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AUTHOR	Cowell, Wayne; Fosdick, Lloyd
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ABSTRACT

Three related documents comprise this final report of a project dealing with the creation, testing and distribution of mathematical software. The first summarizes discussions held by the principal investigators with selected experts on mathematical software, the second consists of a working paper for discussion, and the third is a paper which considers the pros and cons of distributing software via different media. The project's research team conferred with about two dozen leaders in the development of mathematical software, originated the concept of a mathematical software alliance, conducted a Software Certification Workshop, and developed techniques for software distribution. The study recommended that an alliance of institutions should be established to provide a focal point for the creation and dissemination of high quality mathematical software and proposed the formation of a Mathematical Software Advisory Council which would be charged to: 1) initiate a program of research on methods of evaluating mathematical software; 2) assume technical review and policy guidance for selected activities now underway; 3) contract for the development of mathematical software; and 4) provide a plan for the growth of these initial activities. (PB)

COLLABORATIVE RESEARCH IN PLANNING AN APPROACH TO TESTING AND DISSEMINATION OF COMPUTER PROGRAMS FOR RESEARCH AND DEVELOPMENT.

FINAL REPORT.

Wayne Cowell
Argonne National Laboratory
Argonne, Illinois

Lloyd Fosdick
University of Colorado
Boulder, Colorado

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FINAL REPORT

to the

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Wayne Cowell and Lloyd Fosdick

OVERVIEW

We have carried out a one and one-half year study focusing on problems related to the creation, testing, and distribution of mathematical software. During this period we discussed these problems with a number of individuals who are vitally concerned with their solution and who are employed by government laboratories, universities, and private industry. We chose to interview in depth a relatively small group of people who are very active in the mathematical software area, preferring this approach to a broad opinion survey. We have gained insight from extensive and intensive discussions with these experts and they have expressed their interest in becoming involved with a broadly based attack on the problems.

We began with the belief, which has been strengthened, that there is a need for better mathematical software than is currently available, and that something can and should be done about it. Bad software results in the degradation of the computer as an effective scientific tool. While the waste in financial and human resources implied by this fact is not always dramatically obvious, its importance arises from the heavy dependence placed by the scientific and engineering communities on the computer. Thus the consequences of bad software, while perhaps subtle, have a profound effect on the advance of science and technology.

One common observation, illustrating the waste of resources, is that many scientists write their own mathematical software. This practice is a result of their lack of trust in the software available to them and the difficulties they encounter in obtaining and utilizing it. Another form of waste is illustrated by the large gap between the development of *algorithms* and the implementation of these algorithms as computer *programs*. Progress in numerical mathematics in the last decade has resulted in good methods for performing a number of fundamental computations that arise in science and engineering. But during the same period the complexity of computing systems has vastly increased, thus enlarging the problem of molding good software from good methods. The potential of the intellectual advances is not being realized.

Our conversations during the course of this study have convinced us that resources exist which, if properly utilized and further developed, can significantly improve this situation so that scientists and engineers can be provided with mathematical software that they can use effectively, that they can trust, and that will represent the state of the art in numerical algorithms. We will attempt to distill and interpret those conversations in this report.

We recognize that the creation of good software is a difficult and demanding endeavor requiring a variety of talents applied by the best people. It cannot be successful without careful coordination of activities in numerical mathematics, program testing, documentation, and distribution. We have formulated a recommendation for the first steps toward an organizational structure within which experts in these fields can cooperate so that their efforts lead to high quality mathematical software.

After summarizing the purposes of this planning study and the activities in which we have engaged, we shall present brief synopses of opinion on certain key issues. It would be surprising if there were unanimity among those actively engaged in a field as new and volatile as the creation of mathematical software. However, we believe that consistent patterns of opinion amount to a consensus on the major issues and that the will exists to work out the operational details. We claim that we have listened carefully and speak in good faith, but naturally we assume full responsibility for the interpretations and recommendation.

Several documents are attached and form an integral part of this report. A list of them follows, together with the abbreviations we shall use in making reference to them:

SMR Proceedings of the Software Certification Workshop held at Snow Mountain Ranch, Granby, Colorado, August 27-30, 1972; (This is document EM 011 584)

DIS "Summary of Discussion Related To the Issue of the Creation, Validation, and Distribution of Mathematical Software," prepared by Dorothy Lang from notes of Wayne Cowell and Lloyd Fosdick;

MSA "A Mathematical Software Alliance" by Wayne Cowell and Lloyd Fosdick, a working paper for discussion;

DSR "Distributing Software Study and Report," by Dorothy E. Lang for Lloyd Fosdick and discussion.

Purposes of the Study

Three broad purposes were served by the activities in this study. These were:

P1. To explore with the scientific computing community certain basic questions regarding the creation, testing, and dissemination of high quality mathematical software. These questions centered on the following issues:

a. The meaning of quality in software;

b. Education in software evaluation;

c. Research in software evaluation;

d. Determination of user needs for mathematical software;

e. The publication and distribution of algorithms and software.

P2. To prepare a conceptual plan for an organizational structure to focus the processes of creating, evaluating, and disseminating mathematical software; to stimulate discussion of the plan.

P3. To use editorial activities connected with the Algorithms Department of the Communications of the Association for Computing Machinery as a proving ground for techniques in refereeing algorithms submitted for publication.

Project Activities

In pursuit of the above purposes we:

A1. Conferred with about two dozen leaders concerning the questions in P1 and P2; these discussions are summarized in DIS;

A2. Originated the concept of a "mathematical software alliance" in response to P2; a description of the alliance as presented for discussion is given in MSA;

A3. Conducted a Software Certification Workshop at Snow Mountain Ranch near Granby, Colorado, August 27-30, 1972. The proceedings (SMR) were prepared by editing the tape recorded sessions;

A4. Involved student research assistants in editorial activities and studies of techniques for software distribution; the results were reported by Lloyd Fosdick under Discussion Topic II of SMR and by Dorothy E. Lang in DSR.

Brief Synopses

This section provides a condensation of opinion on various topics and serves as a guide to documents where these opinions are more fully expressed.

Software Quality

It is evident that the expression "quality software" connotes a useful concept even though a precise definition proves to be elusive and probably unnecessary. Attachment of this expression to a particular piece of software is a subjective exercise and, in the final analysis, depends on the judgment of recognized experts. The idea of quality recognizes considerably more than characteristics of the software itself; in particular, it includes such attributes as completeness of the documentation, performance of the program relative to its documentation, comparison of the program with others of the same type in terms appropriate to the problem, and adequacy of continuing maintenance and support.

An important notion that emerged was reproducibility of results. The analogy frequently drawn was with the scientific experiment, described in sufficient detail to permit repetition by independent workers. It was felt that a similar principle should apply to quality software, i.e., test procedures should be described in sufficient detail to permit other users to repeat them and reproduce the original results.

It was observed that rigorous proofs of correctness do not exist for most practical programs and the feeling was expressed that their existence is not on the near horizon. Correctness of practical programs will rely on certification procedures and imposition of structures on program organization that permit easy testing and reduce the likelihood of errors. Formal correctness is an important long-term research goal.

Pointers to further discussion:

Characterizing software quality - Discussion summaries, SMR Topic I; Draft definition of "certification," SMR, p. 59; Hull & Cowell, SMR Topic I; Cody ["The Evaluation of Mathematical Software" in Program Test Methods, William C. Hetzel, ed., Prentice-Hall, 1973].

Evaluation methodology - Hull, Cowell, and Newbery, SMR Topic I.

General - DIS, Sections I and II.C. (Note clarification of IMSL position in Battiste, SMR Topic VI.); Ng ["Mathematical Software Testing Activities" in Program Test Methods, William C. Hetzel, ed., Prentice-Hall, 1973].

Education and Internship

While there was general agreement that the subject of software evaluation should be a component of a computer science curriculum, it was not felt that specific courses on this subject were appropriate. Instead, the attitude was that the study of evaluation and development of an appreciation of software quality should be part of other courses; for example, courses in numerical mathematics. Internship programs, permitting on-the-job training in the development of quality software, were also recommended as a potentially productive mechanism for education in this area.

Pointers to further discussion:

Course design - Newbery, SMR Topic II; Thacher discussion summary, SMR Topic II; DIS, Section II.D.

On-the-job training - Fosdick, SMR Topic II; Thacher discussion summary, SMR Topic II; DSR is the report of a student project.

Research In Software Evaluation

While research in numerical mathematics enjoys a high academic status in departments of computer science, the same does not appear to be the rule for research aimed at the creation of methods and tools for evaluation of mathematical software. Part of this is simply a reflection of attitudes with respect to "pure" and "applied" research. However, this situation is also due to the fact that little academically oriented work has been done in this area; consequently there are no established frames of reference. Change is indicated and promising research programs in this area are being initiated at some universities.

Applied research in software evaluation goes on in non-academic institutions in response to mission oriented needs. There is a recognition that bridges joining such activities with those at universities would be very beneficial and should be encouraged.

Pointers to further discussion:

Attitudes toward research - Osterweil and Fairley discussion summaries, SMR Topic III.

Some current research directions - Boyle and Fairley, SMR Topic III; Sadowski, SMR Topic III and with D. W. Lozier ["A Unified Standards Approach to Algorithm Testing" in Program Test Methods, William C. Hetzel, ed., Prentice-Hall, 1973.]

General - Fritsch, SMR Topic III; DIS, Section II.

Liaison with Users

Differences in interests and attitudes create communication barriers between users of mathematical software and the experts who create algorithms and software. Frequently users fail to appreciate the difficulties and hazards of numerical computation with the result that they attempt to write programs in simplistic ways, with poor results. Moreover, they are not always sympathetic to the investment required to produce good software.

Keen awareness of the needs of the user community is uncommon among mathematical software professionals.

Various methods of improving communications have been suggested. These include: small working seminars focusing on a particular applications area; monitoring of software usage to provide helpful feedback; ready availability of expert consultation (in person and by phone) designed to attract users to recommended routines and increase confidence that these routines could be safely used; users groups representing a particular area of interest.

Pointers to further discussion:

User needs - Smith, SMR Topic IV.

User/expert interaction - Ng, SMR Topic IV; Stewart and Hetzel discussion summaries, SMR Topic IV; DIS, Section III and Section V.B.1.

Publication and Distribution

The possibility of a journal of mathematical software was raised on several occasions. Supporting reasons were that such a journal would provide a focal point for work in this area, assist in establishing standards, and be an outlet for professional work providing a professional recognition function as well as a communication function. Journal proponents voiced the opinion that existing journals do not provide an adequate communication mechanism for much work in mathematical software; either the editorial policy precludes publication of such work or the low professional standards of the journal discourage many from using it.

In exploring the role of the private sector in producing and distributing programs we saw again the importance of establishing bridges between universities, government research laboratories, and private enterprise. Obvious conflicts arise between private proprietary interests and the interests of free exchange of information. However, our impression was that the problems raised here could be resolved.

Pointers to further discussion:

Journal of mathematical software - Rice, SMR Topic V; Osterweil and Fairley discussion summaries, SMR Topic III; DIS, Section IV.B.

Private sector role - Battiste, SMR Topic VI; Lawson discussion summary, SMR Topic VI; DIS, Section IV.C.

Organization to Foster Mathematical Software

The concept of a mathematical software alliance grew out of our discussions. A broad plan for the alliance, identifying problem areas, types of activity, and division of labor was discussed at some length with general agreement on the central ideas. The feeling emerged that a planning group should be established to work out the details of its structure, its identification with institutions, its initial tasks, and its funding. (See Recommendation.)

Pointers to further discussion:

A mathematical software alliance - MSA; Cowell, SMR Topic VI· Lynn and Lawson discussion summaries, SMR Topic VI.

Remarks on private sector role - Battiste, SMR Topic VI.

Remarks on NSF network program - Sherman, SMR Topic VI.

General - DIS, Section V; Fosdick [The Production of Better Mathematical Software, CACM, vol. 15, nr. 7, July 1972, p. 611.]

RECOMMENDATION

As a result of this study, we are convinced that an alliance of institutions should be established to provide a national focal point for the creation, evaluation, and dissemination of high quality mathematical software. The document MSA can be used for general guidance, but the initial steps must be carefully taken so that a well-adapted structure evolves.

WE RECOMMEND the formation of a Mathematical Software Advisory Council of 6-10 members representing the mathematical software and user communities and selected from universities, government laboratories and the private sector. We further recommend that this Advisory Council be charged to:

1) Initiate a program of research on methods for evaluating mathematical software. The initial effort would be viable at the level of two man years per year if it could be located at some established institution (most appropriately a university) where senior scientists had a genuine interest in the creation of good mathematical software;

2) Assume technical review and policy guidance for selected activities now underway, in particular the NATS project and research at the University of Colorado on the dynamic and static analysis of computer programs.

3) Enter into contracts with selected firms in the private sector to supply mathematical software adhering to standards of documentation and performance established by the Advisory Council. This endeavor would be conducted to explore the mechanisms for obtaining mathematical software through private enterprise;

4) Provide a plan for the integrated growth of the above initial activities. This plan should deal with

a) organizational structure,

b) funding - short term and long term,

c) technical objectives - short term and long term.

Summary of Discussion Related to the Issue of the Creation, Validation and Distribution of Mathematical Software

The attached material is drawn from discussions Wayne Cowell and Lloyd Fosdick had with a number of individuals who are listed on the last page. In these discussions we tried to focus on specific topics related to the creation, validation, and distribution of mathematical software. These topics are the headings of the attached material. The discussions frequently tended to center on only a few of these topics depending on the special interests of the individuals involved. Thus the views represented here do not necessarily reflect a majority opinion, but they do reflect a fair impression of the comments we received. This material was prepared by Dorothy Lang of the University of Colorado from notes taken by Wayne Cowell and Lloyd Fosdick.

I. SOFTWARE QUALITY: WHAT DOES IT MEAN?

A. Levels or Gradations of Quality

It was the general feeling that gradations such as A,B,C should not be considered for a collection of scientific software; rather it was felt that all of the software should be of top quality. The notable exception was the IMSL group. It was the feeling here that more than one level of acceptability would be appropriate. (It appears that the primary reason this group maintained that more than one level of quality would be acceptable was connected with their interest in being able to place a software package on the market to meet certain schedules or demands before it might have achieved a level of perfection.)

B. Criteria for Quality Software

In recognition that some program might be good according to some definitions and not so good according to others, it is of primary importance to describe the basic characteristics and behavior of the program. This would allow the potential user to make a decision on whether or not the program was good for him without tagging it as "good, better, best". Such information might include things such as core requirements, accuracy, execution time and test case results, etc. It was also pointed out that information about trade-offs among the various characteristics would be very useful to the knowledgeable user; but the naive user should have reasonable defaults among the various options.

C. Complexity and Quality Relationship

It is the opinion of one person that complexity should be minimized, i.e. short programs are better even if more complex programs do more (when they work). This might be an argument for packages in which the components are simple.

II. Research - Testing and Evaluation

A. Role of University and Government Agencies

There was general agreement that the activities concerning development and writing of programs should be distinct (by groups of people) from activities concerning field testing and certification of programs. This leads to an important distinction between basic research in the areas of testing and evaluation, and actual field testing and evaluation of software programs. Such research should interface with the on-going activities of the certification process. However, the boundary between the two is extremely hazy, particularly in discussions concerning the role of universities, government laboratories and agencies, and private industry and their respective relation to the alliance. In general, it is felt that research (including that of testing and evaluation) and development of software should be done at the university level; the systematic field testing, certifying and initial distribution might best be handled by a non-university institution; e.g. Argonne National Laboratory.

B. Establishment of Test Procedures

Presently, the creation of high-quality software is intellectually challenging but is not highly regarded as a professional activity. It is generally agreed that a co-ordinated and consistent program is both important and needed (not only for the establishment of test procedures). The need was recognized, but exactly how this would come about was not determined. Some people are doubtful of directed research (establishment of a program of research) arguing that it is difficult to channel good people into specific research areas and that the current role of universities with respect to research and mathematical software might be sufficient. On the other hand, recognition of specific needs of the scientific community toward which the research group would give its attention, as proposed within the software alliance, might be more effective than letting research in such areas develop by chance. The proposed program is not meant to displace current independent research in mathematical software.

C. Development of Test Procedures

The feeling was expressed by some that rigorous test procedures concerned with proving correctness of programs and other less rigorous standards would not be terribly fruitful in the near future. Support was expressed in developing tools which would aid testing and certification of software. It was felt that the more important component of testing activities should involve a practical consideration of the numerical properties of the algorithm.

The approach taken by IMSL as a company is somewhat different. A member of their advisory panel or a consultant who is an expert in the field is asked for assistance in checking and testing the algorithms. Apparently, no general checklist or procedure is followed for all programs; instead, the advice of their consultant or panel member on what is adequate and necessary is considered sufficient for certification.

Whatever approach is used, it has been suggested that evaluation procedures be documented, so as to be repeatable in the same way a scientific experiment can be duplicated.

D. Education in Testing and Evaluation

There was general agreement that more emphasis should be placed on utilization of computer libraries - particularly in computer-based courses. An example of such use can be found at Carnegie-Mellon where software testing and certification is considered an excellent activity which should be (and is) included as part of their educational program.

III. Determination of User Needs and the Development of Software

A. Directed Research

One method of determining the needs of different people is through directed research. An example of directed research cited in discussion runs as follows:

1) communicate with users in a given area to determine their basic software needs

2) develop such software as input to testing-evaluation-dissemination processes

The belief is that step two requires a level of sophistication relating to software concerns that is lacking with users in a given area.

B. Establishment of Users' Groups

A second mechanism to determine user needs is establishment of users' groups. Such groups would consist of representatives having a need for mathematical software to determine guidelines for development and procedures.

IV. Recognition and Distribution

A. Advertising and Publicizing

It was generally felt by all those asked that there is a market for good software, but that marketing of such software is not emphasized strongly enough. It is important to publicize the existence of quality software if those who should use it are to become aware of it. It follows, then, that distribution must be an active concern of the center.

B. Professional Recognition

One way of publicizing the software of the alliance is by giving professional recognition to any software developed - possibly via a journal published by the software alliance and/or establishment of a professional organization. This could provide a medium for distribution on the first level (awareness). Questions concerning the relationship of such a journal to the algorithms section of the CACM have not been fully explored. Tentatively, it is felt that existing media should continue; and the alliance should co-operate with them by aiding the refereeing process. In turn the alliance might certify and distribute programs developed elsewhere (by other than the alliance).

C. Role of the Private Sector

Several methods for the actual distribution of programs have been proposed. One proposal suggests that private agencies could be contracted for distribution of the software only after said software has been certified. The details of how this might be done is a difficult and politically charged problem - conflict of interest, etc. Any such contracted company should be willing to allow free and open access to information they had regarding the development of computer programs (i.e. no privileged activities). However, should the federal government enter this area, could private distribution organizations become non-existent?

D. Distribution via a Network: The Role of the Alliance with Respect to a Net

Another possible method for the distribution of programs might be through a network such as the ARPA net. Possibly, the alliance could be considered as a node in the net, acting very much like a library for mathematical software. Members of the net could obtain their programs and documentation over the net. This would be one manner of distribution rather different than that envisioned for a private company. The possibility of becoming a library for scientific subroutines which is a node in the ARPA net or the possibility of a future "NSF" net, or both, is extremely inviting and should be given serious consideration.

V. Organization: Structure, Co-ordination, and Funding

A. Structure

According to some, the system should be flexible enough to allow people to follow their own ideas, yet provide enough structure and direction to identify needs and see that they are met. Whatever the structure, both political and practical considerations are important.

It has been proposed that the activities of the alliance be overseen by a board of governors consisting of representatives from the different agencies involved in the alliance. It was the feeling of one individual that the board (of governors) should not include anyone from private industry because of the potential conflict of interest that it might reflect. (Note: a network distribution such as the ARPA net might remove any such possible conflict of interest.) Doubt has also been expressed that the same group of people (or board) would have the talent to handle both financial and technical affairs equally well. A model similar to the IMSL operation was suggested - a board of trustees which receives authoritative expert advice.

In order to clarify the role of the participating institutes and their relation to the alliance, it was thought best by one that the working draft be more specific as to what institutions might be involved in the alliance.

B. Co-ordination (interfacing)

There was general agreement as to the alliance organization and division of labor as outlined in the working draft:

research and development at universities
testing and certification at government laboratories
dissemination and support by private company or network

However, co-ordination of these activities is necessary and several plans directed toward easing exchange of information have developed:

1. establishment of a federal scientific software users group consisting of about a dozen representatives of various agencies having a need for mathematical software. Such a group would act in a consultative and advisory capacity in an attempt to develop a set of guidelines for testing scientific software of importance to the government. This group could be one mechanism of communication to the developers of programs of a more practical nature. Interest was expressed

by (12) in overseeing such a group.

2. establishment of a network of graduate students under supervision to perform some field testing. (This has been a well received idea.)

3. exchange of staff between the research and development group and the dissemination and support group. The same mechanism might also be established between the research and development group and the testing and evaluation group. Given that the normal route of software would be from the research and development group to the dissemination and support group (for systemization - formatting a consistent package), such an exchange could be quite useful. A staff member who is working on systemization of a program would have an opportunity to work with the researcher who is an expert in the area toward which the program is directed. Reciprocally, a member of the research and development group (a faculty member or possibly a graduate student) would have the opportunity to visit the dissemination and support group to work (and learn) the practical aspects of developing computer programs for wide distribution. (This has interesting potential for visiting graduate students when the dissemination and support group is a private company.)

C. Funding

Due to the different agencies and institutions presently having activities funded by a variety of sponsors, possibly, the efforts of participating agencies and institutions should be funded independently (of the alliance), but should be programmatically consistent with the alliance. There was also mention of the possibility of having a software dissemination and testing project funded by several agencies simultaneously such as AEC, NSF, and NASA.

The question was raised whether NSF (or any sponsoring agency) would go along with the idea of a board of governors writing contracts to individuals or groups either for research or for specified services. It has been suggested that possibly NSF could give the grants directly upon the advice and counsel of the board.

There is hope that eventually the center will be able to support itself. However, it is felt that in order for a center to become self-supporting present attitudes, particularly toward money currently spent on software, must change. As an example, it was pointed out that a typical University Computing Center would be more likely to spend 5K on student appointments to develop doubtful programs than to use the same 5K to buy good software. This feeling supports the thesis that distribution must be an active concern of the center (as mentioned previously in section A, topic IV.)

VI. Miscellaneous

A. Support of programs might best be handled by the author(s) rather than the distribution center(?).

B. Hard facts are needed to support the position that an activity such as the alliance, should be created.

C. It is a strong feeling of one individual that the institute should have a physical location. It would facilitate the mechanism of exchanging information among the different co-operating agencies and sections of responsibility (research and development, testing and certification, dissemination and support) as described in section B(3), topic V.

D. Involvement of the private sector in a testing and/or dissemination activity was generally considered a difficult problem.

E. Enlightened management must bring together people and problems.

Note: We have also benefitted greatly from many less structured conversations with individuals we have not attempted to list.

<u>List of Participants</u>

(1) Ambler, Ernest; NBS

(2) Anderson, R. L.; IMSL

(3) Aufenkamp, D. D.; NSF

(4) Battiste, E. L.; IMSL

(5) Colvin, Burton; NBS

(6) Corrucini, Joseph; NBS

(7) Cowell, Wayne R.; Argonne National Laboratory

(8) Forsythe, George; Stanford University

(9) Fosdick, Lloyd D.; University of Colorado

(10) Goldman, Dave; NBS

(11) Hanson, Richard; Jet Propulsion Laboratory

(12) Jeffrey, Seymour; NBS

(13) Johnson, O. G.; IMSL

(14) Krogh, Fred; Jet Propulsion Laboratory

(15) Lawson, Charles; Jet Propulsion Laboratory

(16) Moler, C. B.; University of Michigan

(17) Ng, Edward; Jet Propulsion Laboratory

(18) Oser, James; NBS

(19) Rice, John; Purdue University

(20) Sadowski, Walter; NBS

(21) Steward, Sheldon; NBS

(22) Thacher, Henry, University of Kentucky

(23) Traub, J. F.; Carnegie-Mellon University

June 5, 1972

A Mathematical Software Alliance

Wayne Cowell and Lloyd Fosdick

Working paper for discussion as part of the Argonne National Laboratory-University of Colorado Study "Planning an Approach to Testing and Dissemination of Computer Programs for Research and Development"*

Effective application of the computer to problems in science and engineering requires that fundamental mathematical calculations be performed with great accuracy and efficiency. The scientific user should be able to carry out basic computations easily and to rely confidently on the results. Unfortunately, there is a gap between expectation and accomplishment. Only in a few research institutions did the rapid, somewhat chaotic, growth of high speed computing inspire the creation, careful refinement and effective dissemination of high quality software. But increasing concern for quality and efficiency is felt among scientific users and mathematical software specialists who are seeking return commensurate with personal and capital investments in computing.

To illustrate ways in which this concern has been translated into various kinds of action, we cite three examples:

(1) A Mathematical Software Symposium was held at Purdue University on April 1-3, 1970, under the sponsorship of ACM SIGNUM with funding from ONR. A book "Mathematical Software" (Academic Press, 1971) edited by John R. Rice is based on the proceedings of the symposium and also discusses the current status and possible future directions of work in mathematical software.

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* Work supported by the National Science Foundation.

(2) The NATS project is an NSF-funded collaborative effort by Argonne National Laboratory, S anford University, and The University of Texas at Austin in cooperation with various field test sites, to certify and disseminate mathematical software.

The purpose of this prototype venture is to develop ways of supplying the scientific computing community with highly reliable subroutines.

(3) In the private sector the International Mathematical and Statistical Library (IMSL) of Houston, Texas, provides libraries of subroutines and consulting services to subscribers. The corporate intent is to upgrade and maintain these libraries at current "state-of-the-science" levels.

This paper explores ways of organizing a national effort to meet the need for good mathematical software. Since any such venture must reflect the processes by which such software is created and made available to the user, we will first examine the factors involved in its production.

Systematized collections of computer programs evolve from a conceptual base in theoretical mathematics through a series of steps in which numerical methods are discovered, efficient algorithms for specific tasks are devised, programs based on these algorithms are written, and collections of these programs are packaged, tested, refined, and distributed as supported software. This is a long chain of events touching several areas of interest. Specialists in one area need to see the role that their particular skills and interests play in the evolution of good software and to be able to relate to specialists who concentrate on other aspects of the process.

It seems natural to divide mathematical software evolution into three stages:

Stage I Research and Implementation

Stage II Evaluation and Refinement

Stage III Dissemination and Support

To give meaning to these terms we list below examples of types of activities associated with each stage.

I. Research and Implementation

a. Research in support of software development: error analysis, termination criteria for iterative processes, interval arithmetic, arithmetic characteristics of machine hardware, program testing methodology, hardware media to facilitate exchange of routines. Comment: Emphasis should be on problems arising from practical attempts to produce, test and disseminate mathematical software.

b. Critical surveys of literature (three to twelve months' work by an expert resulting in a report covering, say, numerical treatment of differential equations).

c. Computer based comparisons of methods (e.g. Hull, et al, Comparing Numerical Methods for Ordinary Differential Equations, University of Toronto Computer Center Report No. 29).

d. Development of numerical methods for classes of problems (e.g. linear algebra, differential equations, function approximation), guided by I.b and I.c.

e. Development of efficient algorithms for specific tasks (e.g. eigenvalues of large band matrices, approximation of gamma function), guided by I.d.

f. Writing, debugging and documenting programs which implement the efficient algorithms developed in I.e.

g. Translating programs from one algorithmic language to another.

h. Gathering programs for a given problem area into a collection and unifying the collection into a package with consistent calls, modes of calculation, etc.

i. Writing supervisory control programs permitting the use of packages at a relatively high level of problem description.

j. Organizing workshops involving users and mathematical software specialists.

II. Evaluation and Refinement

a. Development of standard benchmarks and test cases for various classes of problems.

b. Testing and refining programs through trial of standard cases (see II.a), field testing, tailoring to a particular system, and other methods (e.g., on-line test case generation) that may be developed (see I.a). Comment: The methodology of the NATS project is both example and guide.

c. Application of testing methodology as a feature of refereeing algorithms submitted to journals. Comment: This might be accomplished by graduate student assistants working under the supervision of senior referees.

III. Dissemination and Support

a. Distribution of certified programs to the user community and publication of algorithms.

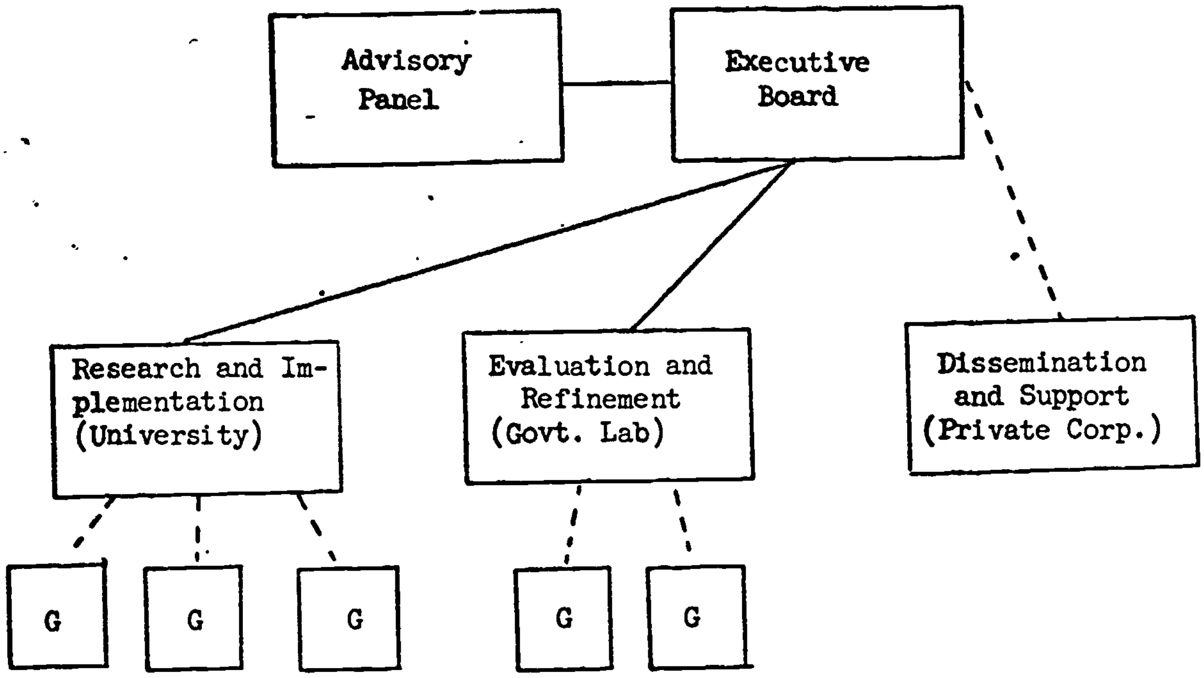
b. Support of certified programs through consultation and remedying of incorrect performance. Comment: This should involve the developers of the routine.

We assert that the high quality mathematical software that now exists and is readily available has, in one way or another, passed through these three stages. Yet very few institutions support activities that extend from research through evaluation to distribution and virtually no individual is really expert in every stage of software evolution. The scarcity of first-rate software is largely explained by the difficulty of bringing such a diversity of interests and skills to bear on the problem. We propose an organizational framework based on the premise that an alliance of institutions is needed to provide the necessary range of talent. Such an alliance must facilitate communication among people with pertinent interests and skills and stimulate them to address the problems discussed above.

We shall assume that a parent organization will supply leadership and initial financial support during the formative stage and will accept responsibility for the continuing vitality of the resulting organization. The parent organization might be (1) a government agency or laboratory, (2) a university, (3) a consortium of universities, (4) a professional society.

The first step would be to form a group of 6-12 persons who are recognized and respected authorities in mathematical software. This group would give expert technical guidance in the choice of particular mathematical software objectives to pursue as the first tasks of an alliance. After work had commenced, the group of experts would continue to review the objectives and evaluate progress toward them. It would be responsible initially to the parent organization and then, through some appropriate mechanism, to the funding agency when the alliance had been established. The advisory and review group would meet regularly to consider matters of technical policy but it would not have operational responsibility for management of the activities. This would be the task of a smaller group, say, of 3-6 individuals who would serve as an executive committee, responsible for formulating, justifying, implementing, and reporting on programs to carry out the objectives of the advisers. The members of the executive group would spend a significant portion of their professional time on affairs of the alliance. Its members should be chosen for their skills in implementing technical and scientific programs. The executive committee would not necessarily be a subset of the advisory group but some overlap may be desirable. Let us call the first group the Advisory Panel and the second group the Executive Board of the Mathematical Software Alliance.

Given the existence of the Advisory Panel and the Executive Board and assuming that federal support for the alliance has been obtained and is administered by the Executive Board, we will now describe alternate structures for nourishing the three stages of software evolution. (In the sequence of actual events, the structure would be described in the proposal for federal support.) We will diagram and comment on four plans. In the diagrams that follow, solid lines represent continuing direct policy control while broken lines indicate that a grant has been made or a contract signed for proscribed research, development, or services.



G = Universities and Non-Profit Laboratories Receiving Grants for Work in Research, Implementation, Evaluation, and Refinement

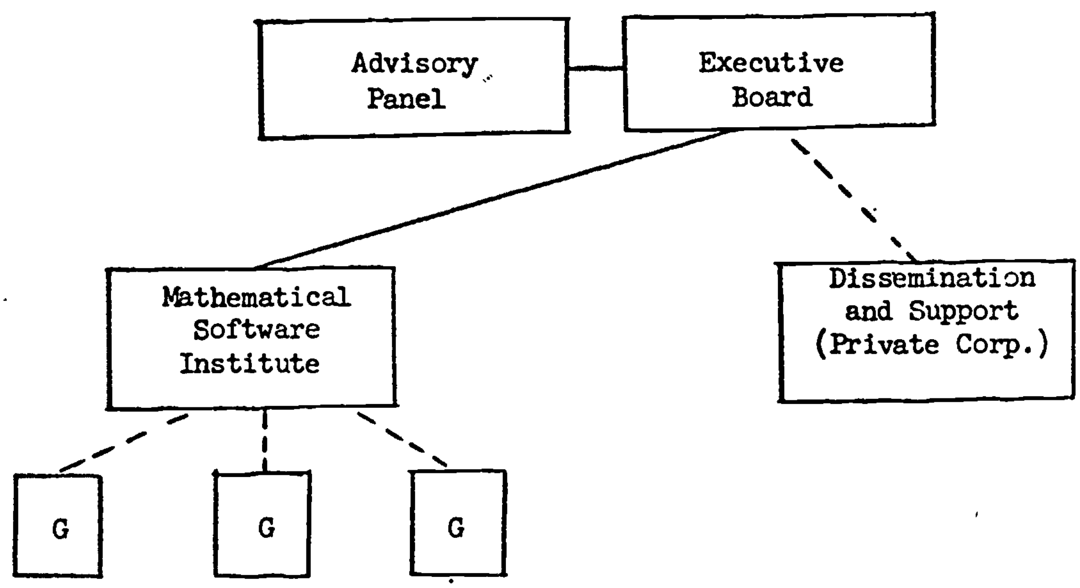
Comments on Plan A: With support from NSF (or some combination of funding agencies) and guided by the Advisory Panel and Executive Board, a university would establish a center for mathematical software which would be concerned with the research and implementation stage. The evaluation and refinement stage would be focussed at a mathematical software evaluation center located at a government laboratory and established with guidance from the Panel and Board. These two stages would be activities of the federal government. The dissemination and support function would be carried out by a private, profit-making (but regulated) corporation under contract to the Executive Board.

Although each of these organizational components would have a physical location, it is understood that research, implementation, evaluation, and support will be widely dispersed activities if the best talent in the nation is to be tapped. It would be the responsibility of the Advisory Panel to identify areas of work and groups or agencies who could be requested to do this work. Support for work would probably be arranged through contracts with or grants to individuals or groups to perform research, development, or testing in an area of interest to one of the centers. Presumably these would be grants from the funding agency directly to the institution. The Advisory Panel could act in a consultative capacity when proposals for such grants are reviewed.

We believe that the ratio of visiting staff to permanent staff should be large (perhaps 2/1 or 3/1) for the research and implementation center. This center would also provide facilities for graduate thesis work in pertinent areas. The ratio of visiting to permanent staff would be somewhat smaller in the evaluation and refinement center but ample support for short and long term visitors should be provided. Visits should be encouraged that enable specialists to see their roles in a wider context. For example, selected staff members of the dissemination and support company should spend time at the research and implementation center to keep current on the latest methods and thus enlarge their ability to support certified routines. Also, students in computer science should have an opportunity to see the evaluation and software marketing process in action.

The usual path of software would be from the research and implementation center to the dissemination and support company (for formatting and consistent packaging) to the evaluation and refinement center and, finally, as certified software, back to the dissemination and support company for marketing and maintenance. The issue of proprietary rights to packages whose components are developed with public money is not clearly resolved and we cannot settle it here. The company with the dissemination and maintenance contract would offer services in the public good and receive a fair return. Another type of interface between government sponsored development and the general public will be discussed below in Plans C and D.

Plan B



Comment on Plan B: The change from Plan A is that the two federally supported centers are combined into one.

Advantages of Plan B over Plan A -

1) A larger "mass" of talent in one place providing greater interaction among those involved in various activities;

2) Individual staff members of the institute have a wider choice of activities or combinations of activities;

3) Possible cost saving due to economy of scale (supplies, computing, etc.)

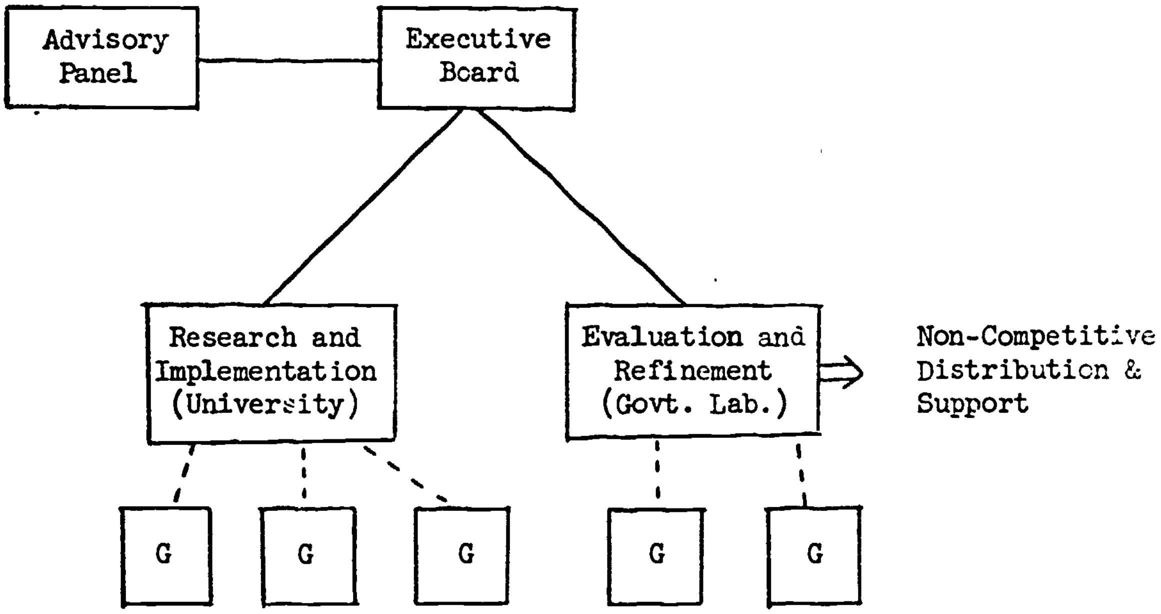
Advantages of Plan A over Plan B -

1) Recognizes explicitly the desirability of an academic environment for research and also the advantage of carrying out "missions" at a laboratory oriented toward structured endeavors.

2) A constructive "adversary relationship" between evaluator and developers is easier to maintain since evaluation is physically separated from development.

3) Greater geographical spread bringing software activities closer to more areas of the country.

Plan C



Comments on Plan C: This is a modification of Plan A which is intended to stimulate competitive private enterprise rather than contract with a particular company to market products subject to regulation. Non-competitive distribution and support could mean one of two things:

1. certified software is distributed and supported (free or for distribution cost) by the two federally funded centers

for a specified and limited period, say one year from the the time it becomes generally available. After this support is terminated the routines will, of course, remain in the public domain but there will be a continuing need for distribution, maintenance, and consultation;

2. distribution and support would be offered indefinitely from the federal centers but a fair market price would be charged for such services.

We foresee the possible emergence of a market for distribution and support services and believe that the computing public can be served by encouraging the private sector to develop capacity in this area.

Comments on the involvement of the private sector: In spite of the unquestioned scientific value of good mathematical software, we do not have a good measure of its value in the market place. One small company (IMSL) is dedicated to marketing a library of subroutines but has not existed long enough to be assured of a long life. Large companies (e.g. IBM) market mathematical software along with many other products and services thus clouding the issue of profitability in the specialized area of concern here. Our conversations with leaders in the mathematical software business show clearly that a number of outstanding questions exist; e.g., what level of software quality assures customer satisfaction at acceptable cost to produce? Partial answers are beginning to emerge through efforts such as NATS which provide additional data on the costs involved in mounting a major certification effort. Pending further information, our tentative conclusion is that research, implementation, evaluation and refinement can be accomplished by collaborative efforts whose costs are acceptable when broadly distributed; i.e., when undertaken as publicly supported ventures intended to produce routines and methodology that will be widely used. However, it appears doubtful that small private capital ventures could afford these aspects of mathematical software development. All of the organizational plans presented in this paper are drawn under the assumption that good mathematical software is a national resource of sufficient importance to deserve underwriting by the federal government and that, moreover, this support should be given in such a way as to encourage the development of private software enterprise which would take over the more costly areas if and when the economics made this possible.

Advantages of Plan C over Plan A -

1) The problem of selecting, contracting with, and regulating a dissemination/support company is avoided.

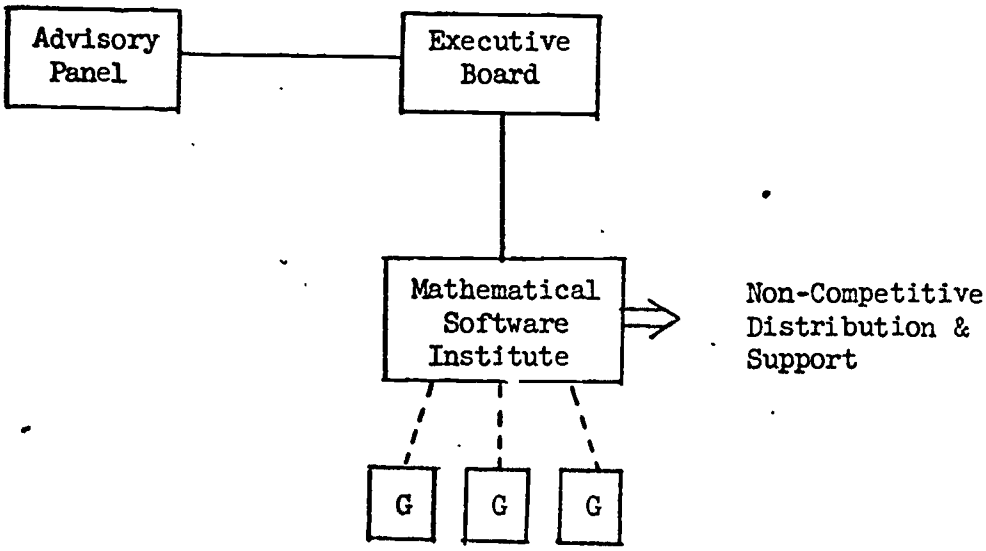
2) In principle, the value of scientific software in an economic sense is determined through the operation of a free market.

Advantages of Plan A over Plan C -

1) The nature of the distribution and support services rendered can be strongly influenced by the Advisory Panel, thus enabling expert opinion to dominate purely economic considerations.

2) The uncertainties of the market place can be minimized by guaranteeing a minimum return to the company, thus ensuring that the distribution and support mechanism will continue to function for the benefit of users without the federal centers bearing the burden of continuing service.

Plan D



Comment on Plan D: This is a Plan B with the dissemination/support company replaced by the dissemination and support concept of Plan C.

Discributing Software

Study and Report

Dorothy E. Lang
Department of Computer Science
University of Colorado

Abstract

This paper briefly discusses the pros and cons of distributing software via different media. Included is a preliminary analysis of the costs involved. An attempt is made to evaluate distribution media and draw some conclusions that might suggest possible solutions for the dissemination of mathematical software.

INTRODUCTION

Distribution of mathematical software must be an active concern of the mathematical software center. It will be important not only to publicize the existence of quality software, but to make such software readily available. Several mechanisms for the distribution of programs have been proposed. This paper attempts to evaluate distribution media and provide sufficient information to enable the establishment of economical distribution mechanisms.

In trying to determine the cost of distributing algorithms, we will consider the following three media:

1. magnetic tape
2. 80-column cards
3. telecommunications

Each of these media is plagued with the problems of character-set compatability - ASCII, BCD, EBCDIC. Its an 8-bit world, but some people refuse to admit it and those who do have their own idea of what the codes should be. Thus, we have ASCII as the standard with limited use, EBCDIC as a powerful loner, and BCD, our old 6-bit standby, as the most popular. Most installations that do not use BCD can easily convert from BCD to their own codes (since BCD has been so popular, apparently installations not using BCD have found it convenient to have available a conversion program). In the fast growing world of communications - terminals, networks, and telecommunications - ASCII is rapidly gaining acceptance. For 7-track tape (which brings up another problem) the 6-bit ASCII standard is the old external BCD code. The dilemma seems best resolved by using the BCD character-set (or ASCII if you prefer) for magnetic tapes, refraining from 9-track tape altogether, and using the ASCII character-set when using telecommunications. Hollerith punch codes used on cards vary from installation to installation (machine to machine). The most notable differences occur with the special character codes. Such problems are unique to the card medium.

In determining costs involved in the distribution of algorithms, certain assumptions have been made. Overhead costs of each method are ignored in figuring cost estimates. This is not as devastating as might first appear. Fixed costs such as creation, development, and maintenance of the library are presently indeterminable. One could choose an arbitrary system (the ARPA network might be one) and calculate cost figures based upon their charges. However, if the system changes, the cost figures change. If the original library size and development estimate is far from actual, then so are the cost figures. Rather than distort the picture any further than necessary, such overhead is presently left out of cost figures with a word to the wise that eventually the figures shown will increase by x amount for each medium. (These figures appear in Appendix D.) A second type of overhead cost is also ignored. This might best be classified as hidden cost and includes such things as secretarial time and clerical salaries, etc.

Lastly, mailing charges and telephone charges vary according to the distances involved. Cut-off points between media for longer distances may be different than for local distances. For example, it may be cheaper to distribute algorithm y locally via terminal lines, but for distances over 1000 miles, it may be cheaper to send the algorithm via cards. To help determine such cut-off points, the cost of distributing each example algorithm is figured for all four media to three destinations. Using the University of Colorado as the distribution origin, costs are figured to Denver, Colorado (25 miles), Albuquerque, New Mexico (422 miles), and Washington, D.C. (1696 miles).

The pros and cons of each medium will be discussed individually. Details of pricing and cost figures appear in the appendices.

SECTION 2

MAGNETIC TAPES

For exchanging large amounts of information (over 5000 card images), tapes are more convenient to use than cards and in addition are economically practical. Only 7-track, 1/2" magnetic tapes will be considered here. Cost calculations are based on a 556 bpi density, 80 character unblocked records (which is the most wasteful format for recording information on tape). The break point between cards and tape is around 2000 cards. This figure may be somewhat lower depending on the price of the tape.

It appears that tapes vary widely in price depending on the manufacturer and size of reel. For example, the range for a 2400' reel of tape runs from approximately $10 to $25. This does not include costs of seals or cannisters. Appendix A, Tables 1-3 contain more detailed price information.

It is also possible to obtain empty tape reels and cut longer length tapes into several shorter ones. For example, the cost of cutting one 2400' reel into four 600' reels is around $22 (including the price of the original 2400' tape, Memorex MRX III) or $5.50 per 600' reel. A 600' tape from the same manufacturer runs $9.00 -- a $3.50 saving per 600' reel. It takes one man about 10 minutes to perform the task using the IBM 1401.

Additional factors besides length of tape affecting tape capacity are record size, block size, and density (bpi). Record size, for purposes here will be fixed at 80 characters/record (a card image). The wide range of tape recording densities (200-3200 bpi) causes variability in amounts of information on a reel of tape. This variability is less, however, than that causes by blocking factors (see Appendix A, Table 4). For most purposes, it appears that even with inefficient recording a single tape can provide a large amount of information.

There are some considerations one must keep in mind about tapes - other than those previously mentioned. Processing tapes is often system dependent and care must be exercised in choosing a recording mode and density, character-set, record size and block size, let alone tape size (both width and length), that is convenient for most users. Exchanging information via magnetic tape also initiates a time lag cycle - long enough to receive, process, and send out a request. If time is a critical factor, perhaps another medium is better. In addition, tapes are extremely vulnerable to shipping damage.

For general purposes of distribution - particularly of entire libraries or large subsets of libraries - tape should be considered an excellent and most viable medium.

In calculating magnetic tape costs the following base was used:[1]

central processor time	$.09 per mil*card images
listing	.70 per mil
mass storage and transfer	.50 per mil
tape	MRXIII Type 25 (Memorex[2])
postal charge	by weight (packing not included)

* Meaning one thousand

[1]Figures are based on sample runs to copy appropriate information onto tape using the CDC 6400 under KRONOS operating system at the University of Colorado. A listing was considered essential in order to determine that a correct copy was made.

[2]Memorex tapes were chosen as a standard mainly due to the availability and completeness of pricing information at the time of this study. Also according to recent information, Memorex tape costs are being lowered considerably in the near future (approximately $4.00 for a 2400' reel). This makes tapes an even more attractive medium. Additional information shows that other manufacturers may have comparable and possibly better prices.

Disregarding parcel post (4th class mail service) and considering only airmail or 1st class mail service, the break point between cards and tape occurs around 2000 card images or 1 box of cards. This is reassuring since anything much over a box of cards begins to become rather cumbersome, in addition to punch code differences which are more annoying than character-set differences.

SECTION 3

CARDS

80-column cards must not be disregarded as they are the most readily available medium of exchange. But cards, too, have problems with varying character codes. Up to a certain point, somewhere between 1000-2000 cards, cards are most convenient. Cards are less prone to damage enroute, and if damaged, much easier to recreate on site. However, transporting more than a box of cards is unrealistic. Not only would a package of any large size take who knows how long to arrive through the mail, just imagine receiving a library of 10,000 cards.

Card costs were calculated two ways - 1) using a card reproducer machine, and 2) using a copy utility to punch a deck on a computer. The following bases were used in the cost calculations:

<u>reproducer machine</u>	
cards[1]	$1.10 per mil
box	.22 per 1/2 box (if needed)
<u>copy to punch utility</u>[2]	
punch	$.50 per mil card images
listing	.70 per mil
mass storage transfer	.50 per mil
CP time	.09 per mil
box	.22 per 1/2 box (if needed)

[1] based on an average cost from Rocky Mountain Tabulating Card Co. price list.

[2] figures based on sample runs using CDC 6400 under KRONOS operating system at the University of Colorado.

SECTION 4

TELECOMMUNICATION

Evaluating exchange of information through use of telecommunications is highly complex. There are many factors to consider in evaluating the communication (phone and data) services available, each dependent on the job involved, equipment available, and transmission distances. The rate structure of the telephone system is also highly complex. The details of such rate structures are not readily available; and furthermore vary considerably depending on origin and distance. Further complicating the situation are the network costs themselves. These too vary depending on the network chosen and its particular charging structure. Factors to be considered are such things as connect time cost, central processor time cost, storage cost, data transfer cost.

Detailed analysis of networks is beyond the scope of this study; however, to be meaningful and to give a clearer picture of costs, they can not be totally ignored. For the purposes of this report, only connect time and CP time will be included in calculating telecommunication costs. Based on the KRONOS network of the Control Data Corporation (see[6]), connect time charges are $8.00/hr., CP time charges are $.20/CP sec. These are relatively low charges compared to some other services (refer to Appendix C, Table 4).

Again, detailed analysis of communication services is beyond the scope of this study. Only three types of voice grade services will be considered here: 1) DDD - direct dial service; 2) WATS - Wide Area Telephone Service; 3) private leased line services. Interstate rates for dial-up service are based on the Message Schedule I rate effective

February 1, 1970. Assuredly, these are now out-of-date; and most likely present rates are higher. The intrastate rate between Boulder, Colorado and Denver, Colorado is presently toll-free.

The WATS rate for Washington, D.C. to Colorado is $1750/mo., for Albuquerque, New Mexico to Colorado, $1650/mo., Colorado intrastate rate has not been calculated.[1] To simplify calculations, figures are based on $1700/mo.

Private line service (leased line) is better suited for data transmission than dial-up lines (DDD or WATS) as the lines are better controlled in addition to being conditioned for data transmission. Conditioning adjusts frequency and phase response characteristics of the channel (line) to meet closer tolerance specifications. Chosen for this study was C1 conditioning which will allow up to 2400 baud transmission rates. The rate structure was based on a half-duplex line with 2 terminals (a 2 point channel) not arranged for switching. This is the cheapest arrangement of leased lines.

In general, transmission speeds range from 10 char./sec. to 9600 baud (bits per sec., approximately 1200 char./sec.). Faster transfer rates naturally are much more expensive, and consequently less readily available. A 10 char./sec. rate is only practical for transferring small amounts of information. Transferring 1000 card images takes 2 hours, 13 minutes. It is rather undesirable to wait that long for an algorithm, let alone

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[1] intrastate rates are not FCC controlled and vary from state to state. As Boulder - Denver connection is toll-free via dial-up service anyway, it is not even practical to consider WATS in this case.

trust the line for that length of time.[1] For example, at the University of Colorado all one need do is tap the handset (or have the operator cut in on your line) while you are connected to the computer to have your transmission become completely garbled. For the sake of sanity, anything over 45 minutes is considered unreasonable (and too expensive), but times up to 4 hours have been included in calculations.

Analysis shows that unless 1200 or 2400 baud terminals are available, costs quickly become exorbitant when compared to tape or cards. Comparisons among the three services studied show some interesting results. It is apparent that WATS is more expensive in all cases - except possibly if a line already exists and there is unused time available. Between leased lines and DDD lines, a more careful analysis is necessary in order to determine which is more economical. Factors to consider are time of day, point to point distance, and degree of loading. In general, a leased line operation maintains a constant connection between terminals and computer. A DDD connection must be made each time transmission is required. On this basis, leased line can only be justified in cases of heavy use.

It might be noted that it is possible to transmit information from terminal to terminal skirting the computer - and thus charges connected with such - altogether. For example, it is possible for one teletype to connect to another teletype, read in a paper tape at one end and punch it out at the other. However, the transmission speeds are too low for such

[1]An interesting psychological phenomenon occurs with the advent of telecommunication. Unless response is immediate or at least minimal, the average person is unwilling to put up with delays. He would rather wait 3-4 weeks for the delivery of a tape than wait the 2+ hours for the transmission of the algorithm via teletype.

a method to be given any serious consideration, and are not included in the comparative analysis.[1]

[1]excepting local distances, the cost was found to be higher than other media in addition to being a lengthy process.

SECTION 5

COMPARATIVE COSTS and CONCLUSIONS

Appendix D contains a series of charts showing the cost of distributing different amounts of information using each type of medium. The first is 1000 card images which is the size of ACM algorithm 343, EIGENP, the last is 16,000 card images, the approximate size of EISPACK, the Eigensystem Subroutine Package, developed as part of the NATS project at Argonne National Laboratory.

These charts show that 2400 baud line terminals are the cheapest medium. However, prices could easily be boosted if based on a more expensive connect time charge - say $16.00/hr. (not unreasonable). This would almost double the charge.

Strictly from a transmission cost stance, it might first appear that telecommunication is the answer to our distribution problems. However, there exist certain mitigating factors that make the medium less attractive. Granted, the character-set is rapidly becoming standardized, but once we start talking in terms of terminal to terminal or network-terminal communication links, we must also consider computer to computer communications. Here things are not so standard and numerous non-compatible protocols exists - particularly with remote terminals. One can not simply set up a library network on computer xyz and announce its availability to all. The computer must be able to "talk" with the terminals - communicate via signals, and sync-codes and observe various protocols. Such conflicts are extremely complex and existing networks are only beginning to resolve them. Setting up a library network in this way could easily restrict distribution to less than half its potential users - certainly an adverse side effect for the proposed function of such a library!

With this in mind, magnetic tape is the next most economical medium except for information of less than approximately 1000 card images. At 2000 card images, tape is comparable to cards and some DDD service costs. Considering that tapes are presently more cost stable, and more available, than telecommunications, magnetic tapes should be considered the most viable medium for distributing algorithms or libraries. With the aid of new and better technology, and the decreasing cost of terminals and data communication lines (and hopefully computer charges) telecommunications may in the not too distant future become a more practical distribution medium. But for now, it appears that magnetic tape is the most economical medium for exchanging information.

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[1] Farber, David J.; "Networks: An Introduction"; Datamation Vol. 18 No. 4 (April 1972)

[2] Nordling, Karl I.; "Analysis of Common Carrier Tariff Rates"; Datamation Vol. 17 No. 9 (May 1, 1971)

[3] Reagan, F.H. Jr.; " A Manager's Guide to Phone and Data Services" Part I; Computer Decisions Vol. 3, No. 10 (October 1971)

[4] Reagan, F.H. Jr.; "A Manager's Guide to Phone and Data Services" Part II; Computer Decisions Vol. 3, No. 11 (November 1971)

[5] Reagan, F.H. Jr., Totaro, J.B.; "Take the Data Communications Lead Off Your System"; Computer Decisions Vol. 4, No. 2 (February 1972)

[6] Trifari, J.C.; "Rating National Timesharing Services"; Computer Decisions Vol. 3, No. 11 (November 1971)

Appendix A

Tape Costs & Capacities

	MRX III TYPE 25	ASTION TYPE 26	QUANTUM TYPE 27
2400'	$14.50	$17.50	$20.50
1200'	$11.25	$13.00	$15.00
600'	$ 9.00	$ 9.75	$10.75
400'	$ 8.00	$ 8.75	$ 9.75
225'	$ 6.00	$ 6.50	$ 7.50

TABLE 1 : MEMOREX TAPE PRICE LIST

(Price includes Wright line tape seal)

CONTROL DATA PREMIUM GRADE MAGNETIC TAPE

Prices for 200', 400' or 600' lengths FOB Destination

QUANTITY	800 BPI			1600 BPI		
	200'	400'	600'	200'	400'	600'
1-49 Reels	5.80	7.55	8.75	6.00	7.75	9.00
50-99 Reels	5.55	7.30	8.50	5.75	7.50	8.75
100-499 Reels	5.45	7.20	8.25	5.50	7.25	8.50
500-999 Reels	5.30	7.00	8.00	5.25	7.00	8.25
1000 Reels or more	Obtain Special Quote			Obtain Special Quote		

Prices for 1200' or 2400' lengths FOB Destination

QUANTITY	800 BPI		1600 BPI	
	1200'	2400'	1200'	2400'
1-99 Reels	14.00	18.50	14.40	19.00
100-299 Reels	13.25	17.50	13.65	18.00
300-499 Reels	12.75	17.00	13.15	17.50
500-699 Reels	12.50	16.50	12.90	17.25
700-999 Reels	12.25	16.00	12.65	17.00
1000-2999 Reels	12.00	15.50	12.40	16.50
3000 Reels or more	Obtain Special Quote		Obtain Special Quote	

NOTE: Deduct .25 each for lengths (1200' & 2400') using the Brightline Tape Seals

Tape prices are F.O.B. destination in the continental United States, if shipped by Control Data Corporation routing. Air shipments or customer routing will be at the customer's expense. Prices do not include applicable local, state or Federal taxes.

STANDARD GRADE MAGNETIC TAPE 1600 (3200 FCI) CERTIFIED

SEALS							
QUANTITY	1-99	100-299	300-499	500-699	700-999	1000-2999	3000-Up
2400'	13.25	12.95	12.65	12.35	12.05	11.75	11.25
1200'	11.25	10.95	10.65	10.35	10.05	9.60	9.25

TABLE 2: Control Data Corporation

Price List, June 22, 1971

HALF INCH MAGNETIC TAPE

Quality	-	Series/500 is the latest state of the art and the only quality offered by IBM.
Testing Density	-	3200 flux changes per inch for recording up to 1600 bits per inch.
Standard Available Lengths	-	300' - Mini Reel 600' - 08-1/2" Reel 1200' - 08-1/2" Reel 2400' - 10-1/2" Reel 2700' - 10-1/2" Reel Also, 100' and 200' lengths are available.
Packing	-	1. Containerless 2. Wrap Around (several styles) 3. Full Cannister (a) Thin Line (b) Standard 4. E-Z Load Cartridge Price range from $5.00 to $20.00 per reel depending on configuration and quantity.

TABLE 3: IBM Tape Configurations

and Prices

3/4" record gap
.1" per card image at 800 bpi
.15" per card image at 556 bpi

UNBLOCKED RECORDS
800 bpi - 2400' reel
.85" per card image $\frac{28800\text{"/tape}}{.85\text{"/card}}$ = 33882 $\frac{\text{cards}}{\text{tape}}$

556 bpi / .9" per card image - 2400' = 32000 cards image/tapes

2400'	32000
1200'	16000
600'	8000
400'	5333
225'	3000
100	1333

BLOCKED RECORDS
10 Records/Block
556 bpi - 2400'
2.25" per block = 12800 blocks = 128,000 and images

600' = = 32,000 card images
225' = = 6,400 card images

20 Records/Block
556 bpi - 2400'
3.75" per block = 7680 blocks x 20 = 153,600

600'	38,400
225'	7,680

32,000 cards = three cases/box or 16 boxes cards

TABLE 4: TAPE CAPACITIES OF CARD IMAGES

Appendix B

Card Costs

CARDS:

RM 11825, Binary	$1.10/m	$11.00/case
RM 5081, Green Stripe	$1.11/m	$11.10/case
RM 1009, Fortran	$1.11/m	$11.10/case
RM 11819, Job card, Yellow	$1.16/m	$11.60/case
RM 11819, Job card, Red	$1.16/m	$11.60/ case
RM 11819, Job card, White	$1.21/m	$12.10/case
RM 5081, Brown, 4 square	$1.16/m	$11.60/case
RM 5081, Blue	$1.16/m	$11.60/case
RM 10938, Calmon	$1.16/m	$11.60/case
RM 11818, Natural	$1.10/m	$11.00/case
Blank White, 4 square	$1.21/m	$12.10/case

TABLE 1: ROCKY MOUNTAIN TABULATING CARD COMPANY COSTS

DATA [illegible] PRICE LIST

Standard Cards Only — [illegible] X 7⅜" — 80, and/or 90 Column.

BASIC CARDS: Natural Card Stock Printed One Side in Black Ink with One Optional Corner Cut

PRICES:

* [illegible] — 48M	$1.40 per M	[illegible] — [illegible]	$1.04 [illegible]
[illegible] — 96M	1.2[illegible] " "	[illegible] — 79[illegible]M	1.0[illegible] per M
1[illegible] — 199M	1.13 " "	[illegible] — 99[illegible]M	1.0[illegible] per M
[illegible] — [illegible]M	1.07 " "	1[illegible] [illegible]	[illegible]

* Quantities 2-4[illegible]M, add $25.00 set-up charge.
Prices are for shipments to one destination. Add $10.00 for each additional destination.

SPECIAL STOCKS:

	Additional Per M
[illegible] Color — Red, Salmon, Blue, Green, Brown, Yellow	.[illegible]
White	.12
[illegible]	2.[illegible]

ADDITIONAL CHARGES FOR SPECIAL FEATURES:

- Horizontal Striping — Standard ¼" width across top edge. Variation must be specified. First Stripe — .01 per M
  Standard colors only — Red, Rose, Salmon, Blue, Green, Brown, Yellow, Purple and Grey
- Colored Ink — Standard only (Blue, Green, Red, Brown, Violet) ($10.00 minimum charge per col. — .[illegible] per M
- Edge Coating — Top and Bottom Edges — any stock — .[illegible] per M
- Reverse Side Printing — Black [illegible] — .[illegible] per M plus $1[illegible] setup
- Scoring, Creasing — .[illegible] per M plus [illegible] setup
  (OM-1, S-1, S-2, S-3A, M-[illegible], M-4, M-5, M-[illegible]A, M-4A and M-5A)
- Other Special Features Available — Tinting Numbering, Prepunching, Perforated Scores, Die-Cutting, Variable lengths, Encoding, Banding Palletizing, also Check or Document Type Cards. Please contact your local Globe Office or Representative for further details and pricing.

TABLE 2: CARD PRICE LIST, GLOBE TICKETING CO.

Appendix C

Telecommunication Costs

		STATION—DDD							
		Day*		Evening*		Night*		Weekend*	
Rate Step	Rate Mileage	Initial 3 min.	Each Add'l Min.	Initial 3 min.	Each Add'l Min.	Initial 3 min.	Each Add'l Min.	Initial 3 min.	Each Add'l Min.
1	1-10	$ .15	$.05	$.15	$.05	$.10	$.05	$.15	$.05
2	11-16	.20	.05	.20	.05	.10	.05	.20	.05
3	17-22	.25	.05	.25	.05	.10	.05	.20	.05
4	23-30	.30	.10	.30	.10	.10	.05	.20	.05
5	31-40	.35	.10	.35	.10	.15	.10	.35	.10
6	41-55	.40	.10	.40	.10	.15	.10	.35	.10
7	56-70	.45	.15	.40	.10	.15	.10	.35	.10
8	71-85	.50	.15	.40	.10	.15	.10	.35	.10
9	86-100	.55	.15	.40	.10	.15	.10	.35	.10
10	101-124	.60	.15	.45	.15	.15	.10	.35	.10
11	125-148	.65	.20	.50	.15	.20	.15	.50	.15
12	149-196	.70	.20	.55	.15	.20	.15	.50	.15
13	197-244	.70	.20	.55	.15	.20	.15	.50	.15
14	245-292	.75	.25	.55	.15	.20	.15	.50	.15
15	293-354	.80	.25	.55	.15	.20	.15	.50	.15
16	355-430	.85	.25	.60	.20	.20	.15	.50	.15
17	431-675	.95	.30	.60	.20	.20	.15	.50	.15
18	676-925	1.05	.35	.65	.20	.20	.15	.50	.15
19	926-1360	1.15	.35	.70	.20	.25	.20	.65	.20
20	1361-1910	1.25	.40	.75	.25	.25	.20	.65	.20
21	1911-3000	1.35	.45	.85	.25	.35	.20	.70	.20

*Day, 8 am-5 pm, Mon-Fri; evening, 5-11 pm, Sun-Fri; night, 11 pm-8 am, daily; weekend, 8 am-11 pm, Sat and 8 am-5 pm, Sun.

TABLE 1: Interstate rates for dial-up service:

Message Schedule 1 Rate, effective February 1, 1970 [2]

State	1st 10 hrs.	Each add'l hr
New Mexico - Colorado	$300	$22.40
Washington, D.C. - Colorado	$315	$23.60
Average	$307.50	$22.95

TABLE 2: Measured WATS Rates

State		
New Mexico	$1750/month	(Band 6)
Washington, D.C.	$1650/month	(Band 5)
Average	$1700/month	

TABLE 3: Full WATS Rates

WATS RATES

Type of Line	Rate per Airline Mile per Month				
	First 25 Miles	Next 75 Miles	Next 150 Miles	Next 250 Miles	Add. Mileage
Half-Duplex	$3.00	$2.10	$1.50	$1.05	$0.75
Full-Duplex	3.30	2.31	1.65	1.155	0.825

TABLE 4: Monthly mileage rates: Private Line Service

Charge per Service Terminal	Monthly Charge	Installation Charge
First station in an exchange		
Half-duplex	$12.50	$10.00
Full-duplex	13.75	10.00
Each additional station on the same service and in the same service		
Half-duplex	7.50	10.00
Full-duplex	8.25	10.00

Note: Where an interchange channel-switching arrangement is provided, each station at the switching point requires a service terminal for each private line to which it is connected which can be operated as a separate-private line.

TABLE 5: Monthly service terminal rates: Private Line Service

Type of Conditioning	Monthly Rate
C1	
Two-point channel	
not arranged for switching per exchange	$ 5.00
arranged for switching per exchange	10.00
Multipoint channel	
not arranged for switching per exchange	10.00
C2	
Two-point channel	
not arranged for switching per exchange	19.00
arranged for switching per exchange	28.00
Multipoint channel	
not arranged for switching	28.00
arranged for switching	28.00
C4	
Two-point channel	
for the first station in an exchange	30.00
for each additional station in the same exchange	9.75
Three-point or four-point channel	
for the first station in an exchange	36.00
for each additional station in the same exchange	9.75

NOTE: On a three-point or four-point channel, C4 conditioning applies only between one exchange (designated by the customer as the central point) and each of the other two or three exchanges. C4 conditioning is not available on channels with more than four points.

TABLE 6: Monthly channel-conditioning rates: Private Line Service

PRIVATE LINE SERVICE RATES [2]

	75% Loading	50% Loading	25% Loading
Full WATS	13.03	19.54	39.08
Measured WATS	22.57	25.39	28.78

TABLE 7: WATS Base Rates ($1700/mo base) [2]

	~~85%~~ 15% Loading	50% Loading	25% Loading
Albuquerque, N.M.	11.88	17.82	35.64
Washington D.C.	13.68	20.51	41.02

TABLE 8: Leased Line Base Rates* (including connect time charges)

* Two terminal, two pt. line, C1 conditioning [2]

TELECOMMUNICATION BASE RATES

	Remote-batch entry	What the costs will be
ALLEN-BABCOCK COMPUTING, INC. 1800 Avenue of Stars, Los Angeles, Calif. 90067 (213) 277-1600. CIRCLE NO. 290	System geared to remote batch and conversational user languages Cobol RPG and Sort. Unrestricted program storage is $14 100,000 characters. First 100,000 characters free	Storage: first 100,000 characters free, additional characters are $14.00/100,000 (IBM 2314 disk), $6.00 per 100,000 characters (IBM data cells). Remote batch $275/hour (prime shift), $175 hour overnight. Conversational, up to $750 per month, $5.25 min [illegible] core, to $21.50 min. (44k) $750 or above, storage is $14.00/month 100,000 characters
COMPUTER SCIENCES 650 N Sepulveda Blvd El Segundo, Calif. 90245. (213) 678 0311. CIRCLE NO. 291	Good support for high-speed terminals, including IBM 1130. Remote-batch "Express" service available for unscheduled fast turnaround jobs. Company's Univac 1108's are well suited for large compute-bound jobs	Remote-batch: $5.00 job plus $1.00 for the first second, 50¢/sec. to 30 secs for "Express", 222¢/sec. for "Standard," 166¢ sec. for "Overnight." Storage: 5¢ track (10 572 characters day); $10 hour connect charge. Conversational: 15 char. sec. terminal, $11.00 per hour connect, 30 cps: $13 hour. Cpu charge 50¢ second, storage: $1.00/page (3,072 characters) month.
COM-SHARE, INC. 2395 Huron Pkwy. Ann Arbor, Mich. 48105. (313) 761-4040. CIRCLE NO. 292	Service supports a variety of low-speed terminals but the company's XDS 940's do not support remote batch terminals, nor Cobol (Com-Share's new XDS Sigma 7 does)	Both standard and national service have a $400 month minimum and 3¢ each .01 minute processing time. Connect is $10.00 hour (standard), $13/hour (net). Storage is 3¢/256-word-block calendar day. These prices are subject to discounts ranging from five to 50 percent.
CONTROL DATA CORP. 4550 West 77th St. Minneapolis, Minn. 55435. (612) 920-8600. CIRCLE NO 293	Cybernet well adapted to remote batch. Prices scheduled for five different turn-around requirements. Support for IBM 1130 and a variety of remote-batch terminals. CDC machines attractive for compute-bound jobs	Kronos: $8.00 hour connect, 20¢ sec. cpu, 30¢/1000 char month storage. Cybernet. 3300 [illegible] 50-$10 00, hour connect. 6600 service: $10-$25 hour. 3300 cpu ranges from [illegible] to 5¢ sec 6600 service, starts at 40¢ sec. Storage is in Data Blocks (1,280 six-bit char.). Prices start at $37.10 for 5,000 data blocks.
GENERAL ELECTRIC CO. 7735 Old Georgetown Rd Bethesda, Md 20014. (301) 654-9360. CIRCLE NO. 294	Mark I, Mark II, and Mark Delta do not support remote-batch terminals. GE's Resource remote-batch service supports terminals as fast as 2400 baud.	Mark I costs $8.50/hour connect plus 5¢ computer resource unit,* plus $1.75 program storage unit (1,536 char.) month. Mark II connect time is $7.00 hour, Swaps cost 25¢ thousand characters, CRU price is 33¢ unit (network charges 40¢), program storage units (1,280 chars.) are $1.10 unit month. Mark Delta service costs $7.00, hour, 25¢ 1000 I, O characters, 30¢ CRU.
NATIONAL CSS INC. 485 Summer St., Stamford, Conn 06901. (203) 327-9100. CIRCLE NO. 295	System supports IBM 1130 computers, among others, as well as an extensive selection of remote-batch terminals. Cobol available.	Conversational connect is $10.00 hour/256k bytes, plus $4.00/hour/additional 256k. Batch connect charges are $10.00/hour. Cpu charges are 38¢/second (conversational), 24¢/second for batch 1, service (jobs from 6 pm to 8 am), 16¢/second for Batch 2 (jobs on 24-hr. turn-around).
SERVICE BUREAU CORP. 600 Mamaroneck Ave. Harrison, N.Y. 10528. (914) 698-3903. CIRCLE NO 296	SBC's CALL 360 operating system will not support remote-batch entry, and the user cannot disconnect until the job is complete - adding to his cpu and connect charges	Connect charges are $11.00 hour for Teletype and 2741's local, $13.80 network. For 300-baud service the charge is $15.00/hour, storage charges for both the network and normal CALL 360 operation run in "components:" $1.50 3440 characters month (monthly component) and 15¢/3440 characters, day (daily component).
TYMSHARE, INC 525 University Ave. Palo Alto, Calif. 94301. (415) 326-5990 CIRCLE NO. 297	Service offers users Cobol and Assembly languages, and support for a wide selection of terminals with speeds up to 30 cps. WATS service to most states can cut costs. Remote Fortran also offered	Local service runs $60 to $390 month minimum, $13-16, hour connect time and 4¢/second cpu time. Network is $2500 month minimum, $15 hour connect, 4¢ second cpu. Prices for disk storage scale downwards: to 500,000 characters. $1.00 1,000 characters month; up to two-million characters month, 75¢/1,000; above two-million the price drops to 50¢, 1000.
UNIVERSITY COMPUTING 1949 North Stemmons Dallas, Tex 75207. (214) 741 5781 CIRCLE NO. 298	Good remote-batch facilities, using seven Univac 1108 computers. For commercial applications user can program in Cobol. Terminal support includes IBM 1130. 1108's are good for compute-bound applications	UCC has three remote-batch rates: "priority" ($1500 hour), "standard" ($1200 hour) and a "weekend" rate ($10.0 hour). On-line drum is 14¢ block day. Fastbac is $7.50 hour (connect), $1.00 1,000 computer resource units. Storage charges are 50¢ 1,000 characters month for demand service, 25¢/1,000 characters if storage is scheduled.

TABLE 9: Network-Timesharing Costs [6]

Appendix D

Comparative Costs of
Distributing Algorithms
via Magnetic Tape, Card, Terminals

WATS rates are figured on 174 hr./mo. (1 full shift per day). 75% loading then would be 130.5 hr./mo. usage. The $8.00/hr. connect time charge and the $.20/CP sec. charge is added to each figure accordingly.

Leased line rates are figured on a 24 hr./day, 728 hr./mo. connect time. Since Control Data Corporation makes no distinction between remote batch and timesharing the connect time charge is included in the hourly cost.

DDD line rates are figured on Message Schedule I, February 1, 1970 plus the connect time charge of $8.00/hr., CP sec. time charge of $.20/CP sec.

Mailing rates for both tapes and cards are figured by airmail only. Weight used does not include packing.

	TAPE				DDD							
					day		evening		nite		weekend	
	225'	400'	600'	1200'	10 char /sec	30 char /sec	10 char /sec	30 char /sec	10 char /sec	30 char /sec	10 char /sec	30 char /sec
Denver, Colorado	8.77	+2.00	+3.00	+5.25	18.18	6.20	18.18	6.20	18.18	6.20	18.18	6.20
Albuquerque, N.M.	8.77	+2.00	+3.00	+5.25	54.03	18.05	46.78	15.60	39.38	13.00	39.68	13.30
Washington, D.C.	8.97	+2.00	+3.00	+5.25	75.43	25.05	53.93	19.75	46.43	15.25	46.83	15.65

	CARDS		LEASED LINE								
			75% loading			50% loading			25% loading		
	comp. punch	repro- duced	30 char /sec	1200 baud	2400 baud	30 char /sec	1200 baud	2400 baud	30 char /sec	1200 baud	2400 baud
Denver, Colorado	5.09	4.40	local costs are not evaluated								
Albuquerque, N.M.	5.09	4.40	8.91	1.98	.99	13.37	2.98	1.49	26.73	5.94	2.97
Washington, D.C.	6.44	5.75	10.26	2.28	1.14	15.39	3.42	1.71	30.78	6.84	3.42

	WATS - full						WATS - measured					
	75% loading		50% loading		25% loading		75% loading		50% loading		25% loading	
	10 char /sec	30 char /sec	10 char /sec	30 char /sec	10 char /sec	30 char /sec	10 char /sec	30 char /sec	10 char /sec	30 char /sec	10 char /sec	30 char /sec
Denver, Colorado	local costs are not evaluated											
Albuquerque, N.M.	49.30	16.54	55.65	21.71	111.29	36.75	71.95	23.83	78.62	25.94	74.80	28.76
Washington, D.C.	"	"	"	"	"	"	"	"	"	"	"	"

DISTRIBUTION COSTS: 1000 Card Images

	TAPE				DDD [illegible]e							
					day		evening		nite		weekend	
	225'	400'	600'	1200'	10 char /sec	30 char /sec	10 char /sec	30 char /sec	10 char /sec	30 char /sec	10 char /sec	30 char /sec
Denver, Colorado	10.06	+2.00	+3.00	+5.25	36.01	12.37	36.01	12.37	36.01	12.37	36.01	12.37
Albuquerque, N.M.	10.06	+2.00	+3.00	+5.25	102.86	34.72	89.41	30.17	75.81	25.47	76.11	25.77
Washington, D.C.	10.26	+2.00	+3.00	+5.25	142.86	48.02	102.76	34.62	89.06	29.82	65.82	30.22

	CARDS		LEASED LINE								
			75% loading			50% loading			25% loading		
	comp. punch	repro-duced	30 char /sec	1200 baud	2400 baud	30 char /sec	1200 baud	2400 baud	30 char /sec	1200 baud	2400 baud
Denver, Colorado	9.54	8.16	local	costs	are not	evaluated					
Albuquerque, N.M.	9.54	8.16	17.62	3.56	1.78	26.43	5.34	2.67	57.87	10.70	5.34
Washington, D.C.	12.33	10.95	20.29	4.10	2.05	30.43	6.16	3.08	60.83	12.32	6.16

	WATS - full						WATS - measured					
	75% loading		50% loading		25% loading		75% loading		50% loading		25% loading	
	10 char /sec	30 char /sec	10 char /sec	30 char /sec	10 char /sec	30 char /sec	10 char /sec	30 char /sec	10 char /sec	30 char /sec	10 char /sec	30 char /sec
Denver, Colorado	local	costs	are not	evaluated								
Albuquerque, N.M.	93.99	31.69	122.95	41.34	209.82	70.30	136.42	45.82	148.99	50.03	164.09	55.07
Washington, D.C.	"	"	"	"	"	"	"	"	"	"	"	"

DISTRIBUTION COSTS: 2000 Card Images

	TAPE				DDD Line							
					day		evening		nite		weekend	
	225'	400'	600'	1200'	10 char /sec	30 char /sec	10 char /sec	30 char /sec	10 char /sec	30 char /sec	10 char /sec	30 char /sec
Denver, Colorado	11.35	+2.00	+3.00	+5.25	**	18.59	**	18.59	**	18.59	**	18.59
Albuquerque, N.M.	11.35	+2.00	+3.00	+5.25	**	55.44	**	47.19	**	39.79	**	40.09
Washington, D.C.	11.55	+2.00	+3.00	+5.25	**	75.84	**	54.74	**	46.84	**	47.24

	CARDS		LEASED LINE								
			75% loading			75% loading			25% loading		
	comp. punch	repro-duced	30 char /sec	1200 baud	2400 baud	30 char /sec	1200 baud	2400 baud	30 char /sec	1200 baud	2400 baud
Denver, Colorado	14.63	12.56	local	costs	are not	evaluated					
Albuquerque, N.M.	14.63	12.56	26.53	5.54	2.77	39.80	8.32	4.16	79.60	16.64	8.32
Washington, D.C.	18.77	16.70	30.55	6.33	3.19	45.81	9.58	4.79	91.80	19.16	9.58

	WATS - full						WATS - measured					
	75% loading		50% loading		25% loading		75% loading		50% loading		25% loading	
	10 char /sec	30 char /sec	10 char /sec	30 char /sec	10 char /sec	30 char /sec	10 char /sec	30 char /sec	10 char /sec	30 char /sec	10 char /sec	30 char /sec
Denver, Colorado	local	costs	are not	evaluated								
Albuquerque, N.M.	**	47.69	**	62.22	**	105.85	**	68.98	**	75.29	**	82.87
Washington, D.C.	**	"	**	"	**	"	**	"	**	"	**	"

DISTRIBUTION COSTS: 3000 Card Images

** Impractical to Calculate

	TAPE				DDD line							
					day		evening		nite		weekend	
	225'	400'	600'	1200'	10 char /sec	30 char /sec	10 char /sec	30 char /sec	10 char /sec	30 char /sec	10 char /sec	30 char /sec
Denver, Colorado	***	14.14	+1.00	+3.25	**	24.68	**	24.68	**	24.68	**	24.68
Albuquerque, N.M.	***	14.14	+1.00	+3.25	**	67.53	**	58.88	**	50.08	**	50.38
Washington, D.C.	***	14.34	+1.00	+3.25	**	93.13	**	67.43	**	58.53	**	58.93

	CARDS		LEASED LINE								
			75% loading			50% loading			25% loading		
	comp. punch	repro-duced	30 char /sec	1200 baud	2400 baud	30 char /sec	1200 baud	2400 baud	30 char /sec	1200 baud	2400 baud
Denver, Colorado	19.08	16.32	local costs are not evaluated								
Albuquerque, N.M.	19.08	16.32	35.24	7.12	3.56	52.87	10.70	5.35	105.73	21.38	10.69
Washington, D.C.	24.66	21.90	40.58	8.20	4.10	60.86	12.32	6.16	121.71	24.62	12.31

	WATS - full						WATS - measured					
	75% loading		50% loading		25% loading		75% loading		50% loading		25% loading	
	10 char /sec	30 char /sec	10 char /sec	30 char /sec	10 char /sec	30 char /sec	10 char /sec	30 char /sec	10 char /sec	30 char /sec	10 char /sec	30 char /sec
Denver, Colorado	local costs are not evaluated											
Albuquerque, N.M.	**	63.33	**	82.61	**	140.54	**	91.57	**	100.02	**	110.08
Washington, D.C.	**	"	**	"	**	"	**	"	**	"	**	"

DISTRIBUTION COSTS: 4000 Card Images

** Impractical to Calculate
*** Information will not fit standard format

	TAPE				DDD [illegible]ne							
					day		evening		nite		weekend	
	225'	400'	600'	1200'	10 char /sec	30 char /sec	10 char /sec	30 char /sec	10 char /sec	30 char /sec	10 char /sec	30 char /sec
Denver, Colorado	***	15.43	+1.00	+3.25	**	30.92	**	30.92	**	30.92	**	30.92
Albuquerque, N.M.	***	15.43	+1.00	+3.25	**	86.77	**	75.57	**	64.12	**	64.43
Washington, D.C.	***	15.63	+1.00	+3.25	**	120.17	**	86.67	**	75.17	**	75.57

	CARDS		LEASED LINE								
			75% loading			50% loading			25% loading		
	comp. punch	repro-duced	30 char /sec	1200 baud	2400 baud	30 char /sec	1200 baud	2400 baud	30 char /sec	1200 baud	2400 baud
Denver, Colorado	24.17	15.96	local costs are not evaluated								
Albuquerque, N.M.	24.17	15.96	44.15	9.10	4.55	66.23	13.66	6.83	132.46	27.32	13.66
Washington, D.C.	31.10	20.39	50.84	10.48	5.24	72.24	15.74	7.87	152.47	31.46	15.73

	WATS - full						WATS - measured					
	75% loading		50% loading		25% loading		75% loading		50% loading		25% loading	
	10 char /sec	30 char /sec	10 char /sec	30 char /sec	10 char /sec	30 char /sec	10 char /sec	30 char /sec	10 char /sec	30 char /sec	10 char /sec	30 char /sec
Denver, Colorado	local costs are not evaluated											
Albuquerque, N.M.	**	79.34	**	103.52	**	176.11	**	114.7	**	125.28	**	137.85
Washington, D.C.	**	"	**	"	**	"	**	"	**	"	**	"

DISTRIBUTION COSTS: 5000 Card Images

** Impractical to Calculate
*** Information will not fit standard format

	TAPE				DDD Line							
					day		evening		nite		weekend	
	225'	400'	600'	1200'	10 char /sec	30 char /sec	10 char /sec	30 char /sec	10 char /sec	30 char /sec	10 char /sec	30 char /sec
Denver, Colorado	***	***	17.90	+2.25	**	37.04	**	37.04	**	37.04	**	37.04
Albuquerque, N.M.	***	***	17.90	+2.25	**	103.89	**	90.44	**	76.84	**	77.14
Washington, D.C.	***	***	18.29	+2.25	**	143.89	**	103.79	**	90.09	**	90.49

	CARDS		LEASED LINE								
			75% loading			50% loading			25% loading		
	comp. punch	repro-duced	30 char /sec	1200 baud	2400 baud	30 char /sec	1200 baud	2400 baud	30 char /sec	1200 baud	2400 baud
Denver, Colorado	28.62	24.48	local	costs	are not	evaluated					
Albuquerque, N.M.	28.62	24.48	52.86	10.70	5.35	79.30	16.04	8.02	158.60	32.08	16.04
Washington, D.C.	36.99	32.85	60.88	12.32	6.16	91.27	18.46	9.23	182.55	36.96	18.47

	WATS - full						WATS - measured					
	75% loading		50% loading		25% loading		75% loading		50% loading		25% loading	
	10 char /sec	30 char /sec	10 char /sec	30 char /sec	10 char /sec	30 char /sec	10 char /sec	30 char /sec	10 char /sec	30 char /sec	10 char /sec	30 char /sec
Denver, Colorado	local	costs	are not	evaluated								
Albuquerque, N.M.	**	95.01	**	103.98	**	210.91	**	137.49	**	150.02	**	165.12
Washington, D.C.	**	"	**	"	**	"	**	"	**	"	**	"

DISTRIBUTION COSTS: 6000 Card Images

** Impractical to Calculate
*** Information will not fit standard format

	TAPE				DDD Line **							
					day		evening		nite		weekend	
	225'	400'	600'	1200'	10 char /sec	30 char /sec	10 char /sec	30 char /sec	10 char /sec	30 char /sec	10 char /sec	30 char /sec
Denver, Colorado	***	***	20.48	+2.25								
Albuquerque, N.M.	***	***	20.48	+2.25								
Washington, D.C.	***	***	20.87	+2.25								

	CARDS		LEASED LINE								
			75% loading			50% loading			25% loading		
	comp. punch	repro-duced	30 char /sec	1200 baud	2400 baud	30 char /sec	1200 baud	2400 baud	30 char /sec	1200 baud	2400 baud
Denver, Colorado	38.16	32.64	local costs are not evaluated								
Albuquerque, N.M.	38.16	32.64	70.49	14.26	7.13	105.73	21.38	10.69	211.46	42.76	21.38
Washington, D.C.	49.32	43.80	81.17	16.42	8.21	121.70	24.62	12.31	243.40	49.24	24.62

	WATS - full **						WATS - measured **					
	75% loading		50% loading		25% loading		75% loading		50% loading		25% loading	
	10 char /sec	30 char /sec	10 char /sec	30 char /sec	10 char /sec	30 char /sec	10 char /sec	30 char /sec	10 char /sec	30 char /sec	10 char /sec	30 char /sec
Denver, Colorado												
Albuquerque, N.M.												
Washington, D.C.												

DISTRIBUTION COSTS: 8000 Card Images

** Impractical to Calculate
*** Information will not fit standard format

	TAPE				DDD Line **							
					day		evening		nite		weekend	
	225'	400'	600'	1200'	10 char /sec	30 char /sec	10 char /sec	30 char /sec	10 char /sec	30 char /sec	10 char /sec	30 char /sec
Denver, Colorado	***	***	***	28.13								
Albuquerque, N.M.	***	***	***	28.13								
Washington, D.C.	***	***	***	28.64								

	CARDS		LEASED LINE								
			75% loading			50% loading			25% loading		
	comp. punch	repro- duced	30 char /sec	1200 baud	2400 baud	30 char /sec	1200 baud	2400 baud	30 char /sec	1200 baud	2400 baud
Denver, Colorado	40.44	48.96	local	costs	are not	evaluated					
Albuquerque, N.M.	40.44	48.96	**	21.38	10.69	**	32.08	16.04	**	64.16	32.08
Washington, D.C.	73.98	65.70	**	24.62	12.31	**	36.94	18.47	**	73.88	36.94

	WATS - full **						WATS - measured **					
	75% loading		50% loading		25% loading		75% loading		50% loading		25% loading	
	10 char /sec	30 char /sec	10 char /sec	30 char /sec	10 char /sec	30 char /sec	10 char /sec	30 char /sec	10 char /sec	30 char /sec	10 char /sec	30 char /sec
Denver, Colorado												
Albuquerque, N.M.												
Washington, D.C.												

DISTRIBUTION COSTS: 12000 Card Images

** Impractical to Calculate

*** Information will not fit standard format

	TAPE				DDD Line **							
					day		evening		nite		weekend	
	225'	400'	600'	1200'	10 char /sec	30 char /sec	10 char /sec	30 char /sec	10 char /sec	30 char /sec	10 char /sec	30 char /sec
Denver, Colorado	***	***	***	33.29								
Albuquerque, N.M.	***	***	***	33.29								
Washington, D.C.	***	***	***	33.80								

	CARDS		LEASED LINE								
			75% loading			50% loading			25% loading		
	comp. punch	repro- duced	30 char /sec	1200 baud	2400 baud	30 char /sec	1200 baud	2400 baud	30 char /sec	1200 baud	2400 baud
Denver, Colorado	76.32	65.28	local costs are not evaluated								
Albuquerque, N.M.	76.32	65.28	**	28.54	14.27	**	42.76	21.38	**	85.54	42.77
Washington, D.C.	98.64	65.28	**	32.96	16.47	**	49.22	24.61	**	98.46	49.23

	WATS - full **						WATS - measured **					
	75% loading		50% loading		25% loading		75% loading		50% loading		25% loading	
	10 char /sec	30 char /sec	10 char /sec	30 char /sec	10 char /sec	30 char /sec	10 char /sec	30 char /sec	10 char /sec	30 char /sec	10 char /sec	30 char /sec
Denver, Colorado												
Albuquerque, N.M.												
Washington, D.C.												

DISTRIBUTION COSTS: 16000 Card Images

** Impractical to Calculate

*** Information will not fit standard format