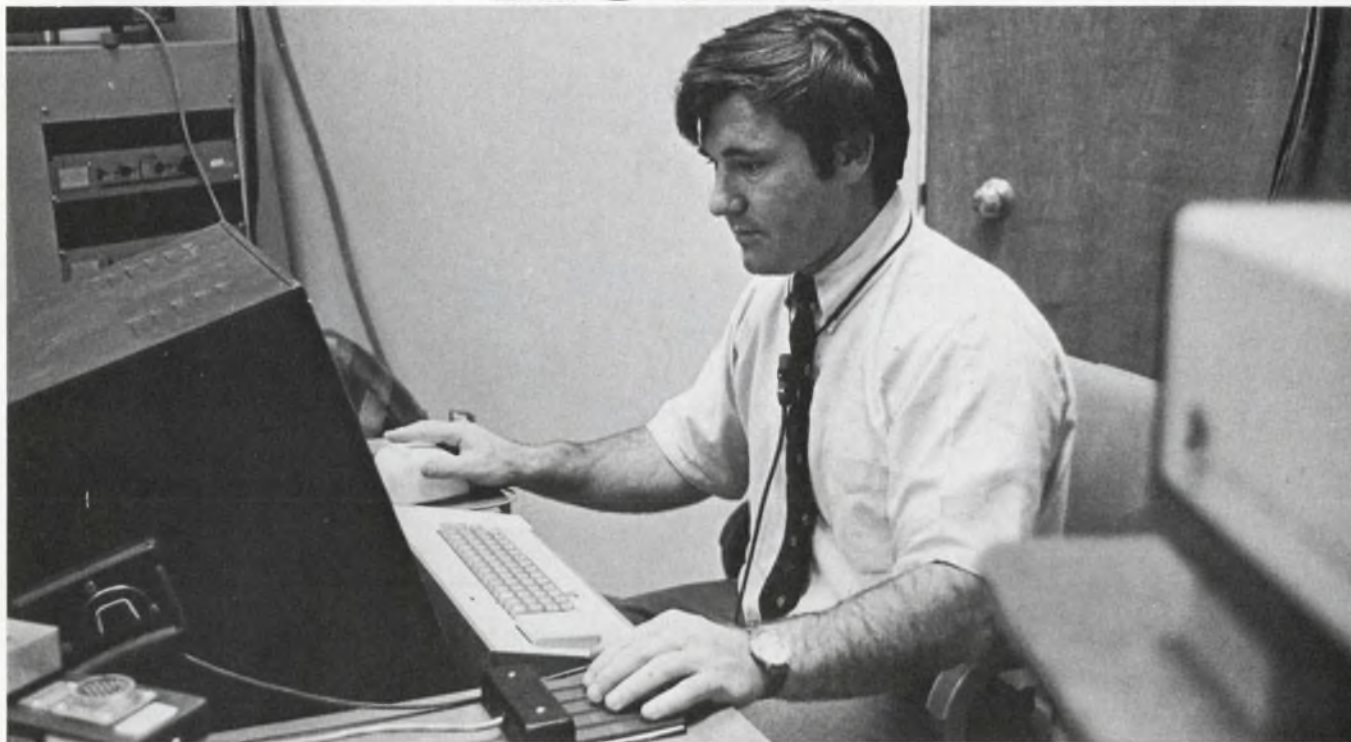
**Interactive computing** is leading toward new modes of thinking and of solving problems. Human imagination is backed up by a computer's speed and memory.

The way in which intellectual work is performed may change as a result of programs like the Stanford Research Institute one illustrated here. See page 25.



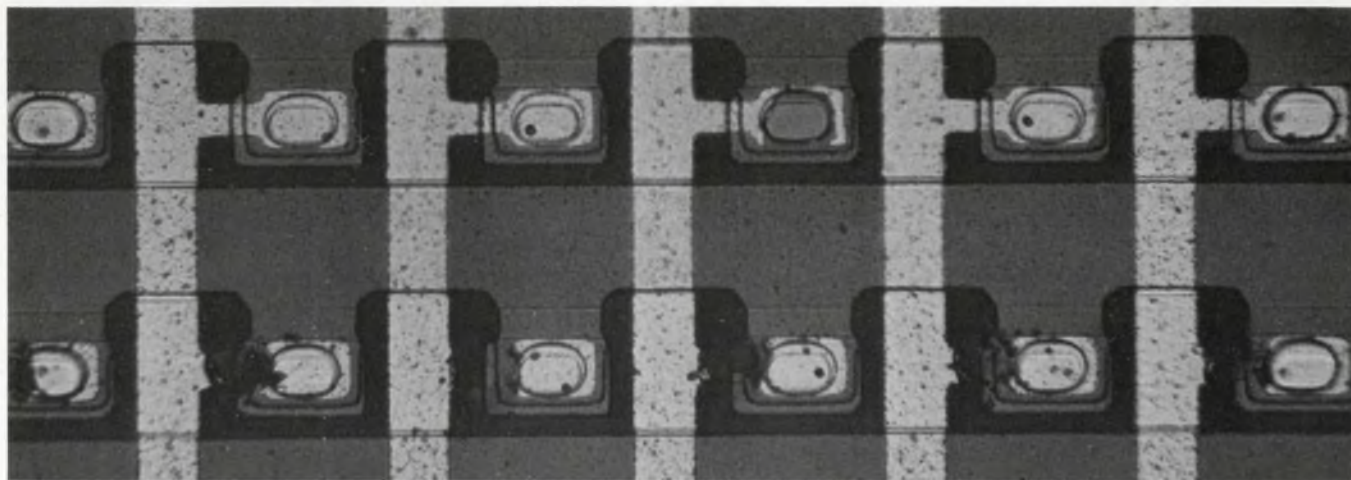


# News



**Spellbound by a graphic console**, a Stanford Research Institute designer churns data into a computer by means of a "mouse" (right

hand) and five "piano keys." This permits text to be written and modified without his eyes leaving the screen. Details on p. 25



**Silicon-on-sapphire** memory was automatically fabricated by a computer-controlled

laser operation at considerable savings in time and cost. See p. 34

## Also in this section:

**Lunar module** tested to the nth degree. Page 36

**News Scope**, Page 21 . . . **Washington Report**, Page 39 . . . **Editorial**, Page 45



# Man-Computer 'Partnerships' Explored

**Interactive techniques are sought to show that computers can augment human intelligence**

**Robert Haavind**  
Managing Editor

In a room at Stanford Research Institute in Menlo Park, Calif., several designers sit at television monitor consoles, engrossed in messages that are continually being painted across the screens. The messages are aspects of design that each man is working on, and the designers are constantly expanding the messages by operating two devices.

One is a five-key instrument that the user taps with the fingers of his left hand. The other is a white plastic object with three buttons on top that can be rolled over the desk top beside the display. A dot on the screen moves in synchronism with the rolling of this plastic "mouse."

The goal of these SRI designers is to develop system techniques that would permit people to use the computer as an "intellectual partner" in their daily work. Whether the worker is a circuit designer, computer programmer, manager or scientist, such system methods would enable him to couple the powerful calculating, organizing and memory capabilities of a large computer to his own thinking.

This mode of computer use, called interactive computing, differs radically from the way in which most computers are used today. In batch processing, today's normal procedure, a complete problem is analyzed to develop an approach suitable for computer solution. Then a program is written and fed into the computer, and, when all calculations have been completed, final answers are delivered. No changes can be made while the problem is running, unless they have been called for in the program.

By contrast, in interactive computing the user could observe inter-

mediate results at various steps of the computing process. Then he could make changes, or even completely redirect the solution. Or he could actually work the problem out himself, using the computer only when calculations had to be made, or alternate choices evaluated.

This approach is being pursued at SRI, Lincoln Laboratory, and other research centers. The SRI team is using the present version of their interactive computing system to achieve further development of the system. They are, in effect, using the system to develop the system!

Things that annoy or impede progress often become the next area for improvement. And in the process of making the improvements, the team members recognize needs for further improvements.

"Intellectual bootstrapping" is the term used by Douglas Englebart (see cover), principal investigator for the Center, in describing this approach.

Dr. Englebart envisions the computer as a tool that can allow men's minds to reach new levels of achievement. Thus his program at SRI is known as the Augmented Human Intellect Research Center.\*

The ways in which intellect can be enhanced involve more powerful methods for structuring, storing and retrieving, and manipulating large amounts of information. Thus bits of data, portions of articles, reports or books, notions, suggestions, insights and other types of information can be assembled in random fashion over a long period of time. Yet all these pieces can be organized in several ways as they

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\* Sponsored by Advanced Research Projects Agency (Information Processing Techniques); NASA's Langley Research Center, and Rome Air Development Center.



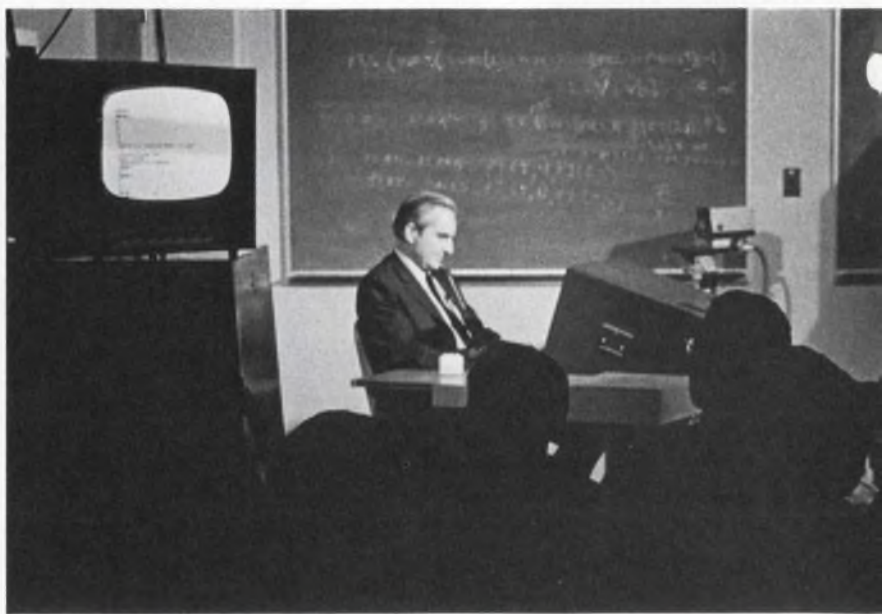
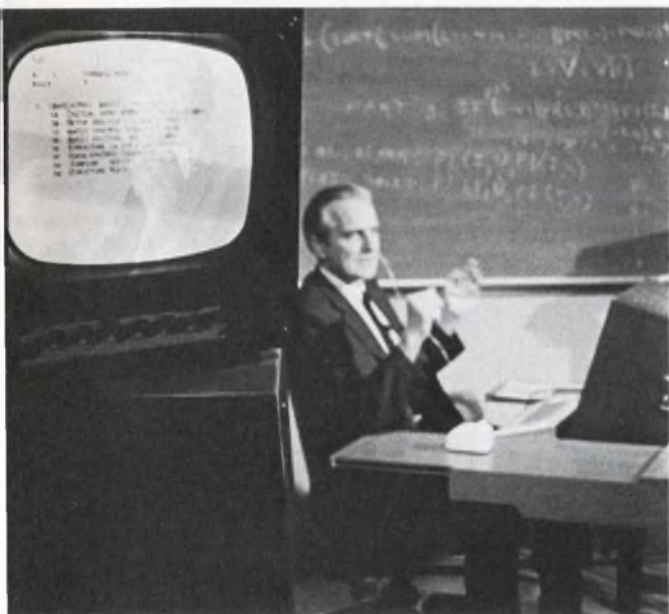
**SRI researchers demonstrate** the use of interactive computing with graphics for group discussion of a system design. General files, as well as individual files, all in the process of development, can be examined, modified or added to by the group. The system being designed is the system they are using.



### Can computers augment intelligence?

Can intellectual workers, given the proper tools to interact easily and rapidly with a computer, enhance the quality of their thinking? Definitely, contends this team of SRI researchers, who are shown here using some of the tools described in this article. To prove their point, they are using their own tools to further the development of their system—a form of intellectual bootstrapping. In this fashion, they are steadily removing annoyances and blocks to achievement, and restructuring their computer languages, programs, and hardware.

SRI photos by Carl J. Moore





(interactive, continued)

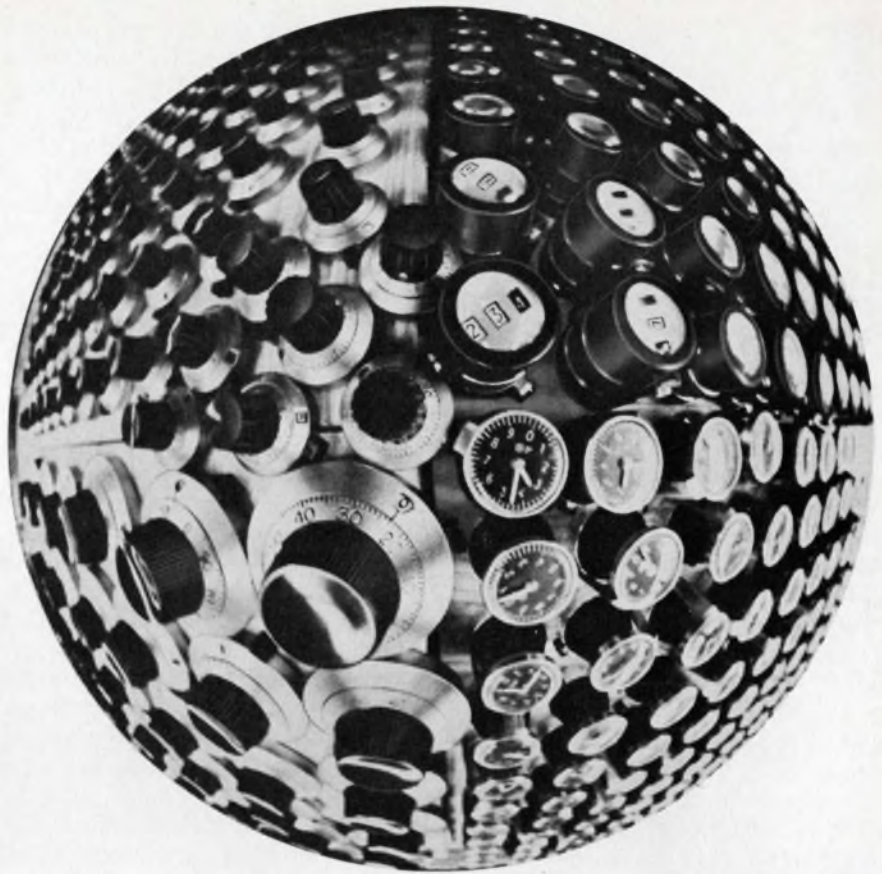
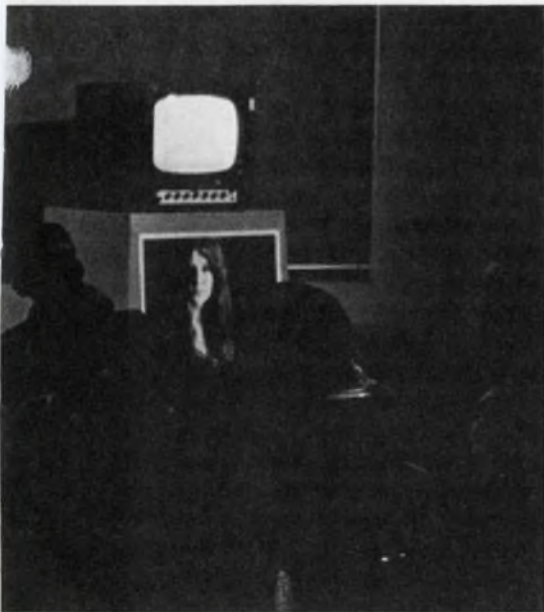
pertain to various aspects of a complex project, so they can be retrieved in seconds any time later by following any one of several trails. Another gain might be made in the structuring of complex arguments so that the person himself, or some other person, can review at any time the steps that led to some conclusion.

Whether the SRI group proves the validity of this contention or not, most of the other researchers in the field agree they have already moved ahead of any other research group in the ability to organize and manipulate textual information rapidly. Because of this capability, the SRI system has been chosen by the Defense Dept.'s Advanced Research Projects Agency to be the information center for the agency's nationwide computer network.

So far the SRI Center has dealt only with textual information, although it is now just beginning to investigate graphics. So why are they using display consoles?

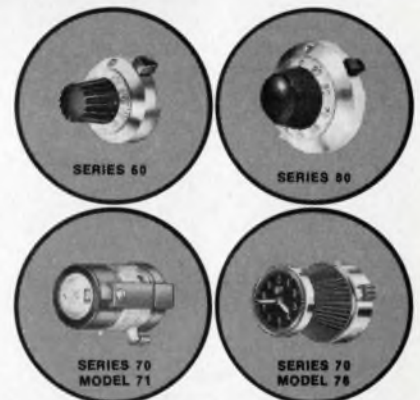
Speed is critical to improving performance, thus allowing more difficult problems to be attacked in an interactive fashion. The graphic display is presently the fastest means available.

But a graphic console is not a panacea. They can be very expensive, and techniques must be carefully worked out so that the operator can proceed smoothly.



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(interactive, continued)

The SRI system approach includes special provisions that attack both of these problems. The heart of the system is a Scientific Data Systems 940 time-shared computer. The system includes a 65-K, 24-bit core memory with a 4.5-megabyte swapping drum and a 96-megabyte disc file. Text drawn from the computer is displayed on a high-resolution, 5-inch CRT. This is then picked up by a precision (875-line) closed-circuit television system camera. Two character generators each feed up to six precision CRT-TV camera combinations. The TV cameras each feed a 17-inch television monitor in the center's "workshop."

This display approach is unique and offers several important advantages. A low scan-beam current can be used in the cameras, so that a short-term image storing effect is achieved. This allows the display on the monitor to be rewritten, or refreshed, as few as 15 times a second without noticeable flicker to the eye. This is vital because the need to refresh a television display—continuously 30 to 40 times a second with normal phosphors—cuts down on the maximum amount

of data that can be presented at one time. The cost of a small CRT-TV camera, amplifier-controller and monitor is about \$5500 per work station. This compares with about \$10,000 needed to buy a similar-sized random-deflection CRT.

Also, the expensive part of the system is centrally located. Additional monitors that could tie into the television camera could be added for about \$600 each.

### The mouse rolls

The five-key handset and mouse mentioned earlier are crucial elements in user convenience. The mouse has two wheels, set at right angles, beneath it. As these wheels spin, they drive X and Y potentiometers that control coordinate selection on the monitor. A dot on the screen moves in accordance with these signals. Thus the user can move his dot to some point on the screen, and then start to write in a message at that point.

One way to write in is through the use of a keyboard. But the five-key handset allows the user to enter data quickly without looking away from the screen. The handset operates according to binary codes. Thus an "A" is typed in by pressing the left thumb, a "B"

by pressing the left forefinger, a "C" by tapping both of these at once. Now, if the right buttons are pressed on the top of the mouse, the operator can begin to write in lower-case letters or, alternatively, numerals or a set of special symbols. In addition the keys can be used to enter control instruction.

The combination of the two units allows the user to intersperse text and various symbols with control actions.

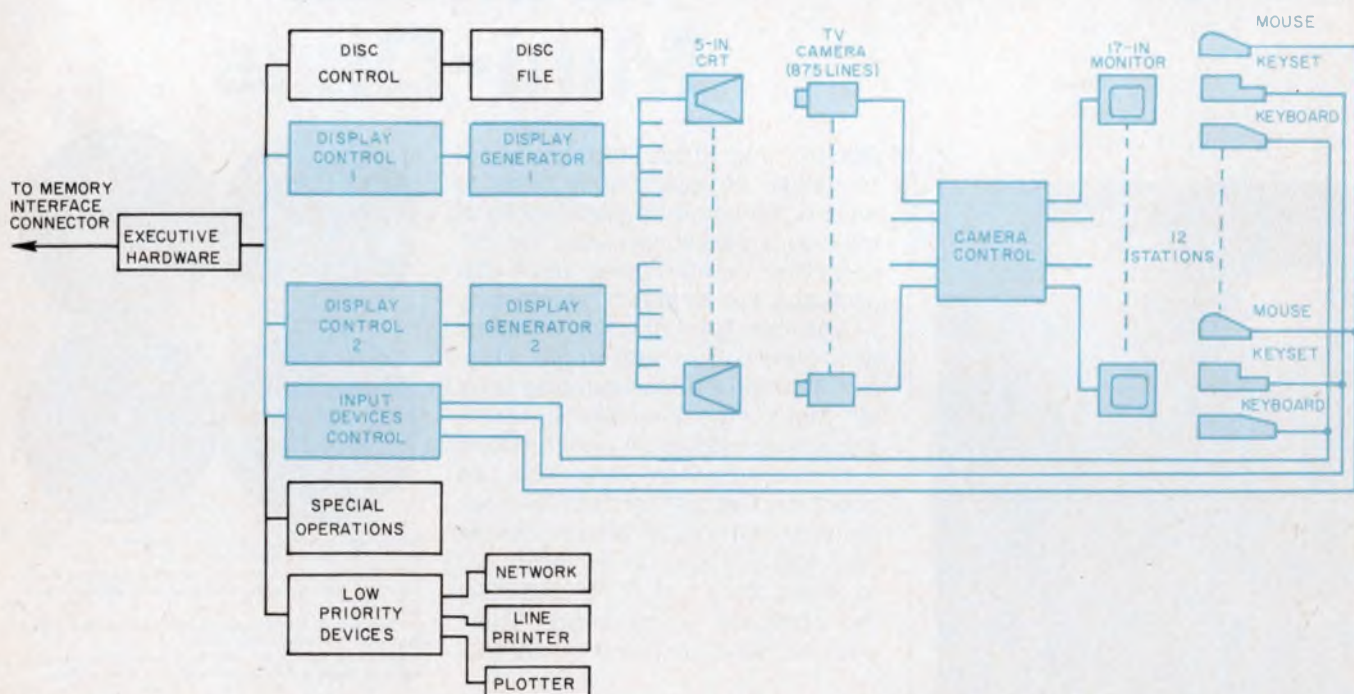
It is clear that some training is needed to become proficient at using the SRI equipment. In addition some mnemonics and programing details must be memorized. Note the group of memory aids pasted around the periphery of a display unit in one of the photographs on page 26.

### It's like driving a car

David Casseres, technical writer for the center, describes learning to use the system as being somewhat like learning to drive a car (he drives a small standard-shift foreign car.)

"But it makes you feel that if you only knew how to fly, you could become a jet pilot," Dave says.

The answer to evolving interactive computing systems that give the user the "jet pilot" feeling is



1. On-line computing system used at SRI includes 5-inch precision CRTs whose presentations are picked up by a high resolution TV camera and then transmitted to one

or more 17-inch monitor consoles. This keeps costs down for expanding the number of user-consoles, since these cost only about \$600 each.



(interactive, continued)

not a hardware problem, says Dr. Walter Sutherland of Lincoln Laboratory, Lexington, Mass.

Dr. Sutherland says the hardest thing to achieve is a software system that does not require the user to be aware of the programming. One reason this is so difficult is that each type of user needs the system for different things. Often he is not even aware of these requirements until he actually starts going to work on his specific problems. Thus the need is for a general system that incorporates all the things that will be needed for many different types of activity, and that allows different sorts of functions to be easily added as the need for them becomes apparent.

The types of computer languages that are being developed for this sort of activity must thus be highly modular and they must be very carefully structured.

Fortran, for example, the most widely used of computer languages, is highly internally linked so that changes or additions must be carefully considered.

The structure problem was the first to be faced in starting to organize the augmentation system concept. Early time-sharing systems had organized material in "pages," a carryover from the structure of printed books. But this did not prove to be efficient, primarily because of the long time intervals expended on continually swapping large amounts of material between core and drums.

Dr. Engelbart chose to organize material in a tree structure because of its advantages for structuring stored files. An analogy might be the title of a book, the chapter titles, then the subheads within a chapter. Thus an initial screen presentation might give the title and chapter titles. The user would then select a chapter title, and the list of subheads within that chapter would appear.

In addition the actual material

included under any particular heading is broken into arbitrary pieces called "statements." The length of a statement is limited by the amount of material that will fit on a single screen presentation. Some statements, however, may be only simple portions of a sentence. In one case, the material might be a portion of an article that the user wants to store. In the second case, the user of the system may be formulating his thoughts as he does early work on some problem.

The basic organization of material is expressed with a sequence of numbers and letters. For example, statement 1C4B6, is the sixth member of group B under the fourth member of category C, etc. In addition a statement can begin with a word in parentheses, and then that word becomes the title of the statement. Then, in any other statement, that statement can be referred to by the same title in parentheses. Another way in which statements can be identified is by means of placing a marker, some symbol, next to one or more statements. This allows a user to gradually build up additional organizational schemes for his material.

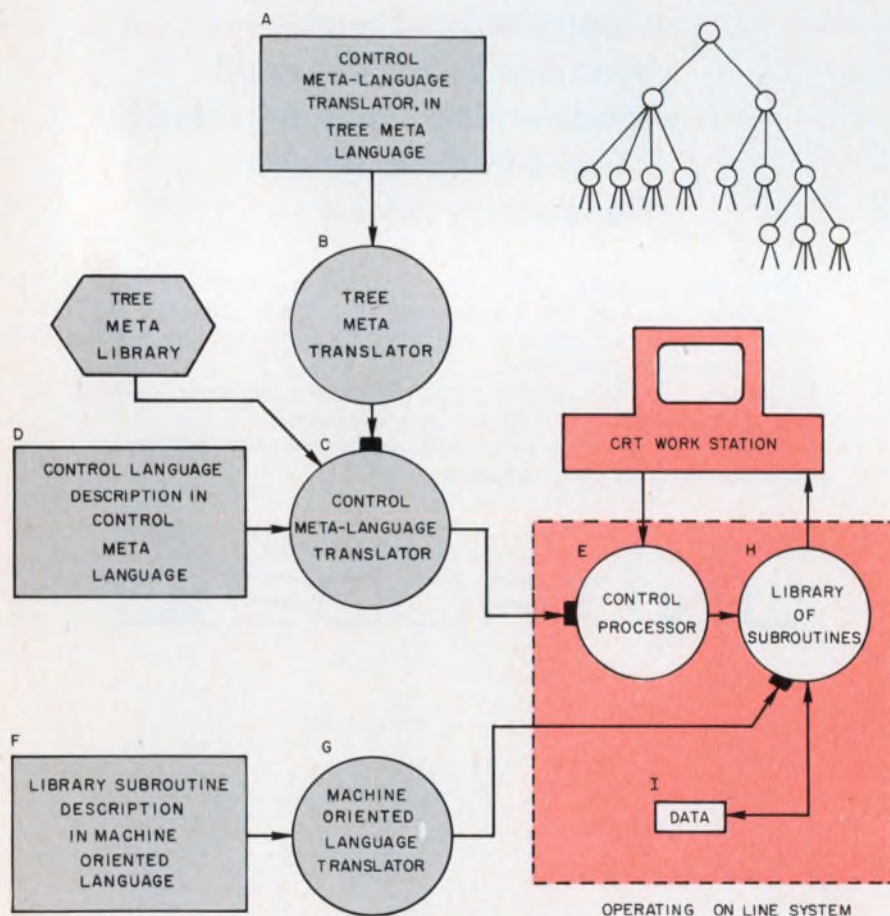
Several other schemes for moving around within a large file are provided. Statements before or after the statement being viewed, or at the head or tail of the particular subcategory can be called.

### Unfurling the scroll

If the user always went through his file in the normal sequence, it would be like looking at a long scroll, unfurling a frame at a time. There are three ways in which he can vary this movement through the file: level clipping, line truncation and content filtering.

In level clipping, all statements will be skipped whose level is below a specified point in the hierarchy. Thus, if the third level were specified, no statements below the third level—that is, below 3 or C—would appear.

A truncation command tells how many lines of each statement to show. A "1" says that only the first lines will appear, for example. Content filtering is performed by specifying statements that the user wishes to view by means of a high



2. A hierarchy of languages help give the on-line graphical interaction system its flexibility. The tree structure used for organizing information for quick retrieval (upper right) is a basic principle upon which the system is designed.



(interactive, continued)

level content-analysis language. For example, statements in which the words "memory" and "allocation" appear within four words of each other might be drawn out.

These sorts of operations, and the basic functions involved in doing such things as deleting characters, words, lines or statements, are accomplished by a variety of system languages. The subroutines performed by the SDS 940 are written in a special machine-oriented language (MOL) developed by the SRI group (see Fig. 2).

When working on line, the Control Processor (E in Fig. 2) receives and processes successive user actions. It calls subroutines from

the library (H) to do such things as locating data in the file, manipulating working data or constructing displays based on the sorts of commands described previously. These library subroutines (in H) are produced from machine-oriented language programs (F) which are translated by the MOL translator (G).

This combination of languages permits programmers to modify existing functions, or to perform a reasonable range of changes or additions to the functions, often by simply revising the control language record.

The SRI designers are now facing some of the trickier problems in getting their system to work smoothly. Each user is assigned a certain number of data blocks on a storage drum. As he adds to his

working file places are developed for each additional statement at the proper place in the file. If some data are no longer required, he can not at present "close the gap" left when he eliminates information. Thus some provision will have to be evolved to sort out the holes left in the file by deletions, and to close it up. Also the present scheme does not allow jumping from branch to branch in doing content searches. The system must travel up a set of connected branches to the top of the tree, and then down a new set of branches.

The widespread use of interactive computing will thus have to await considerable further development, both at SRI and elsewhere, to reach economic feasibility for most organizations. ■■

## An hour's work with an interactive computing system . . .

How will designers of the future make use of the emerging interactive computing systems? Here is a theoretical preview, based on techniques now under investigation.

Andy Handy, design engineer, settles down before a display screen at one side of his desk. After flicking the equipment on, he types in his identification. The screen displays a number of queries, to which he enters the date, the titles of the programs he is using, identification of the system he is helping to design and the subsection and a particular circuit.

In a moment an unfinished circuit appears on the screen. At various points there are wave-shapes and small response curves. Andy had left it in an incomplete state the day before. At the top of the screen a message blinks: "SYSTEM CHANGE." As Andy presses buttons, the circuit becomes a box linked to other boxes, and then a group of these become another box linked to more boxes. Finally a new set of boxes appears, representing the composition of the entire complex system. Blinking at the top of the screen now is a block of text and numerals with the words "SYSTEM CHANGE" for a title.

With some quick key-tapping, Andy returns to the section he

is working on and draws forth details of the effects of the overall system change on his own subsection. Now he zooms back in on the circuit he had started to work on.

After examining some response curves and trying some parameter variations, Andy decides that he is going to have to make some basic modifications if the circuit is going to work at all. Recalling an article, a technical report and a portion of a book—information he read in the last couple of years and that might have some bearing on his problem—he taps some keys and brings a listing onto the screen. Choosing an item from this listing, he obtains a new listing, from which he makes another choice. After several steps in this fashion, the article is displayed.

He shifts page by page until he comes to the part he's interested in, and makes some coded notes at the bottom of the screen to use as a reminder when he returns to his circuit work. He rapidly locates the technical report and the portion of the book, and in each case makes some more notes labeled with a code similar to the one he used for the notes on the article.

Now he returns to his circuit, cancels a portion of it, displays his notes and quickly works out a new configuration. He assigns values, observes responses,

changes values, sets up an iterative procedure to reach an optimum response condition and then sits back for a few seconds. Then the word "SOLUTION" blinks on the screen, and a set of values appears next to the various elements of the circuit.

Satisfied, he begins to draw from a computer-stored file in sequence, pages of catalog data on the types of parts involved in his finished circuit. He sets up some cost/performance equations for a section of the circuit and rapidly narrows his choices.

Returning to the circuit design, Andy designates the specific parts that will be used and then indicates that his work on this section of circuitry is complete. In a few minutes, he knows, orders for the proper devices will be printed out and charges will be entered in the engineering department accounts for his design work. The production department will be informed of the circuit configuration so it can prepare to tool up for its portion of the task. Meanwhile the system design project manager will be notified of all these steps, and will be able to zoom down to the tiny circuit to see that the work meets with his approval.

Andy gets up and stretches, ready for the morning coffee break and satisfied that an hour's work has been well done.



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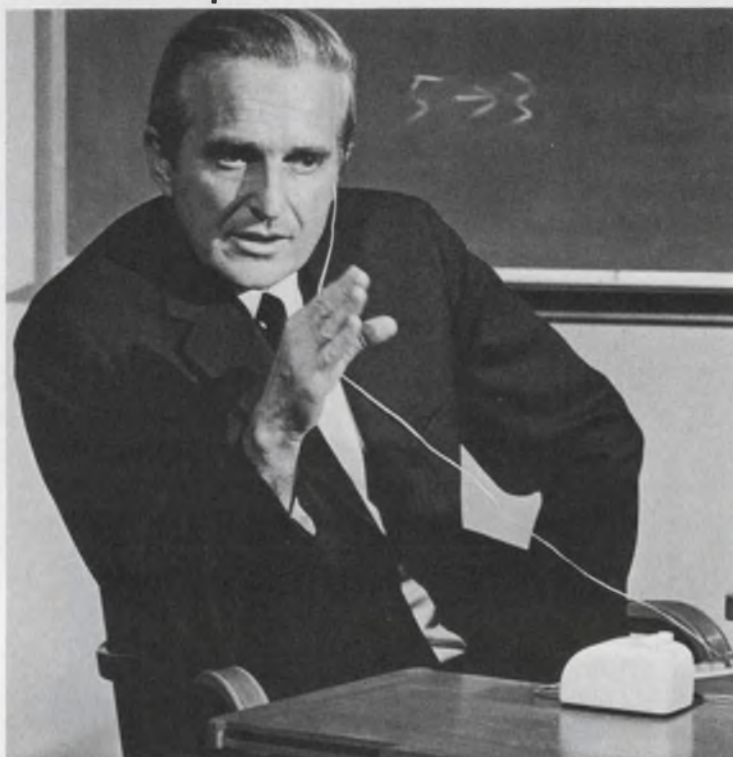
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## SIDELIGHTS OF THE ISSUE

## Meet the mind expanders



Who are the mind expanders? Dr. Douglas Englebart (photo above and on the cover) is one. He uses the computer to augment human intelligence. Englebart is principal investigator for the Stanford Research Institute's Augmented Human Intelligence Research Center.

Some years ago at MIT, where he first began his work, Englebart concedes, he was known as "something of a nut." During this period he met someone who perked up at the mention of his name:

"Englebart? Oh, yes, I've heard of you. You're the—" and the man balked self-consciously.

"Nut?" Englebart volunteered.

"Yes," said the new acquaintance, "but a *solid* nut."

For an insight into the solid progress that Englebart and his not-so-nutty group are making at SRI, turn to page 25.

And speaking of the mind . . .

## . . . You, too, can be creative

Is it possible to increase your brain power? If you are intelligent, can you be turned into a creative engineer who can solve complex problems in unique ways? Dr. Wilmer C. Anderson, research director of the General Time Corp., Stamford, Conn., says it's possible. But—and it's a big "but"—a company must establish the proper environment, and engineers who would improve must apply themselves seriously.

Starting on page 66, Dr. Anderson, who holds more than 40 patents for ideas he has developed, gives some basic hints on how to put a creative program into practice.