large matrix problems. In addition the Air Force is planning to study the special requirements of its statistical control and statistical research centers and to proceed with development of a moderate-size machine intended for such applications. Both the machine for computation of optimum programs and that for statistical operations will require printing out of large amounts of information, and in this connection a prototype model of a very high-speed printer has been developed.

Much has been said about the critical urgency of developing qualified personnel to handle the digital machines as they go into operation. Some of the lessons learned at Aberdeen and Dahlgren in the operation of their computers are: (1) Human error causes considerably more trouble than machine error. Errors in coding and in the setting of dial switches have been a frequent source of irritation in the operation of the Aiken Relay Calculator at Dahlgren. (2) There is need for a simplification of coding procedures. Even for very small calculators, the time required for coding problems has often been considerably greater than the time required for solution on the machine. Surely in the programming and coding of problems we must improve the competence of the operating staff to a very considerable extent.

There is also an important need to explore more fully the mathematical formulation appropriate to the types of problems that arise frequently in applications. The highly competent staffs at Aberdeen and at Dahlgren have been impressed by the extensive difficulty of determining even approximately optimum formulation of their problems and of relying on existing mathematical proofs to assure the convergence of various processes they have had to use. Thus there remains an important creative area for the mathematician in facilitating and implementing the uses of digital machines.

A small attempt at meeting this need is being undertaken by the Office of Naval Research through its support of work in numerical analysis related to the use of digital computers at the Institute for Advanced Study at Princeton, and at the Institute for Numerical Analysis of the Bureau of Standards. But until more machines come into operation, and more practicing scientists experience difficulties in solving their own problems, we must expect that significant progress will be slow. I believe that as the new computers become available to research workers we shall enter a new and exciting period in scientific research, to which physical scientist, mathematician, and engineer have much to contribute.

Building an Effective Technical Library

W. E. Jorgensen and I. G. Carlson

U. S. Navy Electronics Laboratory, San Diego, California

SCIENTISTS AND ENGINEERS for the most part are not concerned with the question of why they need a technical library in their work. Their reaction to such a question would probably be one of surprise, since "everybody knows" that a technical library is necessary in scientific and engineering pursuits. The "why" is a question that concerns the scientist or engineer only when he assumes administrative responsibility for a research and development program. Then he finds he not only must know why but also must be acquainted with the what, when, where, and how (which usually becomes how much). This paper is an attempt to point out the factors to be considered in establishing an effective library for a scientific or technical organization.

Size and Scope

To determine the type of library best suited to the organization, it is necessary to consider the nature of work performed, as the library reflects the subject interests of the organization as a whole. An activity engaged in basic research, for example, would need a much more extensive library than a testing facility, since the former covers broader subject fields.

The size of the library is dependent upon five principal factors: the number of subject fields to be covered, the extent to which each subject is to be covered, the number of people in the organization served by the library, the total budget of the establishment, and the proximity of the library to other technical libraries. In a metropolitan area the library could be quite small, as library materials could be obtained through arrangements with other libraries, possibly even on a contract basis. In areas not close to existing libraries, it is, of course, necessary to build up more complete and self-sustaining collections. The library might range from the storehouse type of collection with its "bookkeeper," to the maximum of a large, diversified collec-

tion of background, as well as current, materials serviced by a staff of professionally trained abstractors, bibliographers, translators, and even subject specialists, assigned as liaison agents to work on projects with the technical and scientific staff. The average library would fall somewhere between these extremes.

If the library is merely a storehouse for technical information, tended by one or two custodians, the scientist or engineer must be prepared to consume valuable hours of his time searching for material he needs. He may find it or he may not, but it is fairly certain he will not find everything that is pertinent to his particular inquiry. And the more material added to this custodial type of library, the harder it becomes to find specific items. The larger library, whose role is not merely passive custody of material, will have staff members who, by reason of their training and experience, can anticipate the library needs of the scientist or engineer. These staff members can call attention to information pertinent to the work of particular scientists or engineers; they can catalogue and organize the library collection to coincide with the subject interests of the organization; and they can prepare bibliographies and reading lists in anticipation of projects requiring background studies of the technical literature. The concept of size of a library, then, includes both the number and kind of professional services required of the staff, as well as the amount and variety of the library materials.

In deciding the size and scope of the library, one has to understand fully the potential value of the library to the organization. The library should not be developed out of proportion to the other supporting services or beyond the actual needs of the whole organization, but, on the other hand, it should not be assigned an inferior role that would hamper its effectiveness. Underestimating the value of the library results in inadequate and inferior library service. The place of the library in the organizational hierarchy should be commensurate with present and potential degrees of responsibility. The success of the library program depends heavily on such visible manifestations of support from management.

Cost

Assuming that it may be desirable to develop and operate a library for a technical establishment, then a logical question is, How much will it cost? Some estimates on library costs are presented here to show the order of magnitude of expenditures to be expected. These estimates are not intended as recommendations for optimum budgets, but are presented to indicate what cost can reasonably be expected. Three aspects are considered: basic investment, current operating cost, and comparisons of cost.

The principal costs on the initial establishment of a library are for salaries, books, periodicals, equipment, supplies, furniture, and housing. The average cost of technical and scientific books is about $5.00 a copy. Technical periodical subscriptions average about $7.50 per year. Adjustable steel book shelving costs $1.50–$3.00 per linear foot of shelf space, not counting installation costs. Steel filing cabinets cost $75.00–$90.00 each. The cost of conventional office furniture, typewriters, etc., is not included here because the figures are readily obtainable. Space for the library is an item of cost in the sense that the establishment has a certain amount of total usable floor space to be allocated among its several divisions, including the library. Thus, the organization must get full value for all space allocated to any of these divisions or groups.

By using the unit costs listed above, one can easily estimate the total cost of establishing a library whose size and scope have previously been determined. To take a hypothetical case as an example, the cost of establishing a basic library for an electronics development activity, remote from other library facilities, with a total staff of 400 people, and an annual budget of $3,500,000, can be based on the following estimated requirements: 6,000 books ($30,000), 200 current periodical subscriptions ($1,500), and 1,000 back volumes of periodicals ($10,000) would give excellent coverage in the fields of mathematics, physics, and electronics. Equipment and supplies would cost an additional $6,000, mostly for shelving and furniture. This means a *basic* investment of $47,500 in books, periodicals, and equipment. Approximately $25,000–$30,000 for a library staff of seven or eight people should be added to this total. After a year or two, when the extra initial work is completed, this staff can be reduced to five or six people to handle the work on a current basis, and the cost of salaries reduced to about $20,000.

Current operating costs can be obtained by using the same unit cost figures. In the example cited, it would cost about $7,500 a year to keep the collection up to date, about $500 per year for equipment and supplies, and about $20,000 for salaries—a total of $28,000 per year. The initial cost of the library represents about 2 per cent of the total budget of the organization for the first year or two and about 1 per cent thereafter, for current operating costs. A survey of college and university library operating costs indicates that these institutions spend on the average about 4 per cent of their total budgets on their libraries (*1*).

Value Received

Obviously the library provides a means for obtaining all sorts of technical information quickly and efficiently. The library also helps the scientist or engi-

neer keep up to date in his special field. Moreover, wasteful duplication of research already reported in the literature can be avoided if published results of previous investigations are consulted prior to starting a project in the laboratory. Once the organization has a library, the scientist or engineer need not be limited to the use of materials in his own library, since he may obtain access to the collections of other, more complete libraries by means of interlibrary loans. All these things the library does for the purpose of preserving and transmitting ideas, so that science may progress without needless duplication and retrogression.

These values are obtained as a result of the work of the library staff, whose education and experience are brought to bear on the problem of organizing information in a systematic manner. But there is more to operating a library than meets the eye. A library is like an iceberg: the visible portion is only a small fraction of the whole. The library user has no contact with the two thirds to three fourths of the staff who work on the acquisition, cataloguing, and indexing of publications. In many libraries the patron never sees these workers. Not seeing them, he quite logically assumes that the librarians in the reference room and at the loan desk constitute the whole force. Even if he does see a room full of cataloguers, he probably wonders what on earth all those people are doing. They are working to make it possible for him to find what he wants in the reference room and at the loan desk. These behind-the-scenes workers search, select, order, borrow, and receive publications that are needed now or that may be used in the future. Then they catalogue, classify by subject, index, cross-reference, record, and file the material received. This is complicated and difficult work, filled with endless detail, and requiring a high degree of skill, training, and experience for its successful performance.

The caliber of personnel doing this work determines the degree of effectiveness of the library. As qualified technical librarians are in great demand, the organization must be prepared to offer salaries commensurate with the training and experience required. In a technical library the head librarian must have a background in scientific and technical fields, plus a good foundation in librarianship and adequate experience in administration and personnel work. These points were discussed in an excellent article on science librarianship by Judith Wallen Hunt in SCIENCE (*2*).

The technical librarian, experienced in organizing information and handling technical publications, can provide the individual scientist or engineer with an effective means for obtaining the information he requires. Technical literature pours off the presses at such a rate that no one can possibly cope singlehanded with the problem of digesting and organizing for future use the information pertinent to his work. For example, a recent study of physics abstracting sponsored by the American Institute of Physics listed 145 abstracting services of physics interest (*3*). Each of these services indexes and abstracts an average of about 6,500 periodical articles per year, which amounts to a combined total of almost a *million* abstracts! Confronted with such tremendous masses of material, the research worker certainly needs the facilities of an adequate technical library and the assistance of experienced librarians, as anyone who has used an inadequate library well knows.

References

1. *Coll. and Res. Libraries,* **11**, (2), 157 (1950).
2. HUNT, J. W. *Science,* **104**, 171 (1946).
3. GRAY, D. E., and BRAY, R. S. *Am. J. Physics,* **18**, (5), 274 (1950).