HELPING PEOPLE THINK

Robert C. Goldstein

MAC Technical Memorandum 25

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(Reprinted from Naval Research Reviews
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Everyone, today, is familiar with the use of machines to ease physical burdens. Since the dawn of civilization, man's progress in gaining control over his environment has been largely determined by the power and sophistication of the machines that he has been able to command. Furthermore, since simple machines can be used to construct more complicated ones, this process, once begun, tends to advance at an accelerating rate.

When general-purpose computers first came into existence in the years following World War II, many optimistic observers felt

The work reported herein was performed at Project MAC, an M.I.T. research project sponsored by the Advanced Research Projects Agency, and was supported by the Office of Naval Research under Contract N00014-69-A-0276-0002.

that they would soon do for man's mental capabilities what other machines had done for his physical ones. We have now passed through the first twenty years of the computer age, and regretably, we do not seem to have made much progress in augmenting man's ability to think. Computers have given man more time to think by relieving him of many highly repetitive clerical tasks, and they have also made it easier by providing relatively quick access to large data bases. However, even these relatively meager benefits are usually available only to those willing to interact with the computer on its own terms. This paper discusses an on-going research program in interactive problem solving and decision making. The goal of this program is to develop a computer based facility for augmenting a man's intellectual ability. Such a system should provide powerful and well human-engineered interactive aids for attacking complex problems and should automatically handle routine ones.

The first requirement of such a system is for a very effective means of communication between the man and the computer. This might take the form shown in Figure 1. The chair provides a comfortable physical environment for the man and serves to minimize outside distractions. Within the chair complex, the man has a number of devices which can be used for communicating with the computer. Several devices are required because information inherently comes in several forms and different devices are best suited to each form. For example, ordinary text is entered through the use of a typewriter-like keyboard. A second, smaller keyboard is provided so that a selection of frequently used specific messages or requests can be entered with the push of a single button. At some point in the future, we should be able to replace both of these keyboards with some sort of speech recognition device which would be far more effective. A special pen and writing surface are provided so that the user can enter sketches, graphs, and other pictorial data conveniently. Finally, there is a device which can be used to point at positions or objects on a display screen controlled by the computer. In our system, this device is a "mouse", a small hand-held object which can be moved about, causing corresponding motion of a spot of light, or cursor, on the screen. It would also be exceedingly valuable to have a means whereby complex pictorial data, such as photographs or three-dimensional objects could be perceived by the computer, but such facilities are not yet developed to the point where they can be included in an operational system.

Communication from the computer to the person is handled primarily through the medium of a display screen whose contents can be altered dynamically by the computer. Both line drawings and text can be presented this way. Color and half-tone capability would be desirable, but will not be included initially. Additional display facilities will be added later for slides, microfilm, and other sources of relatively static information. Telephone and television capabilities will also be provided to facilitate communication with the outside world. Facilities are also provided to permit the user to make a permanent copy of information appearing on the screen. At some point, we would probably also want to consider the use of audio communication from the computer. This is not particularly difficult to provide. However, since the eye has a much higher bandwidth than the ear, it is appropriate that the initial emphasis be placed on visual presentations. The primary value of giving the computer a voice would result from its use as a signalling mechanism. It is possible not to notice a new message silently appearing on a screen, but very hard to miss an aural signal.

In addition to elaborate facilities for man-machine communication, such a system must also be capable of storing and manipulating significant quantities of information. It is probably possible today to give a computer a better memory than a person, particularly if accuracy is considered as well as size.

However, people have a very highly developed ability for screening the information that is constantly being presented to them, and remembering only that which is likely to be of future value. People are also good at using hierarchical memories. That is, they use some portion of their memory to hold a set of pointers to information which they do not choose to remember directly. These pointers refer to other people, or to books and articles, which can be considered as lower levels of an individual's hierarchical memory. Computers can probably not be taught to screen information on input as effectively as people do. Therefore, to achieve the same level of effectiveness, they probably have to retain more information. Fortunately, this does not pose any particular difficulty. However, if the computer is to engage in useful intellectual activities, it must also be given the same benefits as a person in the areas of external communication and library facilities. Probably the most important single reason why computers have been effective only in relatively routine tasks is that the information they are given is too little and too specialized. I would go so far as to suggest that, in lieu of being able to read a newspaper, the computer ought to have direct access to one of the national wire services.

Of course, it is not sufficient for the computer to merely pile up a massive amount of data. It must also be capable of finding patterns, drawing inferences, and evaluating implications with respect to given goals or objectives. This brings us into the general area of modeling. Our system must have at its disposal a rich collection of tools for simulation, statistical analysis, mathematical programming, etc. Such tools would offer the computer not only the ability to draw general conclusions from a mass of specific information, but also to compare alternative courses of action in terms of a set of objectives.

At this point, it might seem that there is no longer any reason to have a man in the system. However, before we can actually take the step of removing him, we would not only have to have great confidence in the computer's information gathering and interpreting capability, we would also have to be sure that its goals were the correct ones. Whatever steps we may take in the coming years toward computerized decision-making systems, it seems unlikely that man will, any time soon, be willing to delegate his goal-setting function. However, this should not cause us any particular concern, since our intent is not to replace man, but rather to utilize his unique capabilities most effectively.

Having seen where we would like to go, let us look at what we have been able to accomplish so far. The work reported here was performed by the MacAIMS (MAC Advanced Interactive Management System) Group at Project MAC under the sponsorship of the Office of Naval Research and the Advanced Research Projects Agency of the Department of Defence. The work of the MacAIMS Group began in June 1968 as an attempt to use the computer to improve the effectiveness of Project MAC's own management. A study was undertaken to identify the most important problem areas. This led to a substantial programming effort that lasted approximately two years. All programs developed during this phase of the project were written in the AED (Algol Extended for Design) language and are used on a modified IBM 7094 computer operating under the Compatible Time Sharing System (CTSS) developed at Project MAC in the early 1960's. CTSS was one of the first large-scale, general purpose time sharing systems. As such, it lacks many features which exist in some newer systems, but is more capable than most time-sharing systems in use today. A number of programs developed as part of this research are in daily use by the MAC headquarters office. These include facilities for personnel administration, purchasing, inventory control, and budgeting. These programs have some excellent characteristics, particularly in the man-machine interface area and in their adaptability to changes in requirements. Examples of enquiries using the personnel and budgeting facilities are illustrated in Figures 3 and 4, respectively.

One should particularly note, in these two examples, how the system correctly interprets abbreviated or misspelled words. This capability, which was not difficult to implement, has proven to be extremely valuable. The programs also provide guidance at strategic points in the interaction if the user does not seem to know what to do. This guidance can also be requested at any point through use of the "help" request.

The major drawback of this system is that the limited memory capacity of the 7094 makes it impossible to combine information from the different application areas. For example, while the budgeting system will make a quick rough cut at a new budget by taking the previous one and making standard adjustments, e.g. for salary increases, it cannot actually look at the personnel data base to find out what current salaries really are. This capability for simultaneously considering information of different types or from different sources is something that people use constantly. Any computer system designed to offer intellectual rather than just clerical assistance must also be able to do this. CTSS also lacks adequate facilities for access control which has restricted our ability to open the system to wider use.

Late in 1969, a new computer system became available at M.I.T. offering substantial improvements in capability. This system is called Multics (for MULTiplexed Information and Computing Service) and runs on a GE 645 computer. It was developed as the result of a long cooperative effort by Project MAC, Bell Telephone Laboratories, and the General Electric Company. Multics was explicitly designed to overcome the limitations of CTSS in a number of areas, including processing power, data storage, and access control. Shortly after Multics became available, a decision was taken to begin a second phase of MacAIMS program development in order to take advantage of the new system's additional capabilities as well as the substantial recent progress in terminal device technology and the large amount of experience gained through the actual use of our CTSS facility. Observation of the system in use by the MAC headquarters staff provided much valuable insight into the relative importance of various capabilities. For example, the abbreviation and misspelling recognition facilities mentioned earlier are used very extensively and will be greatly expanded in the new system.

In terms of the general philosophy of interaction, we hope to orient the new system more toward commands than questions and answers. That is, we want the user to assume the active role, telling the system what to do, rather than merely responding to questions. This brings up the interesting issue of what to do when the user fails to take the initiative. Under some circumstances, this may mean that he is not sure precisely what is going on, or what alternatives are open to him. At other times, he may merely mean that he wishes processing to proceed in a normal fashion. Thus, at every step, the system must be prepared to take some default action in the absence of specific instructions. Our actual operating experience has been very helpful in working out these default strategies.

Probably the most important lesson that we have learned from our past experience has been that the system designers must strive for the utmost flexibility. It is impossible to forsee all the ways in which the system will be used, and its very availability creates additional uses. We have therefore sought to make all aspects of the system alterable under operating conditions without requiring reprogramming. This applies to such system-wide features as the structure of the data base and to such personal issues as the particular style of interaction. This latter capability implies that the system may actually act quite differently when used by different individuals. This is merely a manifestation of the well-known differences between people and particularly, their different styles of management. We believe that our system, to be effective, must interact with each individual in a way which is comfortable for him. Thus, the system will constantly monitor the nature of each user's activity in order to adjust, as far as possible, to his individual style.

The data management system used in the Multics version of MacAIMS is substantially different from conventional information retrieval systems. This new design arises both out of our past experience and the additional capabilities made available to us by the Multics environment. It is based on a relational, or set theoretic, approach to data base organization. In essence, we take the view that all of the information we might wish to store consists of data elements and relations among them. Furthermore these data elements and relations fall naturally into sets. For example, we might have a set of persons names, and a set of telephone numbers. We might then also have a set of relations associating telephone numbers with people. One obvious advantage of this approach compared to more rigid systems is the ease with which exceptional conditions can be handled. For example, the cases of a person who has no telephone number or of one who has several require no special treatment of any kind. A further advantage is that the substantial body of theory concerning sets and operations on them can all be brought to bear on the data management problem.

A relational approach to data management also has some attractive implications for the problem of information security. This comes from the fact that the data elements are stored separately from the relations among them. It would therefore be possible, for example, to give a particular user access to the name set and the salary set without allowing him to associate specific salaries with individuals. In other words, we can protect that particular relation while still allowing the user access to both names and salaries in other relations, for example, a <name,telephone> relation and a <salary,account> relation. As a second example, a user could be given access to all sorts of relations about people for the purpose of some demographic research, while perfectly preserving individual anonymity by denying access to the name set or any other data element set that would permit identifying the individuals involved.

In recent years, a large number of so-called "Management Information Systems" have been programmed, all presumably aimed at meeting the manager's need for better information and purporting to help him make better decisions. Despite all of the effort that has gone into these systems, none of them have been particularly successful. We believe that the primary reason for this is that the problem of helping a man to make better decisions is much more complex than is commonly assumed. It is our hope that the rather elaborate hardware and software facilities discussed in this paper will finally provide a framework in which a computer may provide significant intellectual aid to a decision maker.

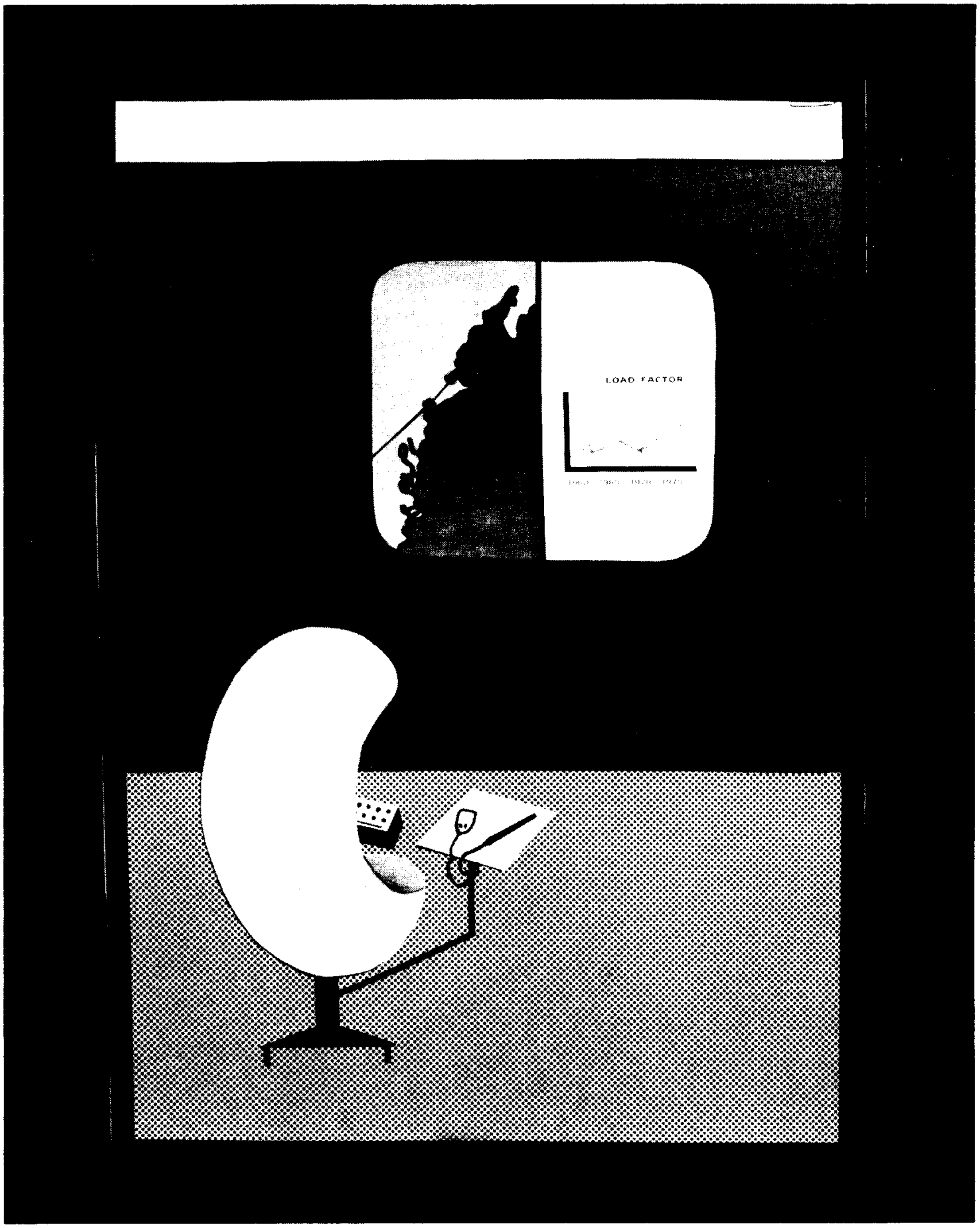

Figure 1 - Proposed User Station Configuration

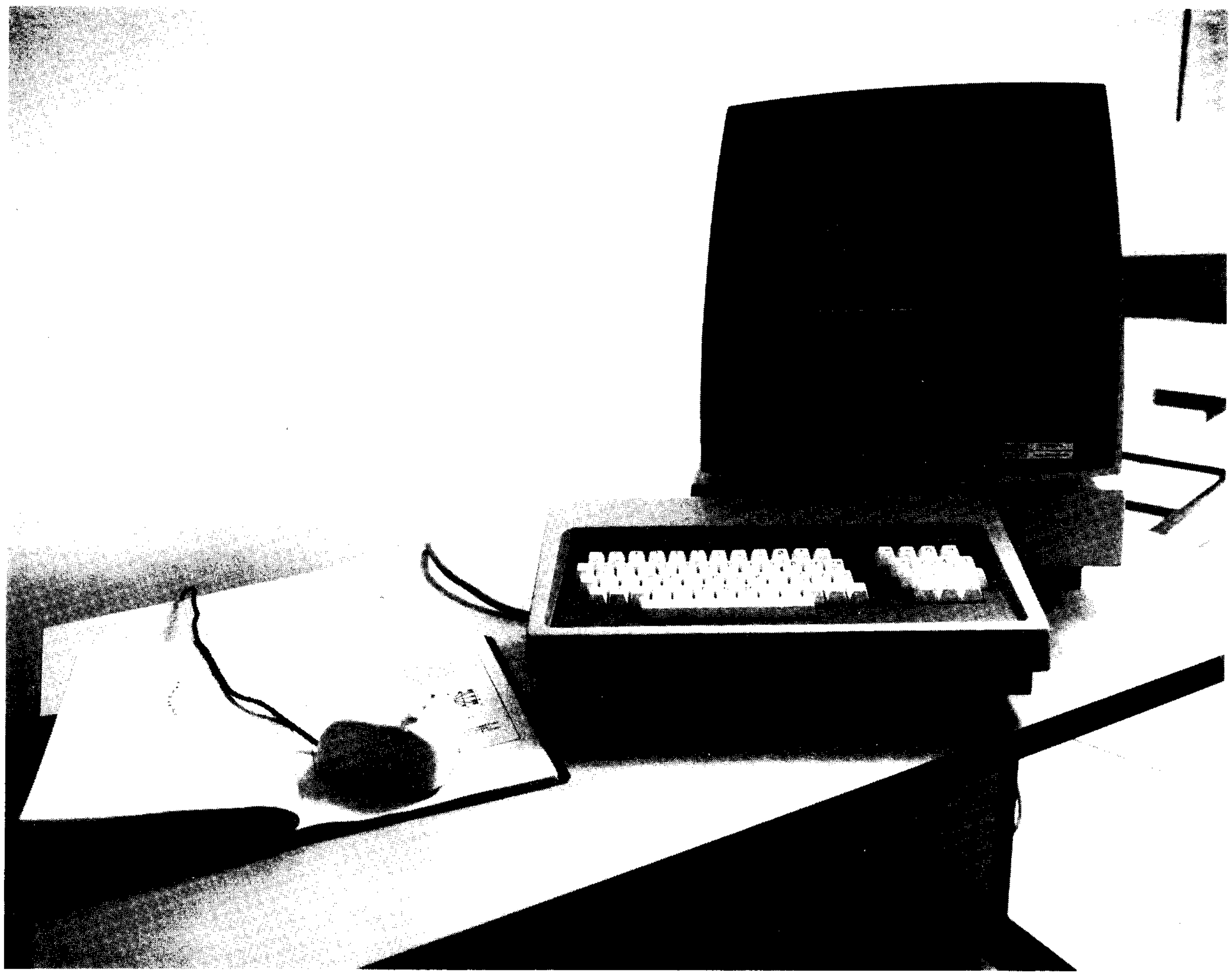

Figure 2 - Prototype User Station Configuration

```
Personnel Record Updating Program   Thursday, October 22, 1970   10:27 AM

Good Morning!

Ready: Jones

Dorothy L. Jones
Malcolm M. Jones
Thomas L. Jones

    First name: thomas l.

Thomas L. Jones
Last changed October 22, 1970

> change rank to res assist
    Effective date:  1 Sept 70

> p
    Research Assistant

> print assign
    A. I. - Vision/Robot                  76388      100%

> c percent ch to 80

> _
    Total percent charged for assignments is 80
    Do you wish to make an adjustment?  yes

> add assign
    Group: [illegible]
    Account Number: 79457
    Percent charged: 20

> p
    A. I. - Vision/Robot                  76388      80%
    Computer Systems Research             79457      20%

> _

Ready:_

Program terminated at user request.
```

Figure 3 - Example of Interaction with MacAIMS

Personnel System on CTSS

```
Good Afternoon!      October 23, 1970    14:53.0

Budget  Preparation  Program

GROUP : prog ling gen
Group not found in the Data File. Do you wish to add it? yes
SPONSOR : ARPA
SUPERVISIOR : Evans
STARTING DATE : 7/1/67
TERMINATION DATE : 30 jun 71
TOTAL FUNDS :  $ 575,000
ACCOUNT NUMBER : 79457

Enter  annual  Budgets
YEAR          AMOUNT
1969:       $ 50000
1968:       $ 35,000
1967:       $ 25,000

Type  changes  Name  changes(+,-,$)
               >_

Type Period : 7/70
Data for this Period and Group does not exist
Do you wish to add it ? yes

C a t e g o r y                         Budgeted Amount
FACULTY OFF             (dir. cost) $ 1200
RESEARCH STAFF OFF      (dir. cost) $ 0
SECRET. CLERICAL OFF    (dir. cost) $ 225.00
GRAD. STUD. STAFF OFF   (dir. cost) $ 992
MIT STUDENTS OFF        (dir. cost) $ 0
SPACE RENTAL                        $ 175.45
POWER                               $ 25
OFFICE SUPPLIES XEROX               $ 15
TELEPHONE                           $ 50
COMPUTER USE                        $ 1,350
TERMINAL EQPM                       $ 225.75
DATA COMM                           $ 54.37
Do you wish to add Additional Categories ? yes
Display list of Additional Categories? no

 C a t e g o r y  Budgeted Amount
 >travel             175.00
 >consult            500
 >_
 Should personnel cost be adjusted for
 fringe benefits and overhead ? yes
 T o t a l                               $     5,794.17

 Type  changes  Name  changes(+,-,$)
               >pow             +115
               >trav            $220
               >_
```

Figure 4 - Example of Interaction with MacAIMS Budgeting System on CTSS

```
Do you wish to display information after changes ? yes


Category                                         Budgeted Amount
FACULTY OFF               (Incl. F.B.+O.H.)         1,670.40
RESEARCH STAFF OFF        (incl. F.B.+O.H.)              .00
SECRET. CLERICAL OFF      (incl. F.B.+O.H.)           313.20
GRAD. STUD. STAFF OFF     (Incl. F.B.+O.H.)         1,240.00
MIT STUDENTS OFF          (incl. F.B.+O.H.)              .00
SPACE RENTAL                                          175.45
POWER                                                 140.00
OFFICE SUPPLIES XEROX                                  15.00
TELEPHONE                                              50.00
COMPUTER USE                                        1,350.00
TERMINAL EQPM                                         225.75
DATA COMM                                              54.37
CONSULTANTS                                           500.00
TRAVEL                                                220.00
Do you wish to add Additional Categories ? no
Total                                       $       5,954.17


Type   changes   Name   changes(+,-,$)
               >_


Type Period : Aug 1970
Data for this Period and Group does not exist
Do you wish to copy data from previous period ? yes
Do you wish to display it ? no
Do you wish to add Additional Categories ? yes
Display list of Additional Categories? no


Category   Budgeted Amount
>capital equip       115,000
>_
Total                                       $     115,000.00


Type   changes   Name   changes(+,-,$)
               >_



Category                                         Budgeted Amount
FACULTY OFF               (incl. F.B.+O.H.)         1,670.40
RESEARCH STAFF OFF        (incl. F.B.+O.H.)              .00
SECRET. CLERICAL OFF      (incl. F.B.+O.H.)           313.20
GRAD. STUD. STAFF OFF     (incl. F.B.+O.H.)         1,240.00
MIT STUDENTS OFF          (incl. F.B.+O.H.)              .00
SPACE RENTAL                                          175.45
POWER                                                 140.00
OFFICE SUPPLIES XEROX                                  15.00
TELEPHONE                                              50.00
COMPUTER USE                                        1,350.00
TERMINAL EQPM                                         225.75
DATA COMM                                              54.37
CAPITAL EQUIPMENT                                 115,000.00
Do you wish to add Additional Categories ? no
Total                                       $     120,234.17
```

Figure 4 (cont'd.)

UNCLASSIFIED
Security Classification

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY *(Corporate author)* Massachusetts Institute of Technology Project MAC	2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED 2b. GROUP None

3. REPORT TITLE

Helping People Think

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*
Technical Memorandum

5. AUTHOR(S) *(Last name, first name, initial)*

Goldstein, Robert C.

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
April 1971	22	--

8a. CONTRACT OR GRANT NO. N00014-69-A-0276-0002 b. PROJECT NO. c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) MAC TM-25 9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)*

10. AVAILABILITY/LIMITATION NOTICES

Distribution of this document is unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
None	Advanced Research Projects Agency 3D-200 Pentagon Washington, D.C. 20301

13. ABSTRACT

This paper describes some results of research in interactive problem solving and decision making. The requirements of a computer system for aiding a human decision maker are described with particular reference to the nature of the man-computer interface.

Some examples of interactive programs developed during the course of this research are also included.

14. KEY WORDS

Man-Computer Interaction   Interactive Systems   Management Information Systems

DD FORM 1 NOV 65 1473 (M.I.T.)

UNCLASSIFIED
Security Classification

MIT/LCS/TM-25

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