CHARLES BABBAGE INSTITUTE
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THE CENTER FOR THE HISTORY OF INFORMATION PROCESSING

Symposium Honors 40th Anniversary of the Founding of Engineering Research Associates, Inc.

All of Minnesota's computing and computer-related industry stems from Engineering Research Associates, Inc. (ERA), a company founded 40 years ago in St. Paul. ERA contributed substantially to the overall technical development of computing and, though it is no longer in business, ERA lives on through the many computing industry enterprises it spawned and influenced.

To honor the fortieth anniversary of ERA's founding, the Charles Babbage Institute of the University of Minnesota's Institute of Technology organized a symposium in September, 1986, with the help and support of Sperry Corporation (now part of Unisys). Academic and industry leaders from all over the country, including the people who made up ERA's original staff, were invited to participate.

This symposium occurred at an interesting juncture in computing developments. During the last 40 years, the efforts of the field's professionals (who defined the principal issues in computing as speed, storage capacity, reliability, and applications) and of the entrepreneurs (who found innovative ways to market the new products) created the computer revolution—they changed the world. Now, the growing sophistication and pervasiveness of today's computers together with formulation of the philosophy of artificial intelligence puts the industry at the threshold of yet another revolution.

Symposium participants used the twin perspectives of past and present to analyze how computing has reached its present state, and what that state is. The

continued on page 2. . .

Former competitors James W. Birkenstock of IBM and William C. Norris of CDC meet again at CBI symposium.

CBI Begins Study of The History of Software

Historians and computer professionals have only recently begun to investigate the history of software; these first studies have focused on narrow issues, concentrating primarily on one legal, economic, business, or technical aspect. What is needed is a comprehensive historical examination that balances business and economic factors against technical factors. However, not enough source material or chronological accounts of key events are yet available to make it possible to write such integrated, analytic history.

As a first step toward this kind of study CBI has recently begun to analyze significant events, companies, individuals, and historical sources. The selective chronology below is a sample of our preliminary findings. CBI undertook this effort in preparation for a study of the software industry. This study will consider origins of the independent software industry; economic infrastructure of that industry; relations to user organizations; relations to hardware and systems manufacturers; economic and legal issues concerning the protection of software; and attempts to develop engineering and management techniques for software development. In a later study this industry history will be integrated with the technical developments to present an analytic history of software.

Selective Chronology of Software*

1945 EDVAC Report introduces stored program concept

1945 programming language Plankalkul developed by Konrad Zuse

1946 Herman H. Goldstine and John von Neumann introduce method of flow diagrams

continued on page 8. . .

Edwin D. Decker (left), former president of Sperry Defense Products Group, and Kenneth H. Keller (right), president of the University of Minnesota, welcomed over 200 people to the symposium.

presentations revealed that, despite computing's obvious new dimensions as both field and industry, categories of technological change in computing are essentially the same as in 1950. The technological development path still extends along the original curve laid down in the 1940s, without discontinuities. That path originates with what is referred to as technology push, in which systems are built, then applications for them are sought. Technically, people are still occupied with technology push, with special-purpose architectures, and with the quest for reliability.

As the presentations continued, it also became apparent that new social issues of global significance are beginning to emerge that will require development and implementation of wise policy. These issues and the rapid growth potential of computing raise important questions about the future, which were addressed in discussions of what we can expect in the way of changes. The speakers were unanimous in suggesting that the major impact of computers is yet to be achieved.

In the Beginning

A number of speakers described having begun in computing using ERA 1103 machines in the 1950s. But ERA's legacy, as participant John Rollwagen, chairman and chief executive officer of Cray Research, Inc., was especially emphatic in pointing out, goes far beyond machines: "The impact [of ERA] has just been phenomenal. I think it still has not really sunk home how much this has meant to the local community, in particular to Minnesota, as well as to the computer community generally in the country." Rollwagen pointed out that, over the years, some 200 companies have either spun directly out of ERA and its descendants, or begun in business because of ERA results. These companies form the core of the Minnesota high-technology community's strengths.

That strength has grown at an astonishing rate. From ERA's small nucleus of employees in 1946, computer and computer-related business employment grew to 19,000 by 1967, and stood at 40,000 by 1982. "More impressive than that, though," said Rollwagen, "is that in 1967, those 19,000 people produced $414 million of value-added revenue. By 1982 that number was almost $2.4 billion, or 16 percent of our total economic (manufacturing) activity."

John A. Rollwagen

At the start, however, no one could have been thinking in such terms. William Norris, founder of both ERA and Control Data Corporation, remembered the fledgling company as a fragile concept and enterprise; it was not at all certain that ERA would even survive, much less exert such profound influence on people and the economy. He described three significant problems faced by the company in its early years. At first, of course, financing did not come easily. 200,000 shares were sold for ten cents each, half to a technical group of founders, and half to a financial group. The financial group provided a $200,000 line of credit, which, with two contracts from the U.S. Navy, proved to be sufficient for a while.

Norris said ERA's second and third problems were staffing and building its business, and "on balance, both I believe were accomplished extraordinarily well." He remarked that the entrepreneurialism of companies like ERA was a major factor in "helping to build the momentum which propelled the United States into world dominance of the computer industry."

The Developing Industry

Other speakers, discussing the aspects of technical development and industry growth that helped the United States open this world market, concentrated on six areas that can be divided into technical and social questions. Not surprisingly, the technical areas were:

Architecture. The concept of describing computer systems as a computer space (classified according to a system's function, performance, and structure) and

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trends in computer system architecture, especially supercomputers.

Software. Growth in the magnitude and complexity of software required today and some needed changes to enhance its development.

Microminiaturization. The physical size limits of electronic components and the socio-economic implications of reaching these limits.

The social questions separate neatly into the following categories:

Cooperation. Academia, industries, and government sharing resources in the promotion of new developments.

Policy agendas. How changes have been stimulated by new computer system developments and uses.

Personal effects. The ways the computer revolution has affected individuals.

Architecture.

Computers top the list of devices resulting from rapid technological development, but as techniques of design and application developed, a new range of

Daniel P. Siewiorek

needs and opportunities emerged with equal speed. Many of the new techniques first appeared in supercomputers or their equivalent in any given period, then filtered down into the designs of lower-capacity machines. In fact, Daniel Siewiorek of Carnegie-Mellon University said, "if I want to find out what's happening in minicomputers now, I look to see what happened in supercomputers five years ago." A review of the last 40 years of architectural design demonstrated the industry's position relative to the past, and offered several hypotheses about

Donald L. Bitzer, director of the Computer-Based Education Research Laboratory and professor of electrical engineering at the University of Illinois at Champaign-Urbana, spoke on "The Changing World of Research and Learning."

what will guide future system designs.

- The quest for absolute reliability is as important today as it was to ERA's early associates, and will continue. Computer systems are becoming more deeply embedded in other technological systems, and as they do so they are required to be increasingly fault-free. New designs will have to achieve something like a full order of magnitude in reliability improvement.
- Users will continue to demand more performance. A number of special-purpose architectures are likely to address this demand. For example, development of knowledge-based systems with architectures that execute symbolic knowledge will become more common.

Lloyd Thorndyke

- Numerous challenges exist in the parallel processing technology area. But as Lloyd Thorndyke, president of ETA Systems, Inc., pointed out, one of these challenges is "the recognition that not all problems are amenable to parallel solutions, because of inherent serial, sequential characteristics." New systems will have to be capable of both kinds of processing, as needed.

Software

All these projections rest upon software development, since aspirations and expectations for computer applications are partly bounded by the limits of software engineering. Mary Shaw, also of Carnegie-Mellon, distinguished two trends that emerged from the 1960s: programming-in-the-small, and in-the-large. Programming-in-the-small involves

Mary Shaw

building single modules to implement a single program. By the mid-1970s, this approach to software development was insufficient.

Since software systems often contain more than one module, implementation of each module and interfacing of each with other modules require different techniques in software development. These techniques constitute programming-in-the-large. The shift from small to large is not simply one of size (bigger problems), but it is actually a change in kind. According to Shaw, a need arose for programs that could automate different pieces of the software development process and recognize the multiple constraints on software use on any system.

This has made software development an increasingly difficult task. Thorndyke

observed that this difficulty exists at a time when "our most pressing need is the development of software technology to capitalize on our hardware capabilities," pointing to the large gap between the peak rate potential of a system and the actual results realized by the user as an example of this problem.

Microminiaturization

One of the most striking phenomena in the progression of computer design is the simultaneous reduction in the size of solid state elements (such as microprocessors), and in the unit cost of their components. These improvements in cost and density resulted simply from making things smaller. An examination of 4K, 16K, 64K, and 256K microprocessors reveals only a difference in size: they grow progressively smaller as their number-labels rise, and in one sense, no real innovation has been involved in the change from one to the next.

The nature of these complex processors, however, suggests that physical limits exist for present designs. Dennis Buss, vice president of Texas Instruments, stated that the size limit for discrete elements in the microprocessor may be around one-half micron—a limit he calls

Dennis D. Buss

the "half-micron apocalypse." (A fingernail that is 0.5 inches in height is the equivalent of 10,000 microns. One-half micron, then is about 1/20,000 of the height of the fingernail.)

Unfortunately, it is getting harder and harder to reduce the size of these elements. Some of the problems involve thermodynamic noise limits and quantum limits based on the Heisenberg uncertainty principle; and in the half-micron region, classical electron transport physics no longer applies. However, Buss thinks we might be able to surmount the half-micron apocalypse barrier by using electron resonance tunnelling. With this technique, erasing a bit from memory would require only an increase or decrease in voltage that would transfer it from one quantum state to another. The new state would be the new information, in a way that is similar to the magnetization of tape in other kinds of memory systems. But however it is achieved, getting below the half-micron limit will require new technology.

The new technology needed for surmounting the barrier will require significant research and development, and will entail additional manufacturing costs. From a business perspective, Buss described four elements affecting decisions in these areas: performance degradation, process control, price competition, and cash flow. In making choices about performance, process, and price, reliability again becomes a major factor, just as it is in new system architecture.

Cooperation

As in ERA's early days, cooperation between segments of the economy still plays a large role in preserving a healthy enterprise. Several new forms of cooperation were discussed during the symposium. According to Norris, "The most productive, affordable, and readily available opportunity to expand innovation and substantially increase the efficiency of research, development, and manufacturing is through public-private technological cooperation." He described three such enterprises that variously involve industry, academia, and government:

- The Microelectronics and Computer Technology Cooperation (MCC): an inter-industry effort to develop base technologies for use by member companies in microelectronics and computing.
- The Job Creation Network: a government-industry effort involving a cooperation office, a seed-capital fund, and a business and technology center. All its activities are directed to helping the creation of small businesses.
- The Midwest Technology Development Institute (MTDI): This institute's three-fold objective is to expand technological cooperation among industries and universities, increase the efficiency of research and commercialization of the results, and provide a mechanism to make technology more available to industry and improve its flow between the Midwest and foreign countries.

In his opening remarks, Kenneth H. Keller, president of the University of Minnesota, mentioned two of the many ways the University cooperates to achieve similar objectives through Institute of Technology programs. The Supercomputer Sciences Center are at the forefront of cooperative efforts to bring the latest research into industry, and thus to the marketplace.

Rollwagen also emphasized continued investment in cooperation by calling to mind ERA development and the people who came from ERA, saying "If we recognize the significance [of ERA], if we invest in our companies, if we maintain the infrastructure that has brought us this far,

Fred W. Weingarten

I see nothing but great excitement ahead for all of us."

Policy Agendas

Fred W. Weingarten of the Office of Technology Assessment, of the U.S. Congress examined the national policy agenda for information technology. He identified several characteristics of the present environment and some of the difficulties that exist in taking the measure of those characteristics to develop a good policy program. He noted that the way information technology interacts with the U.S. economy is not only very complicated, but is described with poor data. This is partly because of a rate of change that makes data quickly obsolete, but mostly due to the difficulty inherent in such concepts as productivity and balance of trade. Moreover, data collection

changes as patterns of behavior change, which affects the continuity of the data, and prevents robust conclusions.

Weingarten concluded that we will simply have to live with some of this, because rapid change will be the future's norm. The economy will continue to be fragmented, compared to its former basis in a few major industries, and success in any business area will depend strongly on information and information technology.

Looking at foreign policy, Weingarten emphasized that an international economy is now the permanent state; that borders are now irrelevant, and we cannot act as if the economy were strictly a domestic one. Thus, he said, we need to stimulate innovation, ameliorate the problems of transition from a small to a large amount of automation, and develop coherent information policies.

John L. Diebold

John Diebold, chairman and founder of The Diebold Group, emphasized similar factors with regard to foreign competition. "We focus on the present form of foreign competition, and I think it's terribly important to realize that what we're going to be dealing with will be a changing form of foreign competition." He referred to Secretary of State George Schultz's statement that the East/West power balance will shift because of this technology. Diebold recommended that policy makers and business people try to understand what tomorrow is going to be like in our and other countries, "and to design our own competition and our own ability to compete in relation to that." As he had stated in another context, "it means a very big departure from some of the practices of the past, it means an agility to move rapidly, it means a great deal of hard work."

Personal Effects

During his discussion of present practices, Donn Parker, a noted analyst from SRI International, called attention to a basic irony in American society: "Our number society, a quantified, digital, number society, yet remains with most of society being innumerate." The numerate person, among other things, can compare large and small numbers correctly, can estimate things logically, knows computers do not make errors nor commit crimes. He said that with such a small numerate population, it is surprising that statistical statements appear everywhere—many of which have no meaning, because the base is not quantified. He used the morning newspaper as a simple example: of 47 articles, 46 contained numbers of some sort, even though they often added no information. Numbers are everywhere! The prime industry in the United States has become numbers.

Donn B. Parker

The tool for handling those numbers, as we all know, is the computer. Gerald G. Probst, former chairman and chief executive officer of Sperry Corporation, described the change these machines have brought about especially since 1972. Originally individual and rather unusual items, computers now sell in batches, and by the millions. This change, and the energy we derive from use of these machines, "is creating shock waves that are cracking the foundations of things the way they are. It's the enemy of the obsolete; it's the enemy of entrenched ways of doing things, it's the enemy of the status quo," said Probst.

But Parker regards the computer as still primitive, in that it requires that a keyboard be used for putting numbers into the machine. We can draw a conclusion from this, I think, that the obsolete and the status quo would go away faster if the design of machines were changed. More people might then become numerate, and the integrity of numbers might improve.

Probst sees other impacts of the computer's use. For example, since the computer emerged from an open society, it is a likely tool to open closed societies. Computers allow information to be freely exchanged; closed societies operate on the opposite principle. Probst believes the computer will give those closed societies the tools to solve their underlying problems, which will inevitably increase their openness. This view is consistent with that implied in the Secretary of State's quoted remark about an East/West power shift. Daniel Siewiorek also referred indirectly to such a shift when he observed that "some automobiles have more computing power than a lot of Third World nations." Each speaker who made a claim for an exciting future for computing implied that other shifts would be as dramatic as the change in store for Third World countries.

Gerald G. Probst

The Future

What is definitely in store for us as we approach the 21st century was elegantly summarized by Lloyd Thorndyke in his closing remarks. "Over the past 40 years we have laid a foundation for sustained growth by developing an infrastructure of technology, educating two generations about computers, and applying the power of these resources. During the next 40 years, we face the challenges of properly directing and harnessing the accelerating capacity of computer technology into productive channels. None of this will come without diligent effort, but the rewards will make moving the frontiers worthwhile." ■

The symposium on "Computing in the 21st Century," offered many opportunities for informal conversation between speakers and attendees.

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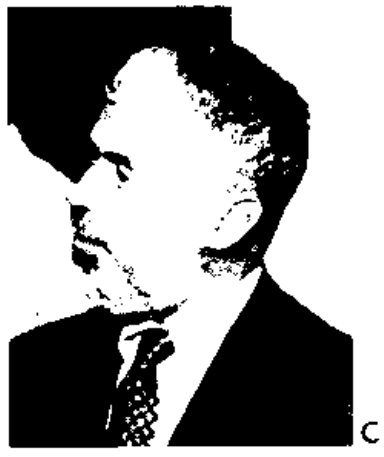

C

D

E

F

G

A *Historians of technology Edwin T. Layton, University of Minnesota, and Michael S. Mahoney, Princeton University*

B *Erwin Tomash, founder of Dataproducts Corporation and founder of the Charles Babbage Institute*

C *Ettore F. Infante, dean of the Institute of Technology at the University of Minnesota*

D *Isaac L. Auerbach, president of Isaac L. Auerbach Consultants, Inc., and Jeffrey Chuan Chu, a consultant in the computer field and an advisor to the president of SRI International*

E *Tibor Fabian, retired president of Mathematica, Inc. and Walter F. Bauer, chairman and CEO of Delphi Systems, Inc. and chairman of the Charles Babbage Foundation*

F *Val Muehlberger, an early employee of ERA, Inc.; William C. Norris, founder of ERA, Inc. and CDC; Martha Russell, associate director of Microelectronic and Information Sciences Center at the University of Minnesota; and V. Rama Murthy, associate president for academic affairs at the University of Minnesota*

G *Lowell E. Johnson, an engineer at ERA, Inc.; Willis K. Drake, founder of Data Card Corp. and Regent of the University of Minnesota; and John E. Parker, president and founder of ERA, Inc.*

Engineering Research Associates, Inc., Personnel Gather

The symposium "Computing in the 21st Century" was designed as a celebration of the founding of Engineering Research Associates in 1946. A celebratory dinner and a special reunion lunch and session became the highlight of the two-day affair. Over 150 people from around the country assembled at the reunion session for "reminiscing and trading war stories." Among the principal founders of ERA present were John E. Parker, president, and William C. Norris, vice president. Norris commented during a symposium session on the major problems to be solved in building ERA. Parker, in his remarks at the dinner, described how he was approached to consider starting ERA and what he did to raise the needed capital. One of the most touching moments of the two days occurred as Parker left the podium: the 300 people present at the dinner offered him a prolonged standing ovation.

ERA people offered stories about technical developments, tales of the interactions between ERA and other organizations such as the U. S. Navy, and memories of an exciting time in a rapidly changing world—all in their human context. What came across was a description of a small business run by people bursting with ideas, anxious to develop them into products to serve a new societal need, and devoted to the concept of team effort. And those ideas were not confined to computing equipment. At one point during the search for profit-making products, one engineer considering the range of possibilities the company could explore suggested an electric can opener. No one at ERA took the suggestion seriously.

The team concentrated on the automated systems that became their trademark—magnetic drums for storage of digital data, the ERA 1101 and 1103, the beginning of the 1100 line of Sperry Corporation. Work on these designs trained engineers and scientists for the subsequent designing of machines produced by other companies, notably Control Data Corporation, Cray Research, and ETA Systems, to name only a few. And not a few of the people in the room have been associated with these companies. The session was to honor the founding of ERA in 1946, but in the end it honored that and the subsequent 40 years of activity that built the high-technology community of Minnesota, a point emphasized at the dinner by Regent of the University of Minnesota Willis K. Drake. ■

Arthur A. Kotz and Edward C. Svendsen

Sidney M. Rubens

John A. S. Webster and H. Dick Clover

John E. Parker

Robert K. Patterson

Steven J. Huss, Robert P. Blixt, and Jay A. Kershaw

Paul Neiland and Edward D. Zimmer

continued from page 1 . . .

1946-48 publication of Institute for Advanced Study reports on programming

1948 Composition code generation algorithm developed by Haskell B. Curry of the Naval Ordnance Laboratory in Silver Spring, Maryland

1949 Short Code, a high level programming language, suggested by John Mauchly and written by William F. Schmidt for the BINAC

1950 Intermediate Programming Language developed by Arthur W. Burks and others at the University of Michigan to help ease the translation from ordinary business English to an internal programming language

1951 Publication of Maurice V. Wilkes, D. J. Wheeler, and S. Gill, Preparation of Programs for an Electronic Digital Computer

1951 Simple algebraic language and compilers (Klammerausdrucke) developed for theoretical computer by Heinz Rutishauser at the ETH in Zurich

1951 Complete compiler (Formules) developed by Corrado Bohm at the ETH in Zurich

1952 Autocode (compiler) written by Alick E. Glennie of the Fort Halstead Royal Armaments Research Establishment and implemented on the Manchester Mark I

1952 Short Code, a high level programming language, written by William F. Schmidt, Albert B. Tonik, and J. Robert Logan for the UNIVAC (I)

1952 Sort-Merge Generator developed by Betty Holberton for the Remington Rand UNIVAC I

195x? COMPOOL data definition facility developed at MIT Lincoln Laboratory for the SAGE Air Defense System

1953 A-2 compiler developed by Grace Hopper and others for the UNIVAC

1953 Algebraic interpreter developed by J. Halcombe Laning and Niel Zierler for the Whirlwind computer at MIT

1953 Speedcoding developed by John Backus at IBM for the IBM 701 computer

1954 Operating system at General Motors Research Laboratory for IBM 701 computer

1954 Autocode developed by R. A. Booker for the Manchester Mark I

1954 PiPi-2 Programming Program, a production compiler, developed by E. Z. Liumbimskii and S. S. Kamynin at the Mathematical Institute of the Soviet Academy of Sciences

1954? Autocoder assembly language and assembler developed for the IBM 705

1954 Planning Research Corp. founded

1955 PiPi Programming Program (compiler) developed by A. P. Ershov and others at the Mathematical Institute of the Soviet Academy of Sciences for the BESM computer

1955 BACAIC high level programming language and compiler developed by Mandalay Grems and R. E. Porter at the Boeing Airplane Company for the IBM 701 computer

1955 MATH-MATIC mathematical programming language

1955 Kompiler 2 (compiler) developed by A. Kenton Elsworth at the Livermore Laboratory for the IBM 701 computer

195x? business-oriented compiler Flow-Matic developed at Remington Rand Univac by Grace Hopper and others

195x? SOAP assembler for the IBM 650 computer

1956 operating system developed by General Motors and North American Aviation for the IBM 704

1956 ADES programming language developed at the U.S. Naval Observatory Laboratory by E. K. Blum

1956 language for machine tool control, APT, developed at MIT by Douglas Ross and others

1956 artificial intelligence program, Logic Theorist, developed by Allan Newell and Herbert Simon at Carnegie Tech

1956 IT (Internal Translator) compiler implemented on an IBM 650 computer at Carnegie Institute of Technology by Alan Perlis and Joseph W. Smith

1956 MATH-MATIC language and compiler developed by Charles Katz and others for the UNIVAC

1956 MARK I report writer developed at General Electric-Hanford for the IBM 702

1956 System Development Corporation founded

1956 high-level programming language, FORTRAN, developed at IBM by team led by John Backus

1957 Mark II report generator developed at General Electric-Hanford for the IBM 702 computer

1957 Klaus Samelson and F. L. Bauer receive German patent for their formula-controlled computer design

1957 IT programming language

1957 Fortransit programming language

1957 COMIT string processing language

1958 Information Retrieval (IR) formatted file system for database management developed by David Taylor Model Basin for the IBM 704

1958 list processing programming language, LISP, developed by John McCarthy at MIT

1958 programming language ALGOL (also known as IAL) developed

1958 AIMACO business data processing programming language

1958 Commercial Translator business data processing language

1958 IPL V list processing programming language

1959 Computer Sciences Corporation incorporated

1959 Applied Research incorporated

1959 business data processing programming language COBOL

1959 TUFF/TUG formatted file system for database management for the IBM 704

1959 9PAC file handling facility on the IBM 709 by SHARE

1959 FACT business data processing programming language

1959 LISP list processing programming language

1959 JOVIAL multipurpose programming language developed at System Development Corporation by Jules Schwartz

1959? high-level string processing language COMIT developed at MIT by Victor Yngve

1959? virtual memory developed on the Manchester University Atlas

1959 SURGE report generator developed by Fletcher Jones of SHARE for the IBM 704

1959 Backus Normal Form for defining language syntax

1959 Sage operating system developed by System Development Corporation for the IBM AN/FSQ7 computer

1959 MAD scientific programming language

195x? ACSI-Matic data retrieval accessing package developed by Jack Minker for the U.S. Army

195x? SAP assembler for the IBM 704 computer

1960 IOCS operating system developed by IBM for their 709/7090 computers

1960 FMS operating system developed by North American Aviation for the IBM 709 computer

1960 macroassembler concept introduced by M. D. McIlroy

1960 Atlas operating system developed by Machester University and Ferranti for the Ferranti Atlas computer

1960 development of ALGOL 60 programming language, a revised version of IAL
1960 TRAC string processing language
1961 SOS operating system developed by SHARE and IBM for the IBM 709 computer
1961 Automatic Data Processing incorporated
1961 SAC/Aids Formatted File System for database management for the Strategic Air Command 438L System
1961 BASE-BALL natural language system developed by B. V. Green and others
1961 QUERY database query language developed by T. E. Cheatham and S. Warshall
1961 Report Program Generator (RPG) developed for the IBM 1401
1961 MADCAP scientific programming language
1961 ALGY formula manipulation programming language
1961 GECOM business data processing programming language
1961 QUICKTRAN on-line programming language
1962 CTSS operating system developed by Francis Corbato and others at MIT for the IBM 7090 and 7094 computers
1962 Generalized Information and Retrieval System (GIRLS) database managment system developed by J.A. Postley of AIS for the IBM 7090 computer
1962 EXEC 1 operating system developed by Computer Sciences Corporation for the Univac 1107 computer
1962 APL programming language developed by Kenneth Iverson
1962 Informatics founded
1962 IBSYS operating system developed by IBM for their 7090 series computers
1962 Advanced Data Management System (ADAM) database managment system developed at MITRE for the IBM 7030 computer
1962 COLINGO database management system developed at MITRE for the IBM 1401 computer
1962 FORMAC formula manipulation programming language
1962 SNOBOL string processing programming language
1963 Master Control Program operating system developed at Burroughs for their B5000 computer
1963 Information Processing System (IPS) developed by NAVCOSSACT for the CDC 1604 computer
1963 high-level programming language JOSS developed at Rand Corporation by J. Cliff Shaw for timeshare environment
1963 Commercial on-line transaction processing system developed at IBM for American Airlines SABRE reservation system for the IBM 7090 computer
1963 CORC scientific programming language
1963 OMNITAB scientific programming language
1963 MIRFAC scientific programming language
1963 Management Sciences of America incorporated
1963 University Computing Company founded
1964 Integrated Data Store (I-D-S) database management system developed by Charles Bachman of General Electric
1964 OS/360 concept announced by IBM for their 360 computer series
1964? operating system OS/360 for the IBM System/360
1964 multipurpose programming language PL/I developed by IBM and SHARE
1964 language for doing non-numeric mathematics, Formac, developed at IBM by Jean Sammet and others
1964 JOSS scientific programming language
1964 AMBIT string processing programming language
1964 PAT on-line programming language
1964 Planning Research Corp. acquired Reliability Research and Technology
1965 on-line programming language BASIC developed by John Kemeny and Tom Kurtz at Dartmouth College
1965 Generalized Update Access Method (GUAM) developed by North American Aviation Space Division for the IBM 7010 computer
1965 Remote-Access Terminal System for data managment developed by Rockwell International and IBM for the IBM 7010 computer
1965 NMCS Information Processing System (NIPS) for file formatting in database management developed by the U.S. Navy for the IBM 1410
1965 Generalized Information System (GIS) developed by IBM for their System/360
1965 expert system program DENDRAL developed by Edward Fiegenbaum and Joshua Lederberg at Stanford University
1965 hierarchical database management system developed by North American Aviation Space Division and IBM
1965 C-10 database management system developed by MITRE for the IBM 1410
1965 COGENT report generator developed by IBm for their 709 computer
1965 CPS on-line programming language
1965 RUSH on-line programming language
1965 Amtran on-line programming language
1965 FLAP formula manipulation programming language
1965 CLP list processing programming language
1965 Planning Research Corp. acquired Mesa Scientific Corp.
196x? interactive operating system, Multics, developed by General Electric, MIT, and Bell Laboratories for the GE/Honeywell 645
196x? string processing language SNOBOL developed at Bell Laboratories by David Farber, Ralph Griswold, and Ivan Polonsky
1966 TOS operating system developed by RCA for the IBM 360 computer series
1966 APL programming language developed by G.G. Dodd of General Motors Research Laboratory
1966 Dialog on-line programming language
1966 MAP on-line programming language
1966 NAPSS scientific programming language
1966 EULER scientific programming language
1967 non-procedural language RAMIS introduced by Mathematica
1967 MANAGE database managment system developed by Scientific Data Systems for the XDS 940 computer
1967 AS-IST database management system developed by Applications Software for the IBM 360 computer
1967 First Symposium on Operating System Principles held in Gatlinburg, Tennessee
1967 LUCID database management system developed by System Development Corporation for the AN/FSQ32 computer
1967 CPUL scientific programming language
1967 POSE scientific programming language
1967 MAC-30 scientific programming language
1967 DIAGMAG scientific programming language
1967 REDUCE formula manipulation programming language
1967 SPRINT list processing programming language
1967 LOLITA list processing programming language
1967 EOL-3 string processing programming language
1967 LEAP multipurpose programming language

1967 AGS Computers, Inc. incorporated
1967 Planning Research Corp. acquired R. Dixon Speas Associates
1967 Planning Research Corp. acquired Behavior Science Corp.
1967 Planning Research Corp. acquired Alan M. Voorhees and Associates
1968 programming language ALGOL 68 developed
1968 OS/MFT operating system introduced by IBM for their medium-sized 360 computers
1968 TSS operating system introduced by IBM for their 360/67 computer
1968 programming language Pascal developed by Niklaus Wirth
1968 MCP operating system developed by Burroughs for their B2500 and B3500 computers
1968 Cullinane incorporated
1968 Mark IV database manangement system introduced by Informatics for the IBM System/360
1968 Cincom Systems, Inc. founded
1968 PAL programming language
1968 Tracor Continuum Co. formed
1968 PROTEUS programming language
1968 GPL general purpose programming language
1968 Planning Research Corp. acquired Crawford, Bunte, Roden
1968 Planning Research Corp. acquired H.B. Maynard and Co.
1968 SEI Corp. founded
1969 IBM announces "unbundling," pricing of software separately from hardware
1969 CP-67/CMS operating system introduced by IBM for their 360/67 computer
1969 OS/MVT operating system introduced by IBM for their large 360 computers
1969 Codasyl COBOL committee developed Data Definition Language for defining a total database amd a Sub-Schema Data Manipulation Language
1969 Data-Manager-1 database management system developed by Auerbach
1969 UNIX multi-user, multitask operating system begun at Bell Laboratories
1969 Cobol Data Managment System (CDMS) developed by the Defense Intelligence Agency for the IBM System/360
1969 Information Management System hierarchical database management system introduced by IBM
1969 TSOS operating developed by RCA for the Spectra 70/46
1969 Time-Shared Data Management System (TDMS) developed by System Development Corporation for IBM System/360 computers
1969 Remote File Management System developed at University of Texas for the Control Data 6000 computer
1969 term "structured programming" introduced by Edgar Dijkstra
1969 McG360 programming language
1969 DML programming language
1969 REL programming language
1969 PLANNER programming language
1969 REF-ARF programming language
1969 IITRAN multipurpose programming language
1969 APAREL multipurpose programming language
1969 NUCLEOL string processing programming language
1969 LEAF list processing programming language
1969 Scratchpad formula manipulation programming language
1969 IAM formula manipulation programming language
1969 PPL on-line programming language
1969 OSCAR on-line programming language
1969 TRANQUIL scientific programming language
1969 SPEAKEASY scientific programming language
1969 STIL scientific programming language
1969 Shared Medical Systems incorporated
1969 Tracor Continuum Co. spun off by Tracor Computing Corp.
1969 M & S Computing incorporated
1969 Planning Research Corp. acquired Frederic R. Harris (now PRC Engineering)
1969 Planning Research Corp. acquired Quinton Engineers
1969 Planning Research Corp. acquired Budlong and Associates
1969 Planning Research Corp. formed International Reservations Corp. 1969 Planning Research Corp. acquired Economic Research Associates
1969 Planning Research Co. acquired Jacobs Co.
196x? Pascal programming language
1970 Multics operating system developed at MIT for the GE 645 computer
1970 Machine Independent Data Management System (MIDMS) developed by the the Defense Intelligence Agency
1970 dataBasic database managment system developed by P. C. Dressen of General Electric
1970 SC-1 database management system developed by Western Electric for the IBM System/360
1970 DMS data managment system developed by Xerox Data Systems for their Sigma 5,7,9 computers
1970 relational database management system developed by E. F. Codd of IBM
1970 Integrated Data Managment System developed by B.F. Goodrich for IBM System/360 computers
1970 S2000 data management system developed by MRI Systems for the Control Data 6000 computer
1970 AIDS scientific programming language
1970 IMP scientific programming lanugage
1970 POEL scientific programming language
1970 LPL list processing programming language
1970 BALM list processing programming language
1970 Vulcan string processing programming language
1970 Gedanken programming language
1970 American Management Systems, Inc. formed
1970 American Computer Systems formed
1970 Integrated Software Systems incorporated
1970 Planning Research Corp. acquired Tonps Engineering
1970 Planning Research Corp. acquired Bruce Campbell and Associates
1970 Planning Research Corp. acquired General Planning and Research Consultants
1970 Planning Research Corp. acquired Vorlinden-Willemsen of the Netherlands
1970 Planning Research Corp. acquired Realtronics
197x? language for doing non-numeric mathematics, Macsyma, developed at MIT by Joel Moses and others
1971 VMOS operating system developed by RCA for the Spectra computer series
1971 ETC programming language
1971 FORMAC formula manipulation programming language
1971 Macsyma formula manipulation programming language
1971 American Computer and Software Company formed
1971 Planning Research Corp. acquired Engineering Consultants
1971 Planning Research Corp. acquired Greenwich Data Systems
1971 Planning Research Corp. acquired System Science Development Corp.

1972 Multics operating system developed by Honeywell for the Honeywell 6180 computer
1972 MCP operating system developed by Burroughs for their B1700 computer
1972 artificial intelligence programming language PROLOG developed at University of Marseilles and Imperial College of London
1972 1100 Executive operating system developed by Univac for their Univac 1100 series computers
1972 object-oriented artificial intelligence programming language SMALL TALK developed at Xerox Research
1972 PL/M high-level language compiler for a microprocessor
1972 VS/9 operating system developed by Univac for their Series 90 computers
1972 Tracor Continuum Co. changed name to TCC
1972 Planning Research Corp. acquired Information Labs
1972 Planning Research Corp. acquired Inmarco
1972 Planning Research Corp. acquired Foster Associates
1972 Planning Research Corp. acquired Storck, Cataldo, Carroll, and Associates
1972 Triad Systems Corporation formed
1973 BS2000 operating system developed by Siemens for their 7500 computer series
1973 Planning Research incorporated
1973 VM 1370 operating system introduced by IBM for their 370 computer series
1973 OS/VS operating system introduced by IBM for their 370 computer series
1973 Pholas data managment system developed by Phillips for the P1000 computer
1973 University Computing Co. changed name to Wyly Corp.
1974 Computer Associates International incorporated
1974 Planning Research Corp. acquired B. A. Berko and Associates
1975 OS/MVS operating system introduced by IBM for their 370 computers
1975 Western Electric licenses UNIX to the academic and commercial sectors
1975 Computervision Corporation formed
1975 high-level programming language ADA is begun by Department of Defense
1975 Management Data Query System (MDQS) database managment system developed by Honeywell
1976 Modula modular multiprocessing programming language developed by Niklaus Wirth
1976 Planning Research Corp. acquired Consoer, Townsend, and Associates
1976 Planning Research Corp. sold Foster Associates
1977 CP/M operating system is developed by Gary Kildall for microcomputers
1977 AGS Cpmouters, Inc. formed Fundamental Systems, Inc.
1977 AGS Computers, Inc. formed AGS Information Services Inc.
1977 Alpha Microsystems formed
1977 Chelsea Computer Systems, Inc. formed
1977 Planning Research Corp. acquired Realty Graphic Co.
1978 AGS Computers, Inc. acquired OHD for Computing Inc.
1978 American Software, Inc. formed by the merger of American Computer Systems and American Computer and Software Company
1978 MicroPro International Corp. formed
1979 CII-Honeywell Bull version of ADA selected as standard
1979 VisiCalc electronic spreadsheet for microcomputers
1979 RI (also known as X-CON) expert system developed by Carnegie-Mellon University finds commercial application at Digital Equipment Corporation
1979 TCC changed name to Continuum Company Inc.
1979 Continuum Company establishes Toronto Comtinuum Company, Ltd. (renamed Continuum Company, Ltd.)
1980 commercial natural language query system INTELLECT introduced by Artificial Intelligence Corporation
1980 CPF operating system introduced by IBM for their System 38 computer
1980 CPF operating system introduced by IBM for their System 38 computer
1980 Software Olus, Inc. formed
1980 M & S Computing changed name to Intergraph Corp.
1980 Software Publishing Corp. formed
1980 Policy Management Systems Corp. formed
1981 MS/DOS operating system for IBM PC developed by Microsoft
1981 AGS Computers acquired Micro Distributors, Inc.
1981 AGS Computers acquired Eastman Design Co.
1981 Software AG System Group incorporated
1981 American Management Systems acquired Executive Systems, Inc.
1981 American Management Systems acquired Florida Computer Systems
1981 Computer Associates International acquires Viking Data Systems, Inc.
1981 Continuum Company establishes Continuum Systems Research Inc.
1981 Chelsea Computer Systems changes name to Hogan Associates
1981 Policy Management Systems Corp. acquires assets of the PMS division of Siedels, Bruce, and Co.
1982 Lotus Development incorporated
1982 Alpha Microsystems acquires Alpha Microsystems Europe
1982 Computer Associates International merges with Capex, Corp.
1982 Continuum Company establishes Continuum Company U.K. Ltd.
1982 Hogan Associates changes name to Hogan Systems
1982 SEI Corp. acquired TMI System Corp.
1983 Computer Associates International acquires Information Unlimited Software, Inc.
1983 AGS Computers acquired DISC, Inc.
1983 American National Standards Institute (ANSI) publishes an official description of ADA
1983 Software Plus changes name to Ashton-Tate
1983 Hogan Systems acquires Henco Research, Inc.
1983 Human Edge Software Co. founded
1983 Planning Research Corp. acquired Sterling Systems
1983 Policy Management Systems Corp. acquired Mutual Data
1983 Policy Management Systems Corp. acquired Business Computer System
1984 AGS Computers acquired Software Design Associates, Inc.
1984 AGS Computers acquired System Strategies, Inc.
1984 Alpha Microsystems acquired Oaragon Computer Service, Inc.
1984 Alpha Microsystems acquired Computer Service Network
1984 Computer Associates International acquires Sorcim Corp.
1984 Computer Associates International acquires Johnson Systems, Inc.
1984 Intergraph acquires controlling interest in Tangent System Corp.
1984 Intergraph acquires controlling interest in Intergraph Systems of Canada

1984 Human Edge Spftware Company and Edge Development Limited Partnership form Human Edge Software Joint Venture

1984 SEI Corp. acquired Financial Services Group of Index Systems Corp.

1984 Policy Managment Systems Corp. acquired Compuclaim Corp.

1984 Wyly Corp. changed name to UCCEL Corp.

1985 American Management Systems sold Florida Computer Systems

1985 Ashton-Tate acquires Forefront Corp.

1985 Lotus Development acquired assets of Software Arts

1985 Lotus Development acquired Dataspeed

1985 Ashton-Tate acquires Multimate International Corp.

1985 Computer Associates International acquires Value Software, Inc.

1985 Hogan Systems incorporates

1985 Human Edge registers with the Securities and Exhange Commission

1985 Planning Research Corp. acquired National Business Consultants

1985 Planning Research acquired Kentron International

1985 Software Publishing Corp. acquired Harvard Software

1985 Policy Managment Systems Corp. acquired Commercial Services

1986 Lotus Development acquired ISYS Corp.

1986 Policy Management Systems Corp. acquired Insurance Companies Inspector Bureau

*NOTE: It is always difficult and controversial to date such complex technologies as software, whose initial conception and public appearance may occur years apart. Unless explicitly stated otherwise, the intention here is to give the year of public appearance. In cases where we know the approximate date of appearance only, the listing appears in the appropriate chronological part of the list with a question mark following the date. The list includes information about the development of programming languages, operating systems, database management systems, and the growth of the software industry. No claims of comprehensiveness are made, and we have not yet made any efforts to verify entries other than to check them in the following sources. ■

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Software Sources at CBI

The CBI archives contain a large variety and quantity of records that document the history of software. These include software surveys, technical manuals and reports, professional organization records, manuscript collections, consulting reports, government documents, and educational materials. This collection of materials is scheduled for rapid expansion as CBI turns more attention to questions of software. A more detailed description sampling our holdings is listed below.

- Computer Manuals
  programming language manuals, assemblers and compilers
  applications manuals
  descriptions of operating systems, executive controllers, input-output routines
  manuals of software developed at universities and colleges, including subroutine libraries
- Product Literature, computer system applications
- Advertising and sales brochures
- Technical Reports from the National Bureau of Standards Literature Collection (1961-1974)
- PL/1 Bulletins (1966-1967)
- ALGOL Bulletins (1967-1976)
- Software surveys: DataPro, Auerbach
- Francis V. Wagner Papers, includes information on SHARE, UNCOL (Universal Computer-Oriented Language)
- History of Programming Languages Conference records
- SHARE records: early minutes, correspondence and technical libraries
- Various other user group records
- Auerbach Consulting Reports, reports analyzing software of specific commercial and military systems
- Other collections indirectly related to software, including: US vs. IBM collection (industry data), Hammer's papers (speeches relating to software), Honeywell vs. Sperry (ENIAC and ABC programming information)
- CODASYL records: minutes and supporting documents of the executive committee and the COBOL committee; miscellaneous documentation of other committees
- Univac Scientific Exchange: early minutes and supporting documentation for the 1103
- Computer education materials: manuals, collection of documents from the Willow Run Special Course on Digital Computers in 1953
- Charles Phillips Papers, relating to COBOL development
- Government Documents related to software development: COBOL, programming of early government computers ■

Programming Languages Conference Records Donated to CBI

In June of 1978 ACM sponsored the History of Programming Languages (HOPL) Conference in Los Angeles. The conference was significant in that it was the first attempt to document the technical factors that influenced the development of thirteen major languages; it also was responsible for spurring general interest in the history of computing. CBI has recently received HOPL records from Jean Sammet, who was the general and program committee chair of the conference.

The purpose of HOPL was "to provide the appropriate written historical record" for programming languages that were created and in use by 1967, remained in use by 1977, and influenced the field of computing. Speakers included those who had played a major part in the development of ALGOL, APL, APT, BASIC, COBOL, FORTRAN, GPSS, JOSS, JOVIAL, LISP, PL/I,SIMULA, and SNOBOL. Papers and presentations were later compiled in *History of Programming Languages* (1981), edited by Richard Wexelblat.

The records of the conference include correspondence, memoranda and reports relating to the administration of the conference, as well as photographs, audio recordings and videotapes of the presentations. Though most of the content of the conference is captured in the Wexelblat book, the records contain additional sources of information from the drafts of papers, written comments to the authors, and correspondence from the participants. Other items range from a paper on language design teams written by a student invited to the conference, to a song about ALGOL-68 submitted by John McCarthy.

The records are available for research, though permission to use the collection must be acquired from CBI. For further information, contact CBI's archivist. ■

CBF Trustees Welcome Four New Members

Election of Trustees and Directors took place at the Charles Babbage Foundation annual meeting in September. In addition to the re-election of several members, Tibor Fabian, Thomas P. Hughes, Herbert C. Johnson, and Patrick J. McGovern were elected to their first terms.

Tibor Fabian joined Mathematica, Inc. in 1961 and served as president and chief executive officer from 1964 until his retirement in 1983. Earlier Dr. Fabian was associated with UCLA's Institute of Industrial Relations and the Management Sciences Research Project. During the 1950s he also served as a consultant to the Rand Corporation and director of operations research at Coopers and Lybrand. Throughout his career he has published articles on management, economics, computer and general business topics. His professional affiliations include the American Economic Association, the Econometric Society, the Institute of Management Sciences, and the Operations Research Society of America.

Thomas P. Hughes is Professor of History and Sociology of Science at the University of Pennsylvania. Prior to assuming this position in 1973, he held academic positions at several universities including Southern Methodist University, Johns Hopkins University, and Massachusetts Institute of Technology. Professor Hughes has published numerous articles and books on European and American history with special attention to history of modern technology and science, including the book, *Elmer Sperry: Inventor and Engineer of Western Society 1880-1930*. Some of the many professional associations he has been involved in as a member or officer include the Society for the History of Technology, U.S. National Committee for the History and Philosophy of Science, and the International Congress for the History of Science.

Herbert C. Johnson has served in executive positions in several Minnesota-based companies. He is currently chairman of Datamyte Corporation. Previously he held positions at MTS Systems Corporation, Research, Inc., Foley Manufacturing Company, and Engineering Research Associates, Inc. Mr. Johnson is very active in state-wide business associations including the Minnesota High Technology Council and the Minnesota High Technology Corridor Corporation which works closely with the University of Minnesota to promote closer cooperation between university researchers and local industry.

Patrick J. McGovern is founder and chairman of International Data Group, Inc. (IDG), an information service company for the technology, telecommunications and office systems fields. Since 1964 Mr. McGovern has been working to disseminate information about computers through two of IDG's main subsidiaries: International Data Corporation, a market research firm concentrating on the information industry; and CW Communications, Inc., which publishes Computerworld and other magazines distributed to an international market. ■

Fellowships Available for Historical Research

Four institutions are currently offering fellowships to support research in the areas of electrical, industrial, aerospace and telephone history. A very brief description is included here, but more information may be obtained from the address listed below each description.

The **Hagley Museum and Library Research Fellowships** for 1987-1988 offer exceptional opportunities to study American industry and technology since 1850 at a research library which holds collections in economic and technological history. The fellowship program is designed to promote integrative and comparative research into the social context and consequences of industrialization of the United States in the century following 1850. Fellows will have opportunities to interact with the Hagley Graduate Program in Industrial America, as well as with scholars in nearby institutions such as the University of Pennsylvania, the University of Delaware, and the Winterhur Museum. Scholars from any humanistic discipline or from related social sciences are encouraged to apply. Fellowships are not awarded to degree candidates or for study leading to advanced degrees.

The maximum stipend is $27,500 for an academic year, and the minimum residency is six months.

For information write to Dr. Elizabeth Gray Hogan, Hagley Museum and Library, Box 3630, Wilmington, Delaware 19807. Completed applications must be received by February 15, 1987.

The **AT&T Fellowship in Telephone History** will again be awarded in 1987 to support research into the history of AT&T, its predecessor and associated enterprises, and the telecommunications industry. This year eligibility for the fellowship is being expanded to include faculty members and post-doctoral researchers in addition to advanced students who have completed their course work in an accredited university graduate program of business history or related fields.

The award is $10,000. The purpose of the AT&T Fellowship program is to provide financial support for research that at least in part utilizes information from the Company's historical archive collection located in New York City and New Jersey.

Information on application requirements may be obtained from Robert W. Garnet, Historical Archive & Publications Division, AT&T, 195 Broadway, Room 1508, New York, NY 10007. The deadline for receipt of applications is April 1, 1987.

The 1987-88 **Fellowship in Electrical History** is for either one year of full-time graduate work in the history of electrical science and technology at a college or university of recognized standing, or for the support of up to one year of research for a recent Ph.D. graduate in the same field. Students with undergraduate degrees in engineering as well as those having degrees in the sciences or humanities are invited to apply.

For a pre-doctoral recipient, the Fellowship stipend is $9,000, with an additional amount of up to $2,000 to pay academic tuition and fees. The stipend is $11,000 for a post-doctoral recipient.

Application forms may be obtained from the IEEE Center for the History of Electrical Engineering, 345 E. 47th Street, New York, NY 10017. The deadline for receipt of applications for the 1987-88 academic year is February 1, 1987.

The American Historical Association is offering a **Fellowship in Aerospace History** supported by the National Aeronautics and Space Administration. The fellowship is for a period of six months to one year to support significant and sustained, advanced research in all aspects of the history of aerospace from the earliest human interest in flight to the present, including cultural and intellectual history, economic history, history of law and public policy, and history of science, engineering, and management. The fellow will be encouraged to take advantage of the opportunity to use the documentary resources of the National Aeronautics and Space Administration and may also spend the fellowship in residence at the NASA headquarters of one of the NASA centers. Applicants must be U.S. citizens and possess a doctoral degree in history or in a closely related field or be enrolled as a student (having completed all course work) in a doctoral degree-granting program.

The maximum fellowship stipend is $25,000. An allowance of up to $1,000 is available for relocation and travel expense if needed. Stipend awards may be based on the previous year's salary, or a salary the recipient would expect to earn during the fellowship term, and are adjustable to the length of the fellowship term. Graduate students are eligible for a maximum stipend of up to $12,000. Funds may not be used to support tuition or fees.

Application forms and information can be obtained from Fellowship in Aerospace History, American Historical Association, 400 A Street SE, Washington, D.C. 20003. The deadline for application is February 1, 1987. ■

Correction

Michael Nash's name was inadvertently omitted as the author of the article, "Computer History at the Hagley Museum and Library," which appeared in the previous issue of this newsletter. ■

THE CHARLES BABBAGE FOUNDATION
for the History of Information Processing