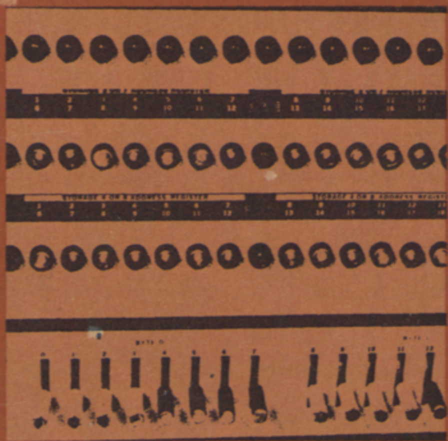
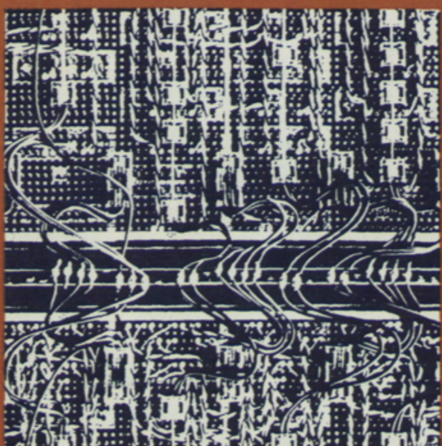
ENGINEERING

CORNELL QUARTERLY





VOLUME 8
NUMBER 3
AUTUMN 1973

THE SCIENCE OF INFORMATION

IN THIS ISSUE

Not machines but knowledge about information itself is the main concern of computer science departments. The functions of Cornell's department and the professional interests of university computer scientists are discussed by Professor Richard W. Conway.

A world authority on information storage and retrieval, Gerard Salton, describes how automatic techniques can be used in the development of new systems to meet the "library crisis." Professor Salton is chairman of Cornell's Department of Computer Science.

From the Apollo mission to the undergraduate laboratory, computers are essential components of experimental equipment. This increasingly important aspect of information science is discussed by Christopher Pottle, associate professor of electrical engineering.

How the computer is affecting society and its members and what can or should be done about it is considered by Visiting Assistant Professor David Lewis, a Cornell Ph.D. in computer science who is directing an interdisciplinary Cornell seminar, The Computerized Society.

New members of the College of Engineering faculty are introduced.

Engineering: Cornell Quarterly, Vol. 8, No. 3, Autumn 1973. Published four times a year, in spring, summer, autumn, and winter, by the College of Engineering, Carpenter Hall, Campus Road, Ithaca, New York 14850. Second-class postage paid at Ithaca, New York. Subscription rate: $2.50 per year.

Opposite: Computerized methods of handling information are evidenced by racks of stored tapes at the Langmuir Laboratory of Cornell's Office of Computer Services.

THE NATURE OF INFORMATION

The Province of Computer Science in the University Today

by Richard W. Conway

The nature of computer science and the role of departments of computer science are often misunderstood. This is only partly because these departments are recent arrivals on the academic scene; it is partly because the name itself is somewhat misleading. Today few university departments of this name are directly concerned with the design, much less the construction, of computing machines. Perhaps even more surprising is the fact that at many universities, such departments are not even among the major research users of the campus computer. Although essentially all of the work in this field is motivated by the existence of modern computing machines, the relationship to present real machines is sometimes indirect.

Computer science is concerned with *information* (at some schools the discipline is called "information science.") While other fields are concerned with the *content* of a body of information *about* some particular subject, computer science is concerned with the nature of information itself—with how information can be measured, represented, organized, manipulated, stored, and retrieved. Of course, the existence of a machine capable of implementing these operations at prodigious rates but modest cost is what makes this work significant and, indeed, accounts for the existence of computer science departments. Nevertheless, the main contribution of university computer scientists is the development of a substantial and interesting body of knowledge and theory about information.

MATHEMATICAL STUDIES IN COMPUTER SCIENCE

The most theoretical aspect of the field is probably the study of the limits of computability. This is essentially a branch of mathematical logic. Roughly speaking, it is concerned with defining and classifying abstract mathematical models of computing machines and determining the power of each class of machine. It also involves classifying problems according to their difficulty or complexity, and matching problems to machine classes.

The second mathematically-oriented branch of computer science—numerical analysis and the study of algorithms (procedures)—is concerned with the nature and relative efficiency of important classes of computation. Differences in efficiency, and therefore in computing time, between different algorithms can be very significant. Comparisons of algorithms used for the very common task of computer sorting (arranging values into increasing sequences) illustrates how efficiencies can vary. For certain common and obvious sorting algorithms, the cost per unit sorted increases linearly with the number of units to be sorted; for other algorithms, the cost per unit increases only as the logarithm of the number of units. Another example is the evaluation of the polynomial $ax^2 + bx + c$. If the steps suggested by the given form are followed in the algorithm, three multiplications and two additions are required. If, however, the evaluation is performed as suggested by the form $(ax + b)x + c$, only two multiplications and two additions are required. The advantage increases with the degree of the polynomial.

Numerical analysis is concerned also with the effect of finite precision arith-

" . . . the ability to program is now the limiting factor in the field."

metic. Where mathematics tacitly assumes infinite or perfect precision in arithmetic operations, real arithmetic is always performed with only a modest number of significant figures. The computer makes it possible to perform enough arithmetic operations in solving a single problem so that the cumulative effect of the errors in this approximation can be astonishingly large. Numerical analysts are concerned, therefore, with estimating the magnitude of errors resulting from this approximation and with devising algorithms that are relatively insensitive to the cumulative effects of the "round-off" phenomenon.

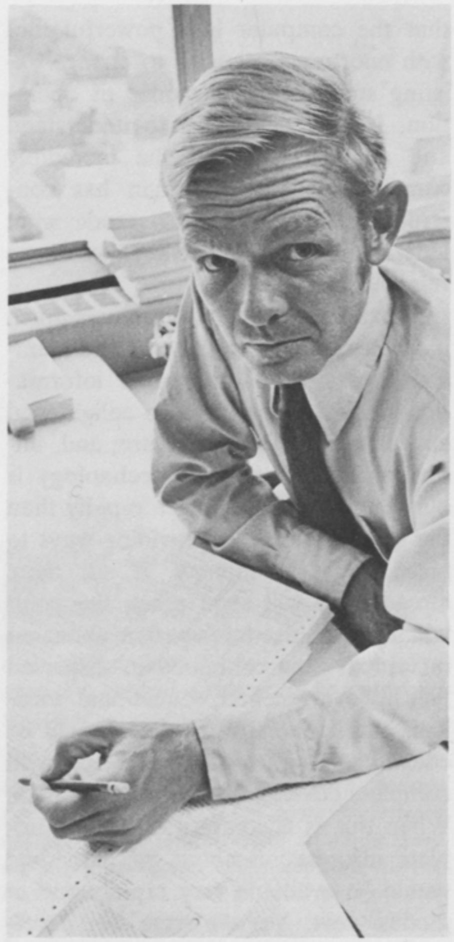
WORKING WITH THE STRUCTURE OF INFORMATION

The third major branch of the field is concerned directly with the structure of information. Gerard Salton's article (see page 8) describes one aspect of this work. Another is the creation of special languages to describe the processing of information; FORTRAN, BASIC, APL, and PL/I are a few of several hundred programming languages that have been developed for various uses. Also, since such languages are not native to real computers, they must be translated into a language usable by the computer, and much attention has been given to the problem of devising compilers to translate these highly structured languages automatically.

Some of this work has had interesting effects on other fields. The development of programming languages, and the study of translation of these languages, has had a profound effect on the field of linguistics. Similarly, the attempt to develop computer programs that exhibit behavior that might be called "intelligent" if displayed by a human has led psychologists and biologists to become concerned with the sharpness of some of their definitions and the adequacy of some venerable models.

SOCIAL IMPLICATIONS OF COMPUTER TECHNOLOGY

A relatively recent addition to the activity of computer science departments is a concern for the social implications of computer technology. It is obvious



that the computer is a powerful tool with enormous capacity to change existing structures and modes of operation. It may enable us to understand and manage some of the incredibly complex systems that man has constructed, but it may also erode what independence and privacy we have retained.

What privacy we have today is much more attributable to the cost and clumsiness of a pencil-and-paper information technology than to an enlightened and protective legal structure; and, unfortunately, information technology is being updated much more rapidly than the legal structure is providing ways to restrict that technology. If not there already, we will soon reach the point where all of the information about an individual now contained in dispersed files in governmental, educational, medical, and financial institutions could be consolidated in a single system with complete coverage from birth to death. When this is accomplished, very complete information about an individual would be available very rapidly and at modest cost. Yet we have not developed the social consciousness, the legal safeguards, or even the technical capability to restrict access to such a data bank.

Computer scientists seem to be participating in the rapid development of a technology that society is unready to control properly. We find an uncomfortable analogy to the situation of physicists in the late thirties and forties, when they presented the world with nuclear explosives. Some technical work is starting on the mechanics of controlling access to information systems, however, and computer scientists are beginning to participate in interdisciplinary efforts to forecast the risks and prescribe the remedies.

TWO TEACHING ROLES OF THE DEPARTMENT

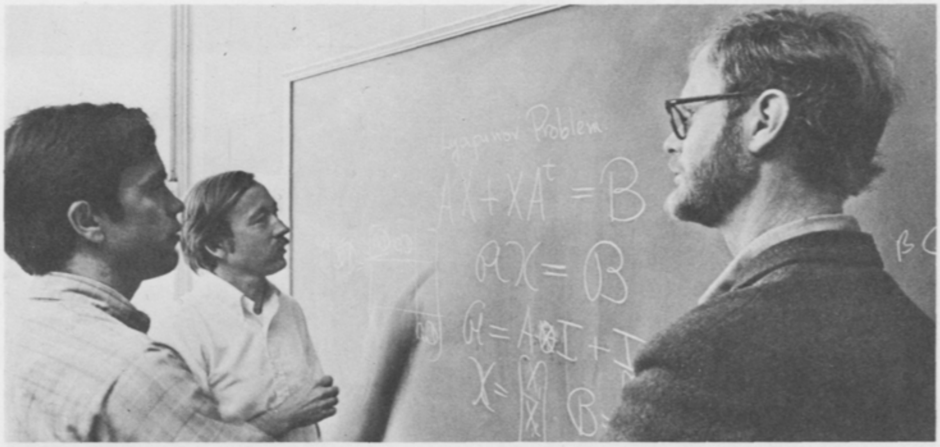
Cornell's Department of Computer Science, a unit of both the College of Engineering and the College of Arts and Sciences, has two different teaching functions. The first is to help teach people to use the computer—that is, to teach computer programming. This is a service role, analogous to the provision by the Department of Mathematics of courses for students who do not major in mathematics. The teaching of computer programming is a major activity, involving nearly 1,500 students each year, and it is steadily growing.

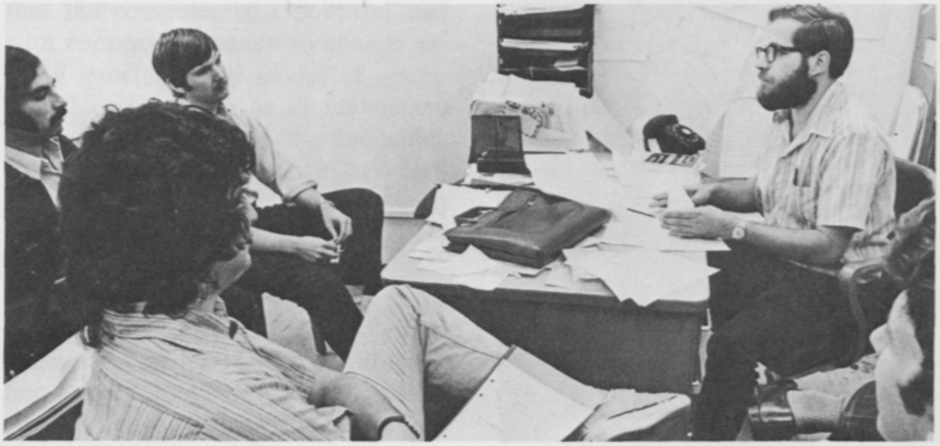
Most of the instruction in introductory programming at Cornell is handled through the unique Learning Center in Hollister Hall. Each student is expected to program a sequence of problems of graduated difficulty. He is assisted in this task by individual consultants, tape-slide units, daily discussions, and daily quizzes, as well as by conventional lectures and textbooks, but all of these facilities are planned for use in quantities and at times of the student's choice. The system accommodates great differences in background and aptitude of students.

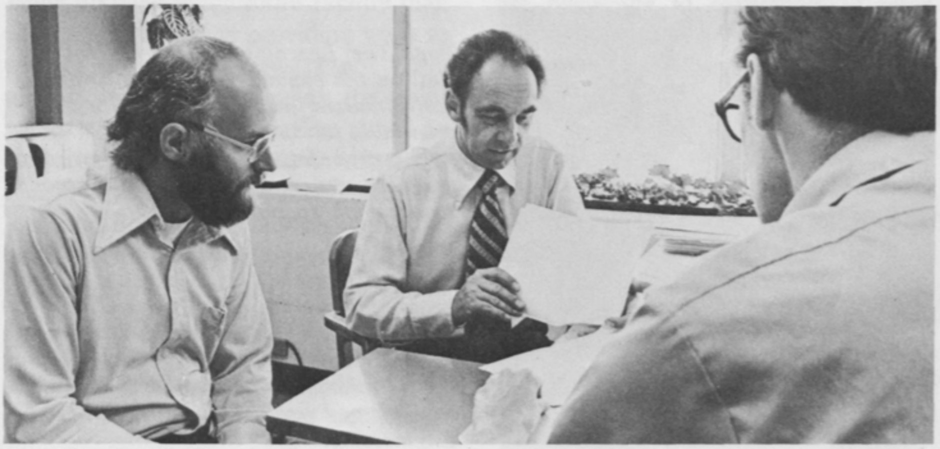
The second teaching role of the department is in offering courses in depth for those students who are interested in the computer *per se* and not just as a tool to apply to some other discipline. Although many schools now offer undergraduate majors in computer science, Cornell does not. We believe it preferable to add elective course work in computer science to studies in another major field, and then follow that with graduate specialization in computer science. In the College of Engineering, undergraduate students with an interest in computer science most frequently major in operations research or electrical engineering, although some with special requirements work through the College Program directly in computer science. In the College of Arts and Sciences, students major in mathematics prior to undertaking graduate work in computer science.

Top: The Learning Center in Hollister Hall on the engineering campus provides individualized help in introductory programming for Cornell students. The Center, staffed largely by upperclass and graduate student advisers, is in its second semester of operation.

Bottom: Help is also available at the Upson Hall terminal of Cornell's central computing facility. This terminal is used extensively by engineering students, who all study computer programming during their freshman year, as well as by other students and researchers in the College of Engineering.







Special expertise in many areas of information science is represented in Cornell's Department of Computer Science. Top (left to right): Jorge Moré, James R. Bunch, and John E. Dennis are specialists in numerical analysis. Left: David Gries, who works with the department's teaching assistants in the basic course, Computers and Programming, specializes in programming languages and compiler construction. Left below (left to right): Robert Constable, Juris Hartmanis, and John Hopcroft share an interest in the theory of computation. Constable is a specialist in computational complexity, and Hopcroft in analysis of algorithms.

Other department members, in addition to Richard W. Conway, author of this article, and their research interests are: Lawrence T. Kou—theory of algorithms; William L. Maxwell, digital simulation and operations research; Charles G. Moore III—systems design and operating systems; Gerard Salton—information organization and retrieval; Robert Tarjan—analysis of algorithms; Ray Teitelbaum—programming languages and compilers; and John Williams—formal languages, programming languages, and compilers.

In addition to these department members, professors from related Cornell units such as the Departments of Mathematics, Operations Research, and Theoretical and Applied Mechanics participate in graduate programs in computer science.

PROSPECTS FOR GROWTH OF THE DISCIPLINE

My personal prediction is that much of the growth in computer science in the next few years is going to occur in relatively practical aspects of the field, and be rather directly responsive to certain serious problems now encountered in the computing profession.

By any reasonable measure, the *ability to program* is now the limiting factor in the field. The existing generation of computers is already straining our ability to construct sizable programs. The cost of programming is generally greater than the cost of the machines on which they are executed, and the programming is generally much less reliable than the hardware. There is clear indication that the late seventies will see a new generation of machines that will be an order of magnitude faster and larger and have greatly enhanced communication capability, but unless a corresponding improvement is achieved in programming techniques, this potential will not be very useful. Improvements will have to be found in languages, in procedures for developing programs and proving them correct, and in the management of large programming efforts. Computer science should continue to be an exciting field in which to work.

Professor Richard W. Conway first came to Cornell as an undergraduate student in mechanical engineering. He was graduated in 1954 with the B.M.E. degree and continued at Cornell for a Ph.D. in operations research, awarded in 1958. He has served on the faculty since 1956, in mechanical and industrial engineering, and, since 1964, as professor of operations research and computer science.

Over the years he has participated in the establishment of the Department of Computer Science, which was formed in 1965, in the organization of the Office of Computer Services, which he directed for two years, in the development of Cornell's PL/C compiler, and in the development of educational programs in computer science. As part of this educational leadership, he has served as Field Representative for the Graduate Field of Computer Science and, more recently, restructured the required freshman course in Elements of Engineering Communication as a partially self-paced introductory course in computer programming.

Conway's professional interests lie in the area of development, operation, and management of information systems. He serves as a consultant to a dozen industrial organizations, including IBM, General Electric, and Eastman Kodak. He is a partner of Compuvisor, a data processing consulting firm that provides a file maintenance and information retrieval system based on a language developed by Conway and some of his colleagues.

He spent a recent sabbatic leave as visiting professor of computer science at the University of Grenoble, France, and an earlier leave as a consultant in the logistics department of the RAND Corporation. In 1968–69 he was awarded an NSF Science Faculty Fellowship and spent the year studying at the Massachusetts Institute of Technology.

Conway is an author, with operations research professor William L. Maxwell and former student Louis Miller, of Theory of Scheduling, *published by Addison-Wesley in 1967. A textbook,* Introduction to Programming, *which presents a new approach to programming instruction, was written by Conway and David Gries, associate professor of computer science at Cornell, and published in July of this year by Winthrop.*

Conway is a member of the Operations Research Society of America, the Association for Computing Machinery, the Institute of Management Sciences, and Sigma Xi.

APPROACHES TO THE NEW LIBRARY

by Gerard Salton

Most libraries, these days, live in a state of crisis. Everything grows rapidly except the size of the library budget: The number of items to be processed increases continually, and so do the processing costs. The services to be rendered grow in variety, and the service costs increase. User requirements become more complex, and the kinds of reference materials needed become more diversified—not only printed materials must be handled, but also information recorded on tapes, fiches, cassettes, films, and so on. These various factors put the library in the unenviable position of having to strain continually in order to keep up with ever-growing requirements.

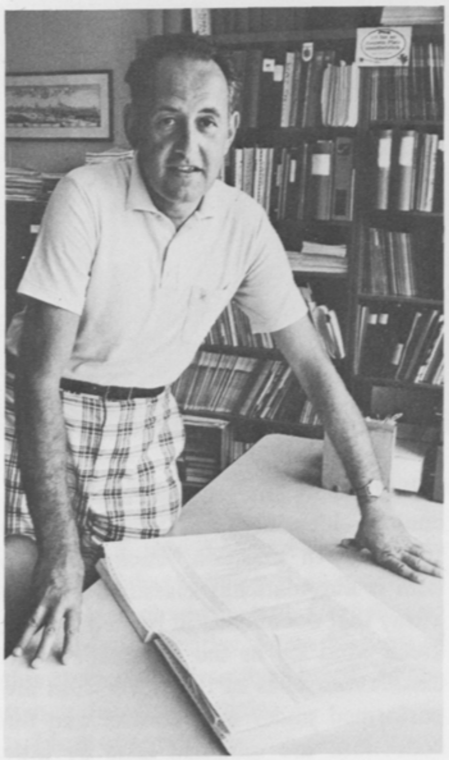
What approaches have been tried by libraries in their attempts to meet the growing demands on their services? What are the most promising alternatives? And how can the computer be used effectively in the design of a new library system?

These matters are of concern to computer scientists as well as to librarians; indeed, the development of automatic procedures for handling such functions as information storage and retrieval and the maintenance of library collections has been a subject of study in Cornell's computer science department for some years. I would like to discuss some experimental methods for the automatic handling of library resources, and examine the potential of these procedures in the library system of the future.

RESPONSES TO THE LIBRARY CRISIS

The response of libraries to the growing demands on their services takes several forms. Inevitably, requests are made year after year for higher budget levels and additional library space. This approach, unhappily, does not offer any fundamental long-range solutions to the library problem.

The second method of attack usually consists of attempting to perform with the aid of automatic equipment some of the procedures that have been handled manually. These include, for example, the ordering and acquisition of library materials, catalog maintenance, and circulation. An examination of standard library housekeeping operations from a data-processing point of view reveals, however, that their implementation in an automatic environment is likely to produce a considerable number of problems: The files which must be processed are very large. The file maintenance and updating operations are extensive. Many inputs exist and a large number of outputs must be produced. Worst of all, real-time control of the collection is considered desirable—that is, one would like to be able to determine the whereabouts of each item at any given moment in time. Such a set of requirements imposes great strains on the computing facilities, because no application involving large files subject to a great deal of updating is easy or cheap to mechanize. In these circumstances, it is not surprising that the application of computers in the library has not proven to be cost effective for the most part. A transfer of current manual library operations to an automatic environment uses none of the strengths of the computer and reveals many of its shortcomings.



Gerard Salton, chairman of Cornell's Department of Computer Science, is working on the development of an automatic system for information storage and retrieval that is applicable to library usage and management.

COOPERATIVE EFFORTS BY GROUPS OF LIBRARIES

A third approach to the library problem is to organize compacts and cooperative arrangements among a number of different libraries so that both the costs and the problems inherent in library mechanization can be shared. This approach implies a willingness on the part of individual libraries to standardize their methods, in the expectation that the same set of procedures might serve the needs of several organizations. In principle, the institution of collaborative procedures makes a great deal of sense in the library environment; in practice, the aims of the collaborating organizations often do not mesh as closely as one might expect. As a result, most existing collaborative schemes are restricted in scope and their influence is still quite limited.

INFORMATION EXCHANGE IN LIBRARY NETWORKS

Another development of importance is the creation of library networks in which corresponding components of the participating libraries are connected and information can be exchanged. For the moment, the network organizations are concerned mostly with the establishment of common housekeeping operations. As communication costs go down and the practice of on-line processing (with computer consoles used for the input-output operations) becomes more prevalent, the importance of the network concept can be expected to grow. At the present time, though, the long-distance transmission of large bodies of information recorded in machine-readable form is not cost effective. Furthermore, the existence of an operational information network raises legal and social questions relating to information ownership and copyright and to the maintenance of information privacy. These problems are not close to solution, and the abandonment of printed books and documents as we know them in favor of machine-stored information transmitted on demand through an information network does not appear likely to occur in the foreseeable future.

APPROACHES TO THE NEW

by Gerard Salton

An alternative to traditional methods of literature search (below) is automatic information retrieval. A service now available at Cornell (see photo at right) is the retrieval from listings in the Index Medicus *of items relevant to a particular study. An on-line system connects a terminal at Cornell's Mann Library to a data base at the State University of New York at Albany. According to operator Elaine Kibbe, shown at the console of the typewriter terminal, twenty or thirty Cornell researchers use the service each month. Ms. Kibbe interviews the user, prepares with him a list of key words, introduces these with proper logic into the stored file, and receives back a bibliography.*

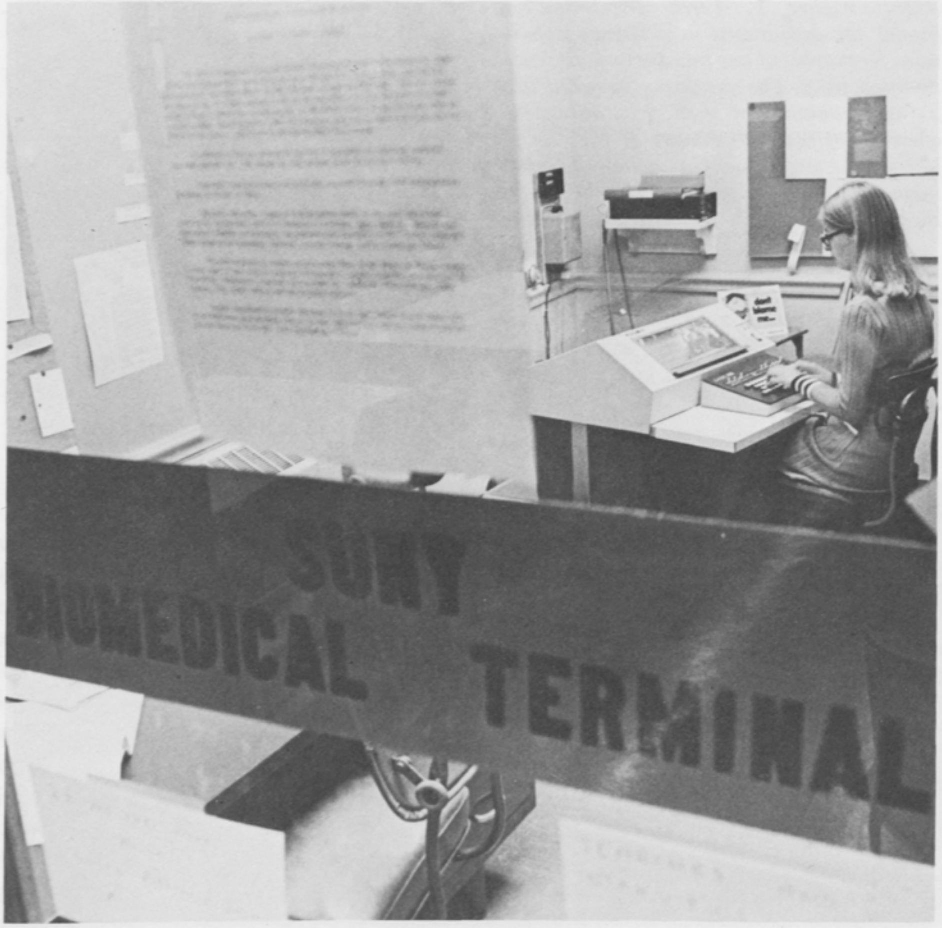
THE OUTLOOK FOR NEW SYSTEMS TECHNIQUES

Library housekeeping operations such as acquisitions, catalog production, and book circulation are relatively easy to standardize. Eventually they will be rationalized and executed cooperatively by a large number of different library organizations.

On the other hand, intellectual library operations such as information indexing, the search and retrieval of stored information, and collection maintenance are not as easy to standardize. The kind of library classification used for a given subject area, or the field arrangement, or the search strategies, may well differ from place to place in accordance with the requirements and backgrounds of the users, and each library might usefully adapt these procedures to best accommodate its particular groups of users. Similarly, decisions to locate items in fast-access storage or to retire them to auxiliary storage are not subject to standardization and should be taken separately by each library center. It is precisely in these user-dependent areas that the computer could be used to advantage, however, for these areas are completely ignored at the present time and applicable manual procedures are inadequate or nonexistent.

THE SMART EXPERIMENTAL RETRIEVAL SYSTEM

At Cornell an experimental computer-operated storage and retrieval system, called SMART, is currently in operation. In this system, all stored documents—and all incoming queries—are automatically analyzed and appropriate content identifiers are automatically supplied. In addition, each resource item is automatically classified in such a way that documents in related subject areas wind up in the same document classes. Searches of the stored files are performed under user control and the collections are modified little by little so as to create a file directly adapted to the user population. Finally, procedures are available for preserving a file of constant size under conditions of collection growth by retiring those



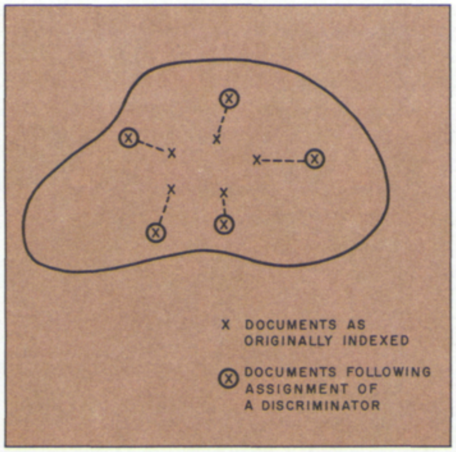
items that are least likely to be wanted by the user population.

SMART was designed in the early 1960s and has developed as a cooperative research project at Cornell and Harvard Universities. Some features of this system are described briefly in the remainder of this article.

Most observers assume that it is not possible to use a computer to determine automatically the content of written texts. Actually, the usefulness of the available content analysis procedures depends very much on the kind of application that is under consideration. For language translation, for example, it is not enough to determine the general context of what is being said; the meaning of each individual word must be specified unambiguously, the truth or falsity of each statement must be established, and the role of each sentence in the text must be ascertained. In a library environment it is sufficient, fortunately, to identify those terms that are reflective of document content and to assign to each a general index of importance, or weight.

The question that immediately arises is what constitutes an important item. An initial conjecture, for example, might be that a good term for purposes of content description would be one that occurs with high frequency in the documents of a collection. While there is some merit in this supposition, its defect is that some terms will occur with high frequency in *all* the documents of a collection. The term *computer,* for instance, will occur everywhere in a collection dealing with computer science. Obviously, such a term will not be useful as a content identifier, since it would have to be assigned to all the documents in the collection and therefore would not serve to distinguish among them.

Actually, it turns out that the best terms are those which occur in a collection of documents with medium total frequency and exhibit a skewed frequency distribution—that is, they occur with high frequency in some documents and with much lower, or zero, frequency in many others. Such terms are good *discriminators* because when they are assigned to a given collection, *Right: Figure 1. Term discrimination model for documents in a library collection. Represented are five documents, each denoted by x. The similarity between two x's is a function of their separation: the closer they are, the greater is their similarity. The assignment of a new discriminator, or identifying term, to the documents may result in decreased similarity.*



Below: Table I. The effectiveness of discriminating terms used in the retrieval indexing of 425 articles on world affairs that appeared in the 1963 issues of Time *magazine. Listed are the ten best and ten worst discriminators.*

GOOD DISCRIMINATORS	POOR DISCRIMINATORS
1. Buddhist	7560. Work
2. Diem	7561. Lead
3. Lao	7562. Red
4. Arab	7563. Minister
5. Viet	7564. Nation's
6. Hurd	7565. Party
7. Wilson	7566. Commune
8. Baath	7567. U.S.
9. Park	7568. Govern
10. Nenni	7569. New

they serve to discriminate among the documents. The effect is to decrease the *similarity* of the various documents (see Figure 1). Specifically, the *discrimination value* of a term may be computed by comparing the average similarity between pairs of documents before and after assigning the given term. If the average similarity between pairs of documents decreases after a given term is assigned, the term is a useful one for content identification.

It has been shown that content indicators chosen automatically by using the term discrimination model operate far better, and more consistently, than subject indicators manually assigned by subject experts or trained indexers.

AUTOMATIC GROUPING OF RELATED DOCUMENTS

If responses are to be obtainable from a mechanized retrieval system within a reasonable time after the submission of a search request, it is necessary to group the documents into affinity classes, for such a classification obviates an exhaustive search of the complete file.

A useful organization system is a *clustered file* such as the one represented in Figure 2. In this organization, documents dealing with related subjects appear in the same document classes, and each class is identified by a dummy item, called the *centroid,* which represents the average document in that class. When a search request is received, it is first subjected to a routine content analysis and then compared with all the centroids in the collection. Centroids sufficiently similar to the query are identified and the individual documents in the corresponding classes are compared with the query. This leads to the retrieval of the items situated closest to the query.

The document classification illustrated in Figure 2 is very similar to a standard library classification, with two exceptions: (1) There is overlap among the classes, in the sense that many documents appear in more than one class; and (2) the classification is constructed automatically, with use of the index terms that were assigned to the documents during the content analysis.

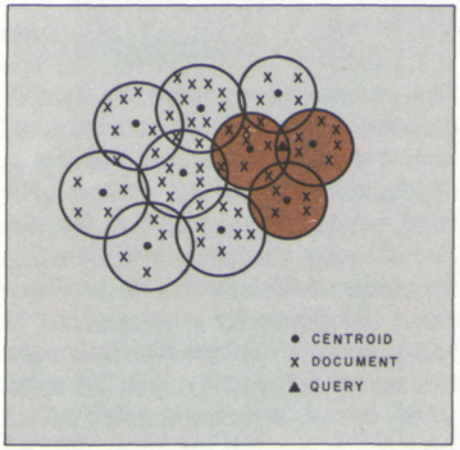


Figure 2. Model of a clustered document space. The documents situated in the orange-colored circles are the ones actually matched against the incoming query.

A large number of automatic processes exist for the task of assigning documents to affinity classes. A simple example is a procedure, usable under some circumstances, that operates in a single pass through the document collection as follows: (1) The first document is called class 1. (2) The next document is compared with class 1. If it is sufficiently similar, it is entered into class 1 and a new centroid is computed; otherwise, the second item constitutes class 2. (3) All subsequent documents are taken up, one at a time, and compared with all existing centroids. If a new item is sufficiently similar to one or more of the centroids, it is entered into the corresponding class or classes and the centroids are recomputed; otherwise, the incoming document constitutes a new class. The process terminates when the last document has been handled.

ASSIGNING DOCUMENTS TO AFFINITY CLASSES

Other, more sophisticated, clustering methods are available. The method actually used to construct the initial classification is probably less important than the procedures used to update the classification as new items are added and old ones removed. Whenever possible, the classification should be updated in such a way that a complete reclassification of all items does not become necessary.

DYNAMIC QUERY AND DOCUMENT MODIFICATION

An automatic search process conducted in a clustered field environment will not immediately retrieve all items requested by the user and reject all those that are not wanted. It is necessary to approach the requested subject area little by little by conducting various partial searches and altering the query from one search to the next.

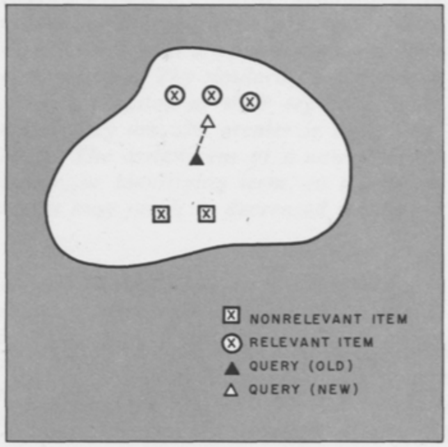
A preferred method for this purpose is known as *relevance feedback:* Queries are automatically updated by the system (not by the user) on the basis of relevance information furnished by the user about previously retrieved documents. Specifically, the process works in the following way. For each query entering the system, an initial search is performed. Then a small amount of output, consisting of some of the highest-scoring documents—those whose similarity to the query is greatest—is presented to the user, who is asked to characterize these documents as being either relevant or nonrelevant to his needs. These judgments are returned to the system and used automatically to adjust the search request in such a way that query terms present in the relevant documents are promoted (by increasing their weights), whereas terms occurring in the nonrelevant items are demoted.

The query updating can be expressed as

$$q^1 = q + \alpha \sum_{i \epsilon R} r_i - \beta \sum_{j \epsilon S} s_j$$

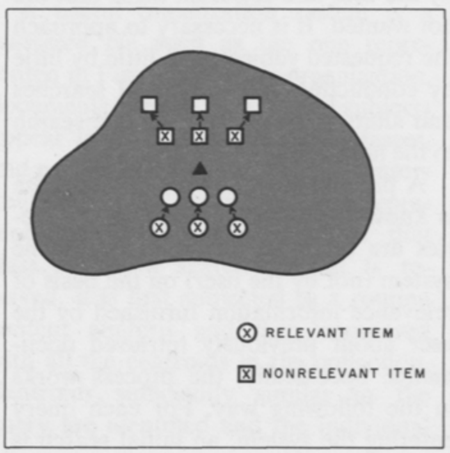
where q^1 is the new formulation, q is the original query, r_i is the i^{th} document in the relevant set R, s_j is the j^{th} document in the nonrelevant set S, and α and β are constants. The relevance feedback system is represented pictorially in Figure 3.

It can be shown experimentally that the relevance feedback process produces large-scale improvements in retrieval effectiveness.



Above: Figure 3. Relevance feedback. On the basis of the user's judgment about the relevance or nonrelevance of previously retrieved documents, a query can be adjusted automatically so that its identifiers correspond more closely with those of the relevant documents.

Below: Figure 4. Document space modification. After a large number of indexing alterations have been made over several years of operation, there may exist an equilibrium in which the most interesting items in a collection have been moved into the central part of the file, and the items that are rarely wanted have been moved to the periphery.



"It is precisely in these user-dependent areas that the computer could be used to advantage"

HOW THE LIBRARY USER CAN MAKE IMPROVEMENTS

The automatic query alteration process described above is based on information obtained from users in the course of the normal retrieval process. No good reason exists, however, for not also utilizing customer intelligence to help improve the indexing of the documents themselves by promoting, so to speak, documents about which the user has reported favorably. For instance, when certain documents retrieved in response to a given query are labeled by the user as *relevant,* it is possible to render them more easily retrievable in the future by making the indexing for each of them somewhat more similar to that of the query used to retrieve them. Similarly, retrieved documents labeled *nonrelevant* can be rendered less easily retrievable by being shifted away from the query. This can be accomplished by adding or subtracting terms or by altering the weight of the terms. The outcome is that after a large number of such interactions, those documents that are most wanted by the users are moved slowly into the active portion of the document space—that part in which a large number of user queries is concentrated—while rejected items are moved to the periphery from where, eventually, they may be retired. This process is illustrated in Figure 4.

COLLECTION GROWTH AND RETIREMENT

The modification operations discussed so far are designed to keep a collection up to date with respect to changes in user interests. There are, however, even more important reasons for providing a dynamic document environment; these have to do with collection growth and retirement. For the most part, library and information center personnel are painfully aware of the severity of problems created by normal collection growth and by the lack of viable retirement policies for journal articles and monographs. Unfortunately, the state of the art is such that the inevitable response of library administrations faced by accelerating document growth rates is an insistence on the need for additional buildings, funds, and personnel. An alternative exists, however: It is possible to incorporate new documents into existing collections and simultaneously reduce collection size by removing those items that are least likely to be wanted in the future.

Let us consider first the question of *collection growth.* In the clustered environment, the principal question to be resolved is how the clusters should be modified when new documents are introduced. In principle it is desirable to reorganize the file as often as possible; in practice the work involved in reclustering a sizable file is considerable, so that alternative methods must be used whenever possible. When the updating rate is less than 50%—that is, when less than half of a collection of documents has been affected by indexing alterations or by the addition of new items—it is possible simply to assign incoming items to those classes to which they are most similar. When the updating rate exceeds 50%, a reclustering operation is in order.

Possibly the most important current problem in library management—one which has been attacked with remarkably little success—is the problem of *document retirement.* By retirement is meant not a complete loss of an item, but merely its removal from the central file system—the one searched every time—to an auxiliary storage area to which access is available only in special circumstances.

The use of computers for data retrieval is demonstrated by a service currently available at Cornell's Water Resources and Marine Sciences Center. A terminal for a retrieval system for information on national water resources and engineering is located in Hollister Hall on the engineering campus. Shown is operator Marcia Connelly. This local terminal is one of three that have been set up for a pilot study of a possible national computer network of data-retrieval centers. Quick-response and comprehensive computer searches of data comprising more than 50,000 items can be requested through any of the three terminals.

The classical approach to document retirement is to introduce concepts such as the half-life of a collection—the time considered to be required for obsolescence of one-half of the currently included items—or the utility of a document as expressed by the number of times it can be expected to be called for during the remainder of its stay in the collection. Unfortunately, measurements of potential obsolescence or utility are impossible to implement with sufficient accuracy for practical application.

WINNOWING THE ITEMS IN A LIBRARY COLLECTION

An alternative document retirement policy can be based on techniques developed for document retrieval. The accessibility of a given item is automatically determined on the basis of three criteria: (1) The degree of correspondence between a given document and a pertinent set of queries; (2) the rank of a given document in the list of retrieved items; and (3) the judgment of the user as to the utility of the retrieved document. On the basis of this information, documents are shifted closer to the centers of user interest or away from them by adjusting the correspondences between query terms and document terms.

If such a policy were implemented correctly, it is clear that items which were rarely or never requested would be shifted toward the periphery, away from the active part of the file, and eventually become irretrievable. Simultaneously, documents which were promoted would become more easily retrievable in the future if new queries, similar to the currently active ones, should be received.

A specific retirement policy, which has been tested experimentally, operates in the following way. The weights of all terms from a promotable document are multiplied by a factor larger than 1 (say, 1.001) and, similarly, the weights of terms from an unfavored document are multiplied by a factor smaller than 1 (say, 0.999). When the average weight of the terms attached to a given document decreases to a specified threshold, the document is "retired." Of course, the threshold picked determines the retirement rate of documents in a given collection.

THE ECONOMICS OF A DYNAMIC FILE SYSTEM

The dynamic file environment described here must be subjected to appropriate cost studies. Obviously, any dynamic file process will require some apparatus not needed for static file management. On the other hand, the costs presently inherent in the maintenance of ever-growing files are staggering, and trained personnel, storage space, and new buildings are becoming scarcer. A self-monitoring, dynamic environment such as the one proposed may be justifiable, both economically and technically.

In time, a dynamic file environment may well become the basis of a viable overall system for library and collection management.

Gerard Salton, professor and chairman of the Department of Computer Science at Cornell, is an internationally recognized authority in the field of information organization and retrieval. He has also conducted research in the areas of automatic data processing, language analysis, and speech and pattern recognition.

Salton, a native of Germany, began his university education as a night-school student at Brooklyn College, which awarded him the A.B. degree, magna cum laude, *in 1950 and the M.A. two years later. From 1952 to 1958, while studying for the Ph.D. at Harvard University, he served as a staff member in the university's Computation Laboratory. He subsequently served as a member of the applied mathematics department at Harvard until he came to Cornell in 1965.*

Salton has lectured and published widely in his specialty fields. In addition to articles for professional journals, he has written a text, Automatic Information Organization and Retrieval, *published by McGraw-Hill in 1968, and edited* The SMART Retrieval System: Experiments in Automatic Document Processing, *published by Prentice-Hall in 1971. In 1962–63 he spent a year at the IBM Research Laboratory in Zürich, Switzerland, as a Guggenheim fellow, and in 1970–71 he spent a sabbatic leave as visiting professor at the Swiss Federal Institute of Technology in Zürich. He is currently serving as a consultant to several firms.*

A member of the Association for Computing Machinery, he was editor-in-chief of the ACM Communications *from 1966 to 1968 and then editor-in-chief of the* ACM Journal *from 1969 to 1972; at the present time he serves on the ACM Council. He is a fellow of the American Association for the Advancement of Science and a member of the Institute of Electrical and Electronics Engineers, the American Society for Information Science, the Association for Computational Linguistics, and the honorary societies Sigma Xi and Phi Beta Kappa.*

THE COMPUTER AS LABORATORY INSTRUMENT

by Christopher Pottle

A common occurrence in engineering classrooms these days is an exchange like this one in an electrical engineering recitation session. The instructor writes on the blackboard a fairly complex expression, the current-voltage relationship for a semiconductor diode

$$i = I_s \left(e^{qv/kT} - 1 \right),$$

supplies values for the fixed parameters and the voltage v, and then, almost before he can open his mouth again, is given a value for the current i by one of the students in the class. Not only does the answer come quickly—it is supplied to eight decimal digits!

What has happened, of course, is that engineering students, along with the rest of the country, have armed themselves with pocket calculators. These miniature instruments have revolutionized the calculator business and rendered the slide rule obsolete; moreover, they are inexpensive enough to pay for themselves quickly when used to shop for bargains at the supermarket. While not the principal subject of this article, the new pocket calculator provides a very public demonstration

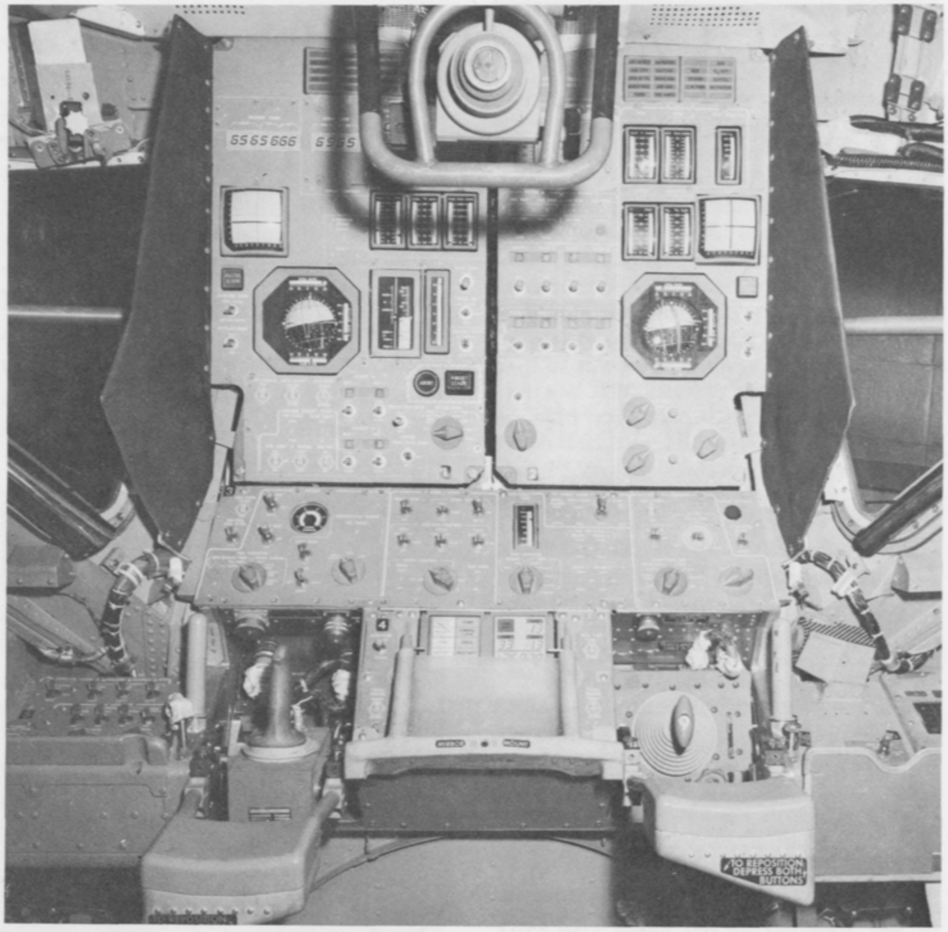
that computing hardware has become small and cheap. This fact has led also to a revolution in the way laboratory research experiments are performed: They have become "computerized."

LAB DEVICES AS WELL AS NUMBER CRUNCHERS

To the public, the term *computer* connotes huge, expensive machines which keep track of income tax returns, make airline reservations, and cause form letters to be mailed. It is true that the major share of computing equipment is engaged in this sort of business data processing. If one singles out the scientific world, however, the picture changes. The large computer installation exists here also; its presence is required by the enormously complex and lengthy calculations needed in many branches of science and engineering. These tasks, known as "number crunching" to the scientific community, totally occupy the time of several of the largest computers in the world. But there is another, quite different, use of computer machinery in science and engineering. This application, which has recently experienced explosive growth, consists of making computer operations an integral part of a laboratory experiment.

What characterizes a computer that is being used as a laboratory device? How is a laboratory computer similar to and how is it different from business data processors and number crunchers? The following characteristics can usually be identified:

1. The primary source of a laboratory computer's input comes not from data generated by human agency, but



Small computers are an essential part of the equipment for space missions. Pictured is the main control panel in the interior of the Apollo Lunar Module. The data keyboard in the lower center of the photograph is used by astronauts to enter data into the onboard computer. (Photo courtesy of the Grumman Aerospace Corporation.)

from electromechanical sensors placed in the environment of the experiment. The computer obtains these data directly through a *data acquisition system.*

2. Often there will be two sorts of output from a laboratory computer. One is prepared for human observation and is used for monitoring the experiment and sometimes to deliver the results obtained. The other is converted into signals which other components of the system may use to control the experiment itself.

3. The architecture of a laboratory computer is not very different from that of other computers; most machines used as laboratory devices are also employed as general-purpose computers. Machines suitable for laboratory use usually have features that make it easy to connect data acquisition equipment.

4. Unless the computer is serving several different experiments, it will be a fairly inconspicuous component of the experimental equipment. The computer will tend to remain attached to the rest of the instruments and will service only one user at a time.

Perhaps one of the most well known uses of laboratory computers was in the Apollo moon program experiment. Several computers were sent up on board both the Command Module and the Lunar Module. Almost everyone became aware of the difficulties experienced and the success obtained with these crucial components.

AN INSTALLATION USING A LABORATORY COMPUTER

Let us consider a computer which is an integral part of the hardware used to perform a certain experiment (see Figure 1). This computer could be one of the small machines known as *minicomputers,* whose presence in laboratory equipment is growing so rapidly; if so, it probably is mounted in a rack with other equipment relating to the experiment. A large experiment might have its computer in a room by itself.

Data obtained during the course of the experiment usually consist of the output of several sensors, which deliver a voltage that at all times is proportional to the quantity being

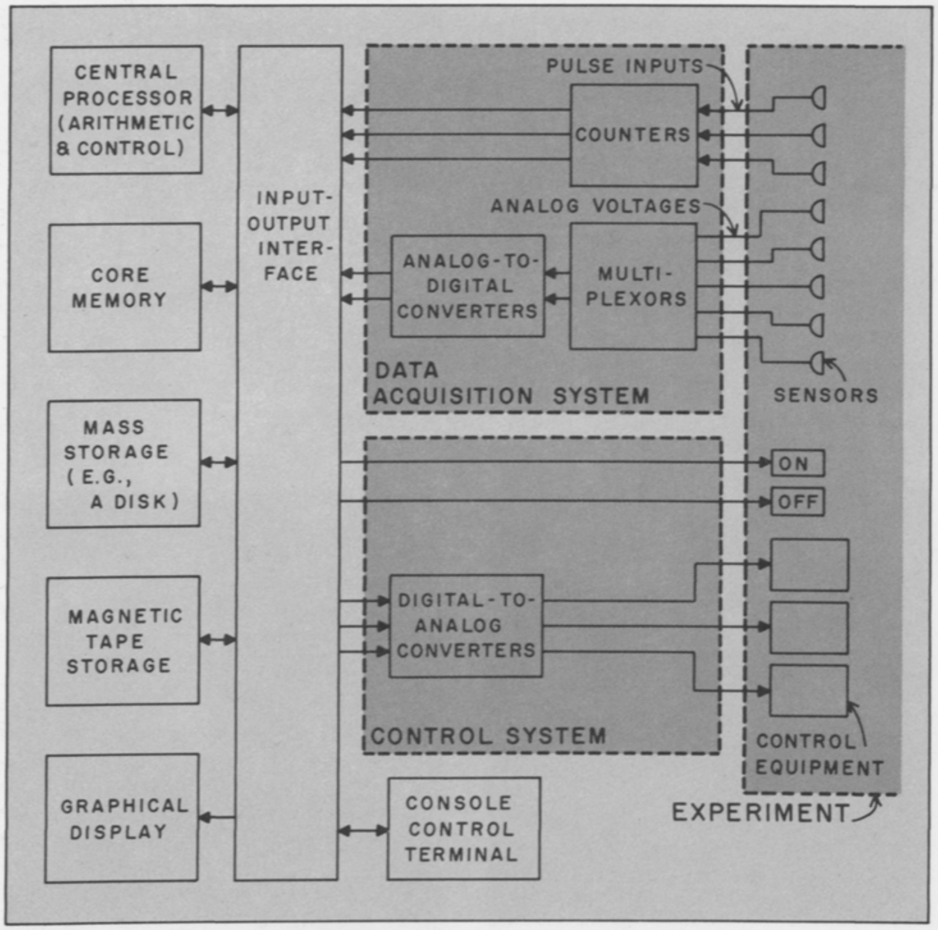


Figure 1. Block diagram of a laboratory computer system.

measured. The computer, however, requires its data to be in the form of binary numbers, and so an electrical component to convert a voltage level to a binary number must be included in the instrumentation. This *analog-to-digital converter* (ADC) is a vital component in most data-acquisition systems. ADC's with an accuracy of one part in 4,000 and able to perform up to 50,000 conversions in one second are cheap and commonplace, and conversion rates of up to ten megahertz and accuracies of one part in 100,000 are possible (though not yet in the same unit).

Experimental data do not always appear in analog form, however. Pulses denoting the occurrence of a particular event are often obtained from an experiment. These pulses do not require conversion, but are used directly to interrupt the computer or to increment an event counter.

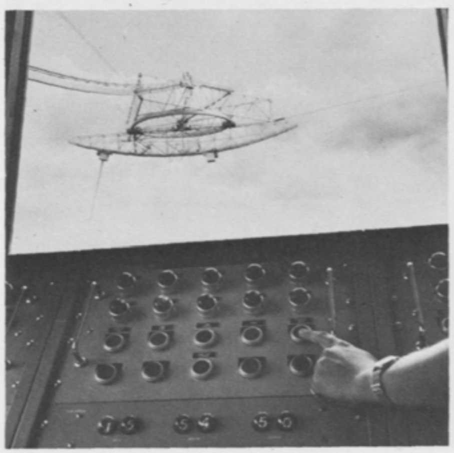
If the computer is being called on to direct the experiment, a control system is required. Control equipment will generally require an analog voltage proportional to the amount of control desired. This voltage is provided by a *digital-to-analog* converter, whose function is thus the inverse of the ADC. Pulse outputs to start and stop the experiment, for example, can be delivered directly from the input-output interface, as shown in Figure 1.

The computer obtains its instructions from a stored program in its main memory. Under operator control from the console, new programs can be loaded from mass memory (for example, a disk) in larger machines or from the console itself, and executed. Under program control, data are acquired, processed, possibly preserved on magnetic tape, and displayed graphically on a display device.

The programs executed by the computer may be prepared in basic machine language on the computer itself, or, if the computer is large enough, in a higher-level language such as FORTRAN. A recent development for small machines is the use of a larger general-purpose brother machine to compile a FORTRAN program into the machine language of its smaller sibling.

APPLICATIONS IN THE COLLEGE OF ENGINEERING

Four facilities available to people in the College of Engineering demonstrate how laboratory computers are used. Three of these facilities are research laboratories or centers with very different objectives and experimental material and with computing equipment that differs in size and speed. The computer installations of all three, however, have the attributes for laboratory use that are described above. The fourth installation is designed primarily to inform undergraduate engineering students about laboratory minicomputers and to give them first-hand experience in operating one as an integral part of simple laboratory experiments.



Left: The 525-ton antenna feed assembly of the radar and radio telescope observatory at Arecibo, Puerto Rico, is visible from the control room of the Cornell-operated facility. Computer processing of data in real time is an important experimental feature.

Right: A minicomputer is part of the experimental equipment used by Thomas Hall, a postdoctoral associate of Professor David N. Seidman, in a study of point defects in metals by means of atom-probe field ion microscopy. The computer makes possible the fast identification of single atoms evaporated in rapid sequence from a metal surface.

THE COMPUTER FOR THE ARECIBO RADIO TELESCOPE

The first laboratory computer that was used extensively by College of Engineering personnel is easily the largest. It is also nowhere near Ithaca, being located next to the control room for the radio telescope at the National Astronomy and Ionosphere Center near Arecibo, Puerto Rico. The computer in use now at the Arecibo observatory is a Control Data 3300, installed in 1969.

In ionospheric experiments, the primary input quantity to the computer is a time function representing the power of radar pulses returned from the ionosphere; it is this signal which is converted to digital form by an analog-to-digital converter. The results usually desired involve the computation of correlation functions of the radar return pulse. These computations were originally carried out by the computer under program control, but because correlations require so many multiplications, the computer was unable to perform the calculations in *real time*—that is, to keep up with data as they arrive. Recently, therefore, the system was improved by the addition of a *hardware correlator,* a special-purpose computer with a wired-in program for carrying out the required multiplications and additions. Some immediate analysis is done directly by the Arecibo computer, but much of the data is recorded on magnetic tape, forwarded to

" . . . we may soon expect to see computers in equipment everywhere."

the many universities that use the Arecibo facilities, and processed further on the users' computers. The incoming data are used also for monitoring purposes while an experiment is in progress. The computer may exert control over an experiment to the extent that the radar transmitter's pulse code and separation are under program control.

The computer at Arecibo is large enough to permit operation in a multiuser mode, serving the on-line laboratory function and also carrying out general-purpose work.

THE MINICOMPUTER FOR RESEARCH IN MATERIALS

Two research groups in the Department of Materials Science and Engineering have been using a recently acquired Data General Nova 1220 minicomputer in their work. One group is performing experiments on an atom-probe field ion microscope; some of this work has been described in this magazine (see the Autumn 1972 issue, Vol. 7 No. 3, pp. 21-29). Under computer control, a pulse evaporates an atom of unknown species from a sharply pointed probe and starts a timer. The atom passes through a time-of-flight tube, which sends pulses to the computer when it enters and leaves. The computer then calculates the charge-to-mass ratio of the atom and compares it with a stored library. After many repetitions of this process, a histogram showing the various species present may be plotted. This kind of study requires the rapid performance of a great number of experiments, an accomplishment that was impossible until the appearance of computers to handle the analysis and control.

A study of quenched-in vacancies in tungsten, also mentioned in the earlier *Quarterly* article, makes extensive use of the high-speed analog-to-digital conversion facilities of this laboratory computer system. A fine tungsten wire is heated up to a temperature close to the melting point and then rapidly quenched. The voltage appearing across the specimen under application of a constant current is converted and processed to yield a curve for temperature as a function of time that has an accuracy of $\pm$ 1°K.

"... an introduction to the operation and potential uses of laboratory computers is (necessary for) most electrical engineering students."

A TOOL FOR CORNELL'S ELECTRICAL ENGINEERS

An ongoing research project at the School of Electrical Engineering is concerned with the characterization of noise associated with line-of-sight and tropospheric microwave communication links. Two properties of interest are the frequency spectrum and the probability density function of the amplitude of this noise. The experimental work consists of making standard analog tape recordings of the noise as observed on microwave links in actual operation. The tapes are sent to Cornell for processing by Computer Signal Processors equipment whose central component is a Varian 620/L minicomputer. To obtain the noise spectrum over a 0.1-second interval, the tape is played back into an ADC which receives and digitizes 1,000 samples of the noise at a rate of 10 kilohertz. These samples are then processed into a spectrum in less than a second by a stored program coded to carry out the so-called *Fast Fourier Transform* (FFT) algorithm, and the spectrum is displayed on a built-in oscilloscope or copied onto a plotter. Also, a histogram representing the probability density function of the noise may be accumulated and displayed in real time: One may see the histogram developing as the tape is played back into the system.

The School has found that this equipment is excellent also as an aid in communicating the elementary concepts of signal processing to undergraduates. Simple periodic waveforms generated with standard equipment can be processed and spectra of their functions displayed almost immediately, giving a convincing classroom demonstration of the relationship of the Fourier series to the actual problem of signal processing.

TEACHING ABOUT LABORATORY COMPUTERS

The electrical engineering faculty realized some time ago that an introduction to the operation and potential uses of laboratory computers is a necessary part of the experience of most electrical engineering students. Last year, with funds from the National Science Foundation Undergraduate Laboratory Equipment Program, matched by the College of Engineering, we were able to purchase a Digital Equipment Corporation PDP 11/40 minicomputer, together with all the peripheral devices represented in Figure 1. We are now designing experiments for use, beginning this spring, in a required junior-year laboratory course. The experiments are planned to meet as many as possible of the following criteria:

1. The experiment itself must be simple. A suitably modified experiment already performed without a computer is a possibility.
2. The experiment should employ a maximum amount of computer equipment without becoming too complex. Especially valuable is an experiment that is controlled by the computer.
3. The results should lend themselves to graphical display.
4. One small part of the computer program should be written by the student in a higher-level language such as BASIC or FORTRAN. Creating, editing, compiling, and running a program from an on-line terminal is an important part of the educational process.

Left: Instrumentation in this data-acquisition room at Cornell's Wilson Laboratory, facility for the University's 12 GeV electron synchrotron, includes four minicomputers. Michael Kolesar, systems analyst, is shown at one of the consoles.

Below: The almost simultaneous processing of data that can be accomplished by means of a laboratory minicomputer is demonstrated in an electrical engineering research laboratory at Cornell. The oscilloscope visible in the upper part of the photograph displays the Fourier spectrum corresponding to the square-wave signal that appears on the oscilloscope at lower left. An operator adjusts computer controls.

THE REVOLUTION IN SIZE AND COST

What has caused the enormous increase in the use of computers, especially minicomputers, as laboratory devices? The answer appears to be their flexibility and low cost. Special-purpose control equipment is inflexible—a slight change in requirements may render the device obsolete—and it is expensive, since only a few pieces are built. A computer, by contrast, is controlled by a stored program which can be changed at will to meet changing needs, and, most importantly, a minicomputer can be purchased at comparatively low cost. The price of minicomputers has decreased drastically over the last four years and is still going down. It is now technologically possible to fabricate an enormous amount of computer logic in a very small space at a unit price that is extremely low if many units are sold.

The new generation of pocket calculators proves the point. These calculators are not based on a discovery of simpler ways to do arithmetic operations. They are extremely complex, but complex circuits no longer require

Right: Professor Pottle and junior student Ronald Linton, seated, inspect the minicomputer recently acquired by the School of Electrical Engineering for teaching purposes. Now being designed are experiments for a junior-year laboratory course.

much room. At the minicomputer level, the next stage above the calculators, a similar drastic change has taken place. A recent advertisement offers a complete central processing unit with memory and with more computing power than the computers of the mid-1950s for less than $1,000. At this price, we may soon expect to see computers in equipment everywhere. Already appearing are computers on automobiles, controlling everything from fuel mixture and ignition to modulated braking and speed control.

Further uses for the computer in research and instruction cannot be far behind. The revolution in computer size and cost presages a new mode of operation in the laboratory.

Christopher Pottle, associate professor of electrical engineering, has a special interest in the use of computers as research tools. At the present time, his research is centered on the development of minicomputers as laboratory instruments.

He is known also for his work on the application of the digital computer to system and signal theory, especially for the development of a large-scale network analysis program, called CORNAP, that is used in universities and industries around the world. He began work on this program at the Bell Telephone Laboratories during the summer of 1965.

Pottle came to Cornell in 1962 from the University of Illinois, Urbana, where he was a graduate student and subsequently a member of the electrical engineering faculty. He took his undergraduate education at Yale University, earning the baccalaureate degree in electrical engineering in 1953, and then worked for a year with the Sperry Gyroscope Company and served for several years in the U.S. Army before beginning graduate study. His advanced degrees are the M.S. (1958) and the Ph.D. (1962), both in electrical engineering.

He has undertaken concentrated research in the area of computer applications during several leaves from Cornell. In 1966-67 he received a Fulbright grant for lecturing and research at the Universität Erlangen-Nürnberg in Germany, and worked on the use of computer techniques in the design of linear circuits and systems. During a sabbatic leave in 1970-71, he worked with the mathematical science group of the IBM Watson Research Laboratories in the development of computer-aided network design techniques, especially the use of computer graphics.

He is a member of the Institute of Electrical and Electronics Engineers, the Association for Computing Machinery, and several honorary professional societies.

COMMENTARY

Our Computerized Society

How is the computer affecting our lives and what can or should be done about it?

This is the essential question being considered by a Cornell seminar, The Computerized Society, that is offered by the Department of Computer Science and cosponsored by the University's Program on Science, Technology, and Society. It is planned as an interdisciplinary project, an attempt to bring the perspectives of the sciences, social sciences, and humanities to a consideration of the impact of computers on society. The course was introduced two years ago under the direction of Ellis Horowitz, who was on the computer science faculty, and his wife Maryanne, a cultural historian who was a research associate with the Program.

This fall the seminar is led by Visiting Assistant Professor David Lewis, a 1971 Cornell Ph.D. in computer science, who is on leave from the Brown University faculty. In this Commentary *he discusses the purposes of the seminar and expresses his views on the computerized society in an interview with the editor of the* Quarterly.

What do you see as the purpose of the Cornell seminar?

I believe that there is a great need for increased awareness by everyone in our society—computer scientists, technologists and businessmen who use computer techniques, administrators and government personnel, and the general public—about the larger issues involved in the rapid expansion of computerization. The Cornell seminar is one way to promote awareness of the potential problems and to stimulate attempts to do something about them. We expect to emerge with more questions than answers, but the point is to get people thnking about the consequences of widespread computerization, which are more complex than is often realized and involve issues many people have not even realized exist.

What are these "larger issues?"

Beyond the technical feasibility of computerization there are enormously important social, legal, and economic ramifications. The existence of national data banks, for example, poses a threat to civil liberties. Centralization of management and control is encouraged or even mandated by computerization of procedures, and this creates an issue that should be examined apart from technological aspects. In a more general sense, there is a fear that computerization fosters dehumanization of institutions and relationships. A crucial issue, in my view, is the broad question of whether technology is a neutral force, or whether it has inherent properties that may cause socially undesirable effects. Does the technological goal of efficiency carry with it hazards that offset its usefulness? If so, the technology is not neutral. The issue of data banks is an example. The Department of Health, Education, and Welfare recently issued a rather negative report on public and private data banks, indicating that legal regulations should be instituted. An immediate question is what the regulations should consist of. Should the existence of such files be permitted to be kept secret? Should an individual have access to his file and the right to challenge its con-

"A crucial issue (is) whether technology is a neutral force."

tents, and what procedures could be set up to implement such a right? Further questions arise about the capability of the legal system to handle regulatory measures.

Do you feel that at the present time technological leaders, and especially computer scientists, lack sufficient awareness of the dangers of computerization?

Though there is not nearly enough, I think there is a growing awareness in the profession. It is a positive sign, and a sign of the times, since all specialists are becoming increasingly conscious of the social implications of their technologies. Of course, beyond awareness there must be the willingness and ability to do something about recognized problems.

Do computer scientists have special qualifications for coping with the nontechnical implications of their technology?

They have an advantage and a disadvantage. With their technical expertise, they know the nooks and crannies of a computer system and how it works—what is happening and what could happen. On the other hand, they are apt to share the tendency of many technologists to view problems in terms of technological solutions, or let themselves be caught up in the momentum of development. Regardless of their preparedness, computer scientists are called upon to help make broad decisions, and they are sure to become more involved as computerization proceeds. An example is Daniel McCracken, who participated in the national debate on anti-ballistic missile proposals. He opposed implementation on moral grounds and also on the technical grounds that computer systems could not yet cope with the demands. Of course, if the technology were more advanced, the moral issues would remain.

How is the Cornell seminar attempting to deal with the larger issues? Specifically, how does it operate?

The seminar includes lectures by visiting specialists, discussion sessions, and group research projects. For our guest lecturers this fall, we are drawing on people from the University and community who will present varying viewpoints. Philip Bereano, who is a professor in the School of Civil and Environmental Engineering here at the College, and also a lawyer, is interested in legal aspects of the use and control of technology. Douglas Van Houweling, of the Department of Government, will discuss his special concern with the use of computers in politics. Peter Francese, an Ithaca data-processing broker, will talk about uses and misuses of data banks. John Aiken, a psychologist and program coordinator at Cornell's Office of Computer Services, will discuss cognitive models, or computer models of the human mind. Students are conducting group research projects that will constitute an overall study of data processing systems at Cornell, in such areas as student records and administrative information. Involved are such issues as rights to privacy, personnel policies, and decision making (how are decisions made and by whom?). A question that might be considered, for example,

Students linger after the class hour to continue their discussion in The Computerized Society, a seminar led by David Lewis, visiting assistant professor of computer science. Enrolled are about thirty-five students, mostly undergraduates, from many University departments; about two-thirds are engineers from a variety of disciplines. The seminar is cosponsored by the Department of Computer Science and the University's interdisciplinary Program on Science, Technology, and Society.

is what a data processing system would require of administrative structure and what the implications might be. Would institutional organization have to be more rigidly defined? Would more centralization of administration and decision making be required? Would Cornell, which traditionally has been sensitive to the value of human contact, suffer from limitations imposed by this computerization? Of course, questions such as these are related to the larger issues I have been talking about.

What is your opinion about the possibilities for avoiding the problems inherent in data-processing applications?

First of all, such problems are only reflections of profound larger issues, including not only the nature of the technology itself and the way we employ it, but, more importantly, the philosophies and values through which we view technology and the world. Regulations, research, and means of control are inadequate because they rarely address the underlying questions. Neglect of this fact by the public and by technologists themselves, not to mention national leaders, can only result in more attempts to fix things up within the system and a probable confirmation of the worst predictions of technological determinism. In this sense, education and the broadening of people's perspectives are the most effective means of combatting the defects of a technological, computerized society.

REGISTER

The Cornell engineering faculty has been augmented this year by the appointment of regular, visiting, or adjunct professors in eight departments or divisions of the College. The Register *introduces the newcomers and reports on some recent changes in the College administration.*

■ Three assistant professors have been named to the operations research faculty, and two visiting professors have joined the department for the academic year.

Stratton C. Jaquette, who served as a visiting assistant professor during the 1973 spring term, joined the regular faculty this fall. He was graduated from Swarthmore College in 1966 with a major in mathematics, and received the degrees of M.S. in industrial engineering and Ph.D. in operations research from Stanford University in 1968 and 1971, respectively. Before and after completing his graduate studies, he worked for Management Science Associates, Science Applications, Inc., and Decision Studies Group, research and consulting firms in northern California. He is a member of the Institute of Management Sciences and the Operations Research Society of America.

Thomas J. Santner, a recent Ph.D. graduate in mathematical statistics from Purdue University, joined the department in September. His previous teaching experience was at Purdue, where he was an instructor for a semester, and at the University of Dayton, where he served as a teaching assistant after completing work for his B.S. degree in mathematics in 1969. He has also had summer work experience as a programmer for the Allis Chalmers Company. He is a member of the American Statistical Association, the Institute of Mathematical Statistics, and the honorary mathematical society Pi Mu Epsilon.

Michael J. Todd came to Cornell this fall from the University of Ottawa, where he taught operations research and planning for two years. A citizen of England, he received his undergraduate education, with concentration in mathematics, at Cambridge University. He was awarded the Ph.D. degree in administration sciences by Yale University in 1972. He is a member of the honorary society Sigma Xi.

Carlos A. B. Dantas, a specialist in statistics from the University of Sao Paulo, Brazil, is spending the year in the Department of Operations Research conducting research and teaching as a visiting fellow-visiting associate professor. Dantas received his undergraduate education in physics at Sao Paulo and earned his advanced degrees in statistics, the M.S. and the Ph.D., at the University of California at Berkeley. He has been a member of the faculty at Sao Paulo since 1966. He is a member of the Institute of Mathematical Statistics and the Sociedade Brasileira de Matematica.

Richard F. Serfozo, who is an associate professor of industrial engineering and operations research at Syracuse University, is at Cornell this year as a visiting associate professor of operations research. A specialist in applied probability, he holds three degrees in mathematics: the B.S. from Wayne State University (1961), the M.A. from the University of Washington (1965), and the Ph.D. from Northwestern University (1969). Before joining the Syracuse faculty in 1969, Serfozo taught at Northwestern and was employed as a product engineer at the Ford Motor Company and as an operations research analyst at the Boeing Company. He is a member of the American Association for the Advancement of Science, the American Mathematical Society, the Institute of Mathematical Statistics, and the Operations Research Society of America.

■ The Department of Computer Science has four faculty members new to the University this fall.

Lawrence T. Kou, a specialist in the theory of algorithms, was appointed an assistant professor. A native of China, he received his undergraduate education in electrical engineering at National Taiwan University. He came to the United States for his graduate education, earning the M.S. in electrophysics at the Polytechnic Institute of Brooklyn in 1969 and the Ph.D. in electrical engineering and computer sciences at the University of California at Berkeley this past June. He has had engineering experience with Microwave Associates, Inc., and with Sylvania Electric Products, Inc.

Ray Teitelbaum, also appointed assistant professor, is about to receive the Ph.D. degree in computer science from Carnegie-Mellon University. His B.S. degree in mathematics was granted by the Massachusetts Institute of Technology in 1964. Before beginning his graduate studies, Teitelbaum worked in the area of bubble chamber pattern recognition at Columbia University. His field of specialization is programming languages and compilers.

Gideon Ehrlich of the Weizmann Institute of Science in Israel is a visiting assistant professor of computer science this year. He is a specialist in the theory of algorithms. Educated in Israel, he holds B.Sc. degrees in mathematics and physics from Technion and Bar-Ilan University, and M.Sc. and Ph.D. degrees in computer science from Weizmann.

David Lewis has returned to his graduate school as a visiting assistant professor to teach the fall term course in The Computerized Society, a University seminar sponsored by the Department of Computer Science and the Program on Science, Technology, and Society. Lewis received the Ph.D. in computer science from Cornell in 1971, and since then has been a member of the Brown University faculty. He did his undergraduate work at Harvard University, earning the B.A. degree in mathematics in 1966. He is a specialist in artificial intelligence and language processing.

■ In the School of Civil and Environmental Engineering, *James J. Bisogni, Jr.* has been named assistant professor, and *Raymond A. DiPasquale* was appointed adjunct associate professor for the current academic year.

Bisogni began full-time teaching in the School as an instructor during the 1972 fall term; after his receipt of the Cornell Ph.D. in sanitary engineering in January, he became an assistant professor. Bisogni was graduated from Lehigh University in 1968 with the degree of B.S. (with honors) in civil engineering, and holds also the M.S. in sanitary engineering from Cornell. He is a member of the American Society of Civil Engineers, the New York Water Pollution Control Association, the American Water Works Association, Sigma Xi, and Chi Epsilon.

DiPasquale, an Ithaca-based structural consultant, holds the degrees of B.S. in civil engineering from Purdue University (1951), B.Arch. (with highest honors) in architecture from the University of Illinois (1957), and M.S. in architectural engineering from Illinois (1958). Since then he has worked in structural analysis and design and in 1971 organized his own consulting firm. He has had previous academic experience at Illinois and, from 1961 to 1969, at the Cornell College of Architecture. He is a registered architect in New York and Illinois, a fellow of the American Society of Civil Engineers, and a member of the American Concrete Institute, the Prestressed Concrete Institute, the International Society for Bridge and Structural Engineering, the International Association for Shell Structures, the Construction Specifications Institute, and the honorary societies Tau Beta Pi, Sigma Xi, and Sigma Tau.

■ In the Department of Agricultural Engineering, *William J. Jewell* has been appointed associate professor and *Lynne H. Irwin* assistant professor.

Jewell came to Cornell from the University of Vermont, where he had been an associate professor of civil engineering since 1969. Previously he had taught at the University of Texas and had conducted research in water pollution as a postdoctoral fellow at the University of London. He received the degree of B.S. in civil engineering from the University of Maine (1963), the M.E. in sanitary engineering from Manhattan College (1964), and the Ph.D. in environmental engineering from Stanford University (1968). His special interests are in the areas of biological and chemical mechanisms involved in pollution control, effects of natural and man-made pollution on water bodies, and nitrogen control systems. He is a member of the Association of Environmental Engineering Professors, the American Society of Civil Engineers, the American Water Works Association, the Water Pollution Control Federation, and the National Wildlife Federation.

Irwin, whose undergraduate and graduate education is in civil engineering, has special interests in highway engineering, rural road problems, and community development. He received the B.S. and M.S. degrees from the University of California at Berkeley in 1965 and 1966, respectively, and the Ph.D. from Texas Agricultural and Mechanical University in 1973. His experience includes three years as an assistant professor of civil engineering at California State University at Chico, two years as a research associate at Texas A&M University, and several months on the staff of a consulting engineering laboratory. He is a registered professional engineer and a member of the American Society of Civil Engineers, the American Society for Engineering Education, the American Society for Testing and Materials, the American Road Builders Association, and the Highway Research Board.

■ Two assistant professors, *John L. Cisne* and *Daniel E. Karig*, have joined the Department of Geological Sciences.

Cisne, a specialist in paleontology, recently completed Ph.D. studies in geophysical sciences at the University of Chicago. He received the B.S. degree in geology and geophysics from Yale University in 1969. He has had geological, marine biological, and oceanographic field experience, including work at the Scripps Institution of Oceanography, and the Pacific Marine Station. His professional affiliations are with the American Association for the Advancement of Science, the Ecological Society of America, the Palaeontological Association, and the Paleontological Society, and he is a member of Sigma Xi.

Karig, a marine geologist and geophysicist, began his professional studies at the Colorado School of Mines, which awarded him the degrees of Geol.Eng. and M.Sc. He received the Ph.D. degree in earth science in 1970 from the University of California at San Diego, where he studied at the Scripps Institution of Oceanography. Karig has had field experience with the U.S. Corps of Engineers, with the Los Angeles County Flood Control District, and as an independent geologist in this country and in New Zealand. Since completing his graduate studies, he has conducted postdoctoral research at the University of California. This past summer he joined a cruise off the Philippines to study the formation of island arcs, and he plans to continue research at sea next summer in Indonesia. He is a member of the Geological Society of America and the American Geophysical Union.

■ *Robert A. Buhrman,* a specialist in solid-state and low-temperature physics, joined the applied and engineering physics faculty in January as an assistant professor, after completing his Ph.D. studies at Cornell. Buhrman studied at Johns Hopkins University for the B.E.S. degree in engineering physics, awarded in 1967, and served there as a research assistant in space science and as a teaching assistant in computer science. He has also had summer research experience with the U.S. Army Materiel Command. He is a member of the American Physical Society and Tau Beta Pi.

■ *Robert J. Thomas,* a specialist in the area of control theory with application to power systems, has joined the School of Electrical Engineering faculty as an assistant professor. He holds three degrees from Wayne State University: the B.S.E.E., awarded in 1968, the M.S.E.E., 1970, and the Ph.D., 1973. His experience includes summer work in physics research at the Ford Motor Company, as well as graduate research and teaching at Wayne State. He is a member of the Institute of Electrical and Electronics Engineers, Sigma Xi, Eta Kappa Nu, and Tau Beta Pi.

■ An assistant professor in the Division of Basic Studies this year is *Noshir A. Langrana*, who completed his Ph.D. degree work in mechanical engineering at Cornell this summer. He is a native of India and took his undergraduate education at the University of Bombay, which awarded him the B.E. degree in mechanical engineering in 1968. He is a member of the American Society of Mechanical Engineers.

Several changes in the administrative staff were implemented in the current academic year. These involved the Division of Basic Studies, two Schools, the admissions and student personnel offices, and the general administrative staff.

■ *Malcolm S. Burton,* associate dean with responsibility in the area of undergraduate education, assumed also the duties of director of the Division of Basic Studies this year. A professor of materials science and engineering, he has been a member of the Cornell faculty since 1946. He holds the B.S. degree in mechanical engineering from Worcester Polytechnic Institute and the M.S. in metallurgy from the Massachusetts Institute of Technology, where he began his teaching career. His previous administrative functions at Cornell include service as assistant director and acting director of the Department of Materials Science and Engineering. His research interests have centered on the application of new developments in materials science, and he has spent two sabbatic leaves as a research metallurgist with industrial and developmental laboratories. He is a member of the American Society for Metals, the American Society for Engineering Education, the American Institute of Mining, Metallurgical and Petroleum Engineers, and Sigma Xi.

■ The new assistant director of the Division of Basic Studies is Assistant Professor *George D. Meixel,* who has worked with Dean Burton in developing the academic program and organization of the Division for the past year. Meixel earned two degrees in engineering at Cornell, the B.S. in engineering physics, awarded in 1967, and the Ph.D. in aerospace engineering, conferred this past summer. He is a member of the honorary society Tau Beta Pi.

■ *George B. Lyon* was named assistant director of the School of Civil and Environmental Engineering in January 1973. An associate professor, he also serves as secretary of the School and College faculties. He holds the degrees of B.S.C.E. from the University of Illinois (1940) and the M.S. in hydraulics and fluid mechanics from the State University of Iowa (1942), and he is registered as a professional engineer in Illinois. During his twenty-six years on the Cornell faculty, Lyon has served also as an industrial consultant in hydrology and surveying. In 1967-68 he spent a sabbatic leave with the U.S. Coast and Geodetic Survey, studying relative movement within the earth's crust. He has served as a consultant to the New York State Association of Professional Land Surveyors, which elected him to honorary membership last year. He is a member also of Sigma Xi and Chi Epsilon.

■ *Julian C. Smith*, professor of chemical engineering and a member of the faculty since 1946, was named associate director of the School of Chemical Engineering. He is also chairman of the College's Graduate Programs Committee and has served as director of continuing education. Smith, a specialist in heat transfer, the flow of granular solids, and mixing phenomena, holds the Cornell degrees of B.Chem. (1941) and Chem.E. (1942). His early professional experience included four years in research engineering with E. I. duPont de Nemours and Company; at the present time he is a consultant for duPont and for the Atlantic Richfield Hanford Company. He is a registered engineer in New York State and is a member of the American Chemical Society, the American Institute of Chemical Engineers, and the American Society for Engineering Education.

■ *Donald G. Dickason*, who served as director of engineering admissions for seven years, was named assistant dean and director of student personnel. His association with the University goes back to his undergraduate years. He studied at Cornell for the B.A. degree in economics (1953) and for the M.Ed. degree in guidance and personnel (1968); and before joining the College of Engineering staff, he served as director of admissions relations for the University. He is currently president of the National Association of College Admissions Counselors, a guidance coordinator for the Engineers' Council for Professional Development, and a member of the American Society for Engineering Education.

■ Promoted from associate director to director of engineering admissions was *David C. Johnson,* who has been on the staff since 1969. He is a graduate of DePauw University and a candidate for the M.A. degree in education at Cornell. Before coming to Cornell, he served as assistant director of admissions at Ohio Wesleyan University. He is a member of the National Association of College Admissions Counselors, the American Personnel and Guidance Association, the American Association of College Registrars and Admissions Officers, and the American Association of Junior and Community Colleges.

■ The College's new director of engineering minority programs is *LaVoy Spooner,* a Cornell engineering graduate. He was awarded the B.S. degree in 1971 and the M.Eng. (Chemical) degree in 1972. During his senior year, he served as a student adviser and tutor in the Engineering Advising and Counseling Center. After completing his studies, he worked in the field of product development for the Proctor and Gamble Company.

■ *Donald F. Berth*, who served the College administrative staff for ten years beginning in 1962, returned this year as director of engineering projects. His previous work at the College was in the areas of public relations, publications, and student academic services. He had subsequent experience in institutional development at Hampshire College, and is currently a consultant to several educational institutions. He holds B.S.Ch.E. and M.S.Ch.E. degrees from Worcester Polytechnic Institute, and is pursuing doctoral studies in higher education at Cornell. He is a member of the American Chemical Society, the American Society for Engineering Education, the American Association for the Advancement of Science, and the Society for the History of Technology.

FACULTY PUBLICATIONS

The following publications and conference papers by faculty members and graduate students of the Cornell College of Engineering were published or presented during the period February through April 1973. Earlier publications inadvertently omitted from previous listings are included here with the date in parentheses. The names of Cornell personnel are in italics.

■ AGRICULTURAL ENGINEERING

Gallaway, B. M., *Irwin, L. H.*, and Epps, J. A. 1973. *An appraisal of methods for the structural improvement of the Big Brown haul road.* Report for the Industrial Generating Company, Dallas, Texas.

Irwin, L. H., and Dunlap, W. A. 1973. *Properties of composite materials for use in expedient paving systems.* Report for Air Force Weapons Laboratory, Air Force Systems Command, Kirtland Air Force Base, New Mexico.

Loehr, R. C. 1973. Animal Wastes—Magnitude of the Problem and Potential Solutions. Phosphate Removal from Duck Production Wastewaters. Papers read at Annual Meeting of Waste Water Equipment Manufacturers Association, 16 March 1973, in Chicago, Illinois.

Loehr, R. C., *Klausner, S. D.*, and *Scott, T. W.* 1973. Disposal of Agricultural Wastes on Land. Paper read at 4th Environmental Engineering Conference, 16 February 1973, at the University of Montana, in Bozeman.

Lorenzen, R. T., and *Guest, R. W.* 1973. Design of milking center waste management systems. In *Dairy housing conference papers*, pp. 349–58. St. Joseph, Michigan: American Society of Agricultural Engineers.

Millier, W. F., and Brown, G. K. 1973. *Citrus fruit appearance, weight loss, and internal condition inferences for mechanical harvesting.* Publication ARS-w-5 of the Agricultural Research Service, U.S. Department of Agriculture, Western Region.

Pellerin, R. A., *Millier, W. F.*, *Rehkugler, G. E.*, *Throop, J. A.*, and *Bradley, R. B.* 1973. A multi-level harvester for fresh market fruit. In *Proceedings of the 118th annual meeting of the New York State Horticultural Society*, ed. H. E. Johnson, vol. 118, pp. 49–59. Rochester, New York: New York State Horticultural Society.

Rehkugler, G. E. 1973. Characterizing the shape of a hen's egg. *Poultry Science* 52: 127–38.

———. 1973. Technique for routine stress analysis of the hen's egg. *Transactions of the American Society of Agricultural Engineers* 15(6):1086–90.

Shepardson, E. S., *Pollock, J. G.*, and *Rehkugler, G. E.* 1973. Mechanical harvester for New York lettuce. *New York's Food and Life Sciences Quarterly* 6(2):13–15.

■ APPLIED PHYSICS

Buhrman, R. A., and *Halperin, W. P.* 1973. Fluctuation diamagnetism in a "zero dimensional" superconductor. *Physical Review Letters* 30:692–5.

Dolan, G. J., and *Silcox, J.* 1973. Critical thicknesses in superconducting thin films. *Physical Review Letters* 30:603.

Halperin, W. P., *Buhrman, R. A.*, and *Richardson, R. C.* 1973. A Study of the β Phase Transition in Liquid ^{3}He. Paper read at Meeting of the American Physical Society, 23–26 April 1973, in Washington, D.C.

Kim, K., and *Nelkin, M.* 1973. Dynamic structure factor of a disordered harmonic solid. *Physical Review B* 7(6):2762–71.

■ CHEMICAL ENGINEERING

Himmelstein, K. J., and *Bischoff, K. B.* 1973. Mathematical representations of cancer chemotherapy effects. *Journal of Pharmacokinetics and Biopharmaceutics* 1:51–68.

———. 1973. Models of ARA-C chemotherapy of L-1210 leukemia in mice. *Journal of Pharmacokinetics and Biopharmaceutics* 1:69–81.

Finn, R. K., and *Tannahill, A. L.* 1973. *Process for the bio-oxidation of nitrogen deficient waste materials.* U.S. Patent 3,721,-622.

Kiran, E., and *Rodriguez, F.* 1973. Effects of gamma radiation on aqueous polymer solutions—a comparative study. *Journal of Macromolecular Science—Physics* B7:209–24.

Smith, J. C. 1973. Applications of Drying Technology. Paper read at Luwa New Products Seminar, 4–5 April 1973, in Charlotte, North Carolina.

■ CIVIL AND ENVIRONMENTAL ENGINEERING

Atan, Y., and *Slate, F. O.* 1973. Structural lightweight concrete under biaxial compression. *Journal of the American Concrete Institute* 70:182–6.

Brutsaert, W. 1973. *Heat and water vapor exchange between water surface and atmosphere.* Office of Research and Monitoring, U.S. Environmental Protection Agency, report EPA-R2-73-259.

———. 1973. Water availability as it relates to droughts. In *Proceedings of the 2nd international hydrology symposium: Floods and droughts*, pp. 574–82. Fort Collins: Colorado State University.

Chowdhury, A. H., White, R. N., and *Scott, N. R.* 1973. Multi-Story Reinforced Concrete Frame Models. Paper read at ASCE National Structural Engineering Conference, 9–13 April 1973, in San Francisco, California.

Gallagher, R. H., and Zienkiewicz, O. C., eds. 1973. *Optimum structural design.* London: J. Wiley.

Haith, D. A. 1973. A Model for Land Disposal of Nitrogenous Wastes. Paper read at 74th National Meeting of the American Institute of Chemical Engineers, 11–15 March 1973, in New Orleans.

Meyburg, A. H. (1973). A Note on the Problem of Aggregation with Special Emphasis on its Implications on Disaggregate, Behavioral Travel Demand Models. Paper read at Annual Meeting of the Highway Research Board, 22–26 January 1973, in Washington, D.C.

Nilson, A. H. 1973. Analysis of Light Gage Steel Shear Diaphragms. Paper read at National Structural Engineering Conference of the American Society of Civil Engineers, 9–13 April 1973, in San Francisco, California.

Nilson, A. H., and Ammar, A. R. 1973. *Analysis of light gage steel shear diaphragms, part II.* Research report no. 351 of the Department of Structural Engineering for the American Iron and Steel Institute.

Philipson, W. R., Arnold, R. W., and *Sangrey, D. A.* 1973. Engineering values from soil taxonomy. *Highway Research Record* 426:39–49.

Shoemaker, C. 1973. Optimization of agricultural pest management I: Biological and mathematical background. *Mathematical Biosciences* 16:143–75.

Szilard, R., *Fisher, G. P.*, and Zia, P., eds. 1973. *Analysis of structural systems for torsion* (special publication 35). Detroit, Michigan: American Concrete Institute.

■ COMPUTER SCIENCE

Conway, R. W., and Wilcox, T. R. 1973. Design and implementation of a diagnostic compiler for PL/I. *Communications of the ACM* 16(3):169–79.

Hartmanis, J., and *Hunt, H. B.* 1973. The LBA Problem and its Importance in the Theory of Computing. Paper read at Symposium on the Complexity of Real Computational Processes, 18–19 April 1973, in New York, New York.

Hartmanis, J., and Walter, H. 1973. Group theoretic characterization of linear permutation automata. *Journal of Computer and System Sciences* 7(2):168–88.

Salton, G. 1973. Automatic processing of foreign affairs queries. *Information Storage and Retrieval* 9(3):165–80.

———. 1973. Introducing Programming at Cornell. *SIGSCE Bulletin* 5(7):18–20.

———. 1973. Recent studies in automatic text analysis and information retrieval. *Journal of the ACM* 20(2):258–78.

■ ELECTRICAL ENGINEERING

Ankrum, P. D. 1973. *Semiconductor electronics*, Spanish edition. Englewood Cliffs, New Jersey: Prentice-Hall International.

Berger, T. 1973. Rate distortion theory: a tutorial and survey. In *Proceedings of 5th annual southeastern symposium on system theory*, pp. 73–9. Raleigh-Durham: North Carolina State University and Duke University.

Bolgiano, R., Jr. 1973. Exploration of the Clear Troposphere by Microwave Radio. Paper read at Karl Brocks Memorial Colloquium, 22 March 1973, at the University of Hamburg, Germany.

Brice, N. M., and *Williams, G.* 1973. A Monte-Carlo study of energetic electron diffusion in Jovian magnetosphere. *EOS (Transactions, American Geophysical Union)* 54(4): 446.

Carlin, H. J. 1973. Coupled Line Models for Dispersion. Invited paper read at Harvard University Division of Engineering and Applied Physics, 27 April 1973, in Cambridge, Massachusetts.

———. (1973). Coupled Lines and Dispersive Systems. Invited paper read at Rice University, 30 January 1973, in Houston, Texas.

———. 1973. Coupled Lines for Dielectric Loaded Guide and Stripline. Invited paper read at Bell Telephone Laboratories, 6 April 1973, in Andover, Massachusetts.

———. 1973. Digital Filters and Transmission Lines. Invited paper read at Lincoln Laboratories, Massachusetts Institute of Technology, 14 February 1973, in Cambridge, Massachusetts.

———. (1972). Dispersive Coupled Lines and Waveguide Modeling. Invited paper read at Massachusetts Institute of Technology, 6 November 1972, in Cambridge, Massachusetts.

———. 1973. Network Methods for Distributed Structures. Invited paper read at IEEE International Circuits Conference, 10 April 1973, in Toronto, Ontario, Canada.

———. 1973. Network methods for distributed structures—a simplified circuit model for microstrip. In *Proceedings of the 1973 international symposium on circuit theory*, IEEE cat. no. 73CHO 765-8CT, pp. 25–7. New York: IEEE Circuits and Systems Society.

———. (1972). Network Theory and Applications of Coupled Lines. Invited paper read at McMaster University, 6 December 1972, in Hamilton, Ontario, Canada.

———. 1973. Network Theory is Dead, Long Live Network Theory. Invited paper read at IEEE Boston Section Meeting, 7 March 1973, in Boston, Massachusetts.

———. (1973). Principles of Transmission Line Networks. Invited paper read at Sir George Williams University, 23–24 January 1973, in Montreal, Ontario, Canada.

Carlin, H. J., and Noble, D. 1973. Circuit properties of coupled dispersive lines with applications to waveguide modeling. In *Network and signal theory*, PPL conference publication 12 (Proceedings of the NATO Advanced Study Institute on Network and Signal Theory), ed. J. K. Skwirzynski and J. Scanlan, pp. 258–69. London: Peter Peregrinus Ltd.

Carmel, Y., and *Nation, J. A.* 1973. Resonant Interaction of an Intense Relativistic Electron Beam with a Periodic Rippled Magnetic Field. Paper read at Spring Meeting of the American Physical Society, 23–26 April 1973, in Washington, D.C.

Dawson, R. H., and *Frey, J.* 1973. Enhanced Performance of GaAs Field Effect Transistors. Paper read at IEEE Workshop on Compound Semiconductor Microwave Devices, 12–13 February 1973, in New York, New York.

Eastman, L. F. 1973. Design and Experi-

ments on High Average and C. W. Power LSA Oscillators. Paper read at IEEE Workshop on Compound Semiconductor Microwave Devices, 12–13 February 1973, in New York, New York.

———. 1973. *Gallium arsenide microwave bulk and transit time devices.* Dedham, Massachusetts: Artech House.

Eastman, L. F., Dalman, G. C., Lee, C. A., and *Frey, J.* 1973. *Advanced concepts of microwave generation and control in solids.* Report for Rome Air Development Center.

Gray, R. W., and *Farley, D. T.* 1973. Theory of incoherent-scatter measurements using compressed pulses. *Radio Science* 8:123–31.

Johns, T. W., and *Nation, J. A.* 1973. A resistive electrode, high energy, transverse laser discharge. *Review of Scientific Instruments* 44(2):169–71.

McDonough, T. R., and *Brice, N. M.* 1973. A new kind of ring around Saturn? *Nature* 242(5399):513.

———. 1973. A new kind of ring around Saturn. *EOS (Transactions, American Geophysical Union)* 54(7):704.

Manheimer, W., and *Ott, E.* 1973. Parametric Instabilities Due to the Coupling of High and Low Frequency Modes in a Plasma. Paper read at Spring Meeting of the American Physical Society, 23–26 April 1973, in Washington, D.C.

Mondelli, A., and *Ott, E.* 1973. Toroidal Plasma Equilibria with a Relativistic Component of Circulating Electrons. Paper read at Sherwood Theory Meeting, 12–13 March 1973, in Austin, Texas.

Ott, E., and Manheimer, W. 1973. Electromagnetic Velocity Space Instability of an Unneutralized Intense Relativistic Electron Beam. Paper read at Spring Meeting of the American Physical Society, 23–26 April 1973, in Washington, D.C.

Ott, E., McBride, J., and Orens, J. H. 1973. Low-frequency parametric instabilities of magnetized plasmas with two ion species. *Physics of Fluids* 16(2):270–6.

Read, M., and *Nation, J. A.* 1973. Limiting Currents in Un-neutralized Electron Beams. Paper read at Spring Meeting of the American Physical Society, 23–26 April 1973, in Washington, D.C.

Szentirmai, G. 1973. Synthesis of multiple-feedback active filters. *Bell System Technical Journal* 52:527–55.

Tang, C. L. 1973. Source Considerations in Integrated Circuits. Lecture given in short course on Integrated Optics, 26–30 March 1973, at the University of California at Santa Barbara.

Thorp, J. S., and *Lee, S. Y.* 1973. A Geometric Approach to Minimax Control for Discrete Time Systems. Paper read at 16th Midwest Symposium on Circuit Theory, 12–13 April 1973, at Waterloo, Ontario, Canada.

■ GEOLOGICAL SCIENCES

Barazangi, M., Isacks, B., Oliver, J., Dubois, J., and Pascal, G. Descent of lithosphere beneath New Hebrides, Tonga-Fiji, and New Zealand: Evidence for detached slabs. *Nature* 242:98–101.

Bird, J. M. 1973. Evolution of Continental Margins. Origin of Mountain Belts. Papers read at ARCO Symposium on Continental Drift, 22–23 February 1973, in Dallas, Texas.

———. 1973. Evolution of Western Appalachian Margin. Generalized Plate Margin Relations. Papers read at Permian Basin Graduate Center Symposium on Continental Drift, 26–28 April 1973, at Midland, Texas.

Oliver, J. E., Huestis, S., and Molnar, P. 1973. Regional Sn velocities and shear velocity in the upper mantle. *Bulletin of the Seismological Society of America* 63:469–75.

Wells, J. W. 1973. *Guynia annulata* (scleractinia) in Jamaica. *Bulletin of Marine Science* 23:59–63.

———. 1973. New and old scleractinian corals from Jamaica. *Bulletin of Marine Science* 23:16–55.

Wells, J. W., and Lang, J. C. 1973. Systematic list of Jamaican shallow-water scleractinia. *Bulletin of Marine Science* 23:55–8.

■ MATERIALS SCIENCE AND ENGINEERING

Berger, A. S., Seidman, D. N., and *Balluffi, R. W.* 1973. A quantitative study of vacancy defects in quenched platinum by field ion microscopy and electrical resistivity measurements: I. Experimental results. II. Analysis and interpretation. *Acta Metallurigica* 21:123–35 and 137–47.

Blakely, J. M. 1973. Space Charge at Silver Halide Crystal Surfaces. Paper read at Physical Electronics Conference, 26–28 March 1973, at the University of California, Berkeley.

Ching, L.-S., *Day, J. P.,* and *Ruoff, A. L.* 1973. Pressure and temperature dependence of the elastic constants of LiBr and LiCl. *Journal of Applied Physics* 44:1017–20.

Day, J. P., Ho, P. S., and *Ruoff, A. L.* 1973. A cw interferometer for elastic constant measurements. *Review of Scientific Instruments* 44(4):478–81.

Grant, A. J., Weiser, K., Gambino, R. J., and *Ast, D. G.* 1973. High field conductivity in amorphous As_xTe_{1-x} films. *Bulletin of the American Physical Society* 18:362.

Kramer, E. J. (1972). Scaling laws for flux pinning in hard superconductors. *Journal of Applied Physics* 44:1360–70.

———. 1973. Propagation of Shear Bands in Polystyrene. Paper read at Conference on Yield, Deformation and Fracture of Polymers, 26–30 March 1973, in Cambridge, England.

Larsen, R. E., and *Ruoff, A. L.* 1973. Pressure-induced elasticity changes in V_3Si. *Journal of Applied Physics* 44:1021–5.

Penney, T., Grant, A. J., Gambino, R. J., Moustakas, T., and *Ast, D. G.* 1973. Hall mobility in the amorphous As-Te system. *Bulletin of the American Physical Society* 18:362.

Pétroff, P., and *Seidman, D. N.* 1973. An *in-situ* field ion microscope study of irradiated platinum—I. Stage I recovery behavior. *Acta Metallurgica* 21:323–34.

Scala, E. 1973. *Composite materials for combined functions.* New York: Hayden Book Company.

Seidman, D. N. 1973. The direct observation of point defects in irradiated or quenched metals by quantitative field ion microscopy. *Journal of Physics F: Metal Physics* 3:393–421.

Shelton, J. C., and *Blakely, J. M.* 1973. Segregation to a Ni(111) Surface: A Surface Phase Transition. Paper read at Physical Electronics Conference, 26–28 March 1973, at the University of California, Berkeley.

Thomas, E. L., and *Ast, D. E.* 1973. Operation of a channeltron image intensifier in the electron microscope. *Journal of Physics E* 6:273–6.

Thomas, E. L., and *Sass, S. L.* 1973. On the orthorhombic to hexagonal phase transformation in polyethylene single crystals. *Die Makromolekulare Chemie* 164:333–41.

■ MECHANICAL AND AEROSPACE ENGINEERING

Bauer, S. H., Lederman, D. M., *Resler, E. L., Jr.*, and Fisher, E. R. 1973. The homogeneous gas phase H_2–D_2 metathesis at room temperature: Reaction induced by specific vibrational excitation. *International Journal of Chemical Kinetics* V:93–106.

Cusano, C., and *Phelan, R. M.* 1973. Experimental investigation of porous bronze bearings. *Journal of Lubrication Technology* 95 (series F) (2):173–80.

Gebhart, B. 1973. Natural convection flows and stability. *Advances in Heat Transfer* 9:273–48.

George, A. R. 1973. Interaction of sound and sonic booms with turbulence. In *Proceedings of the interagency symposium on university research in transportation noise*, vol. 1, pp. 288a–288h. Stanford: Stanford University.

Gouldin, F. C. 1973. Controlling emission from gas-turbines—the importance of chemical kinetics and turbulent mixing. *Combustion Science and Technology* 7(1):33.

Homicz, G. F., and *George, A. R.* 1973. Broad-band radiation from rotors in turbulent flow. In *Proceedings of the interagency symposium on university research in transportation noise*, vol. 1, pp. 194–210. Stanford: Stanford University.

Leibovich, S. (1972). *Feasibility of electric and electromagnetic separation of oil and water.* Report to Esso Production Research Company.

———. 1973. *A natural limit for offshore oil skimming and containment operations.* Report to Esso Production Research Company.

Mollendorf, J. C., and *Gebhart, B.* 1973. Thermal buoyancy in round laminar vertical jets. *International Journal of Heat and Mass Transfer* 16:735–45.

Osborne, C. 1973. Unsteady thin-airfoil theory for subsonic flow. *AIAA Journal* 11(2):205–9.

Sachdev, P. L. 1973. Some analytic methods in the theory of blast-wave propagation. *Journal of Mathematical and Physical Sciences* VII(1):79–92.

Sachdev, P. L., and *Seebass, R.* 1973. Propagation of spherical and cylindrical N-waves. *Journal of Fluid Mechanics* 58 (part 1): 197–205.

Shen, S. F., and *Chan, S. T. K.* (1973). Variational Approach to the Lifting Surface Problem. Paper no. 73–87, read at AIAA 11th Aerospace Sciences Meeting, 10–12 January 1973, in Washington, D.C.

Tobler, W., and *Krauter, A.* (1972). Tractor-semitrailer dynamics: Design of the fifth wheel. *Vehicle System Dynamics* 1(2): 123–60.

■ OPERATIONS RESEARCH

Garfinkel, R. S., and *Nemhauser, G. L.* 1973. A survey of integer programming emphasizing computation and relations among models. In *Mathematical programming*, ed. T. C. Hu and S. M. Robinson, pp. 77–155. New York: Academic Press.

■ THEORETICAL AND APPLIED MECHANICS

Dunn, J. C. 1973. On recursive averaging processes and Hilbert space extensions of the contraction mapping principle. *Journal of the Franklin Institute* 295(2):117–33.

Rand, R., and *Podgorski, W.* 1973. Geometrical dynamics: A new approach to periodic orbits around L4. *Celestial Mechanics* 6: 416–20.

ENGINEERING: Cornell Quarterly

Editor: Gladys J. McConkey

Photographer: David Ruether

Graphic Artist: Barbara Bernstein

Design Services: Lynda Thompson, Office of University Publications

Lithographers: General Offset Printing Co., Springfield, Massachusetts

Typography: Dix Typesetting Co. Inc., Syracuse, New York

Please address any correspondence, including notification of change of address, to ENGINEERING: Cornell Quarterly, Carpenter Hall, Ithaca, New York 14850.