A History
of Information Science
1945–1985

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Academic Press, Inc.
Harcourt Brace Jovanovich, Publishers
San Diego   New York   Berkeley   Boston
London   Sydney   Tokyo   Toronto

TABLE 2

Man–Computer Interaction: Relevant Chapters in *ARIST*[a] and Other Key Works, 1960–1970

Year	Volume	Author(s) and title	Affiliation
1960	NA	J.C.R. Licklider "Man–Computer Symbiosis"	Bolt, Beranek, and Newman
1965	NA	J. McCarthy "Time-sharing Computer Systems"	MIT faculty
1966	1	R.M. Davis "Man–Machine Communication"	Department of Defense
1967	2	R.G. Mills "Man–Machine Communication and Problem Solving"	MIT
1968	3	J.C.R. Licklider "Man–Computer Communication"	See above
1970	5	H.D. Huskey "Computer Technology"	University of California at Santa Cruz
1970	5	R.L. Simms, Jr., and E. Fuchs "Communications Technology"	Bell Telephone Laboratories
1970	NA	C.T. Meadow "Man–Machine Communication"	National Bureau of Standards

[a]*Annual Review of Information Science and Technology.*

vations, and problems in the field of man–computer interaction. Tables 2, 3, and 4 list some of these important reviews.

Early Online Systems: 1940–1970

The decade from 1960 to 1970 was a period of experimentation into online retrieval for various purposes (Table 5). Until this time, research in information science was conducted largely in Washington, D.C., or in one of the East Coast universities, particularly those whose personnel were interested in the computer as an ally in problem solving. Telecommunications problems had to be worked through; the concept of time-sharing had to be realized; and there was still much experimentation needed into methods for improving the man–computer interaction.

TABLE 3
Man–Computer Interaction: Relevant Chapters in *ARIST* and Other Key Works, 1971–1979

Year	Volume	Author(s) and title	Affiliation
1971	NA	M. Greenberger, ed. "Computers, Communications, and the Public Interest"	Johns Hopkins University, Professor of Computer Science and Director of Information Processing
1972	7	J.L. Bennett "The User Interface in Interactive Systems"	IBM Research Lab
1972	NA	J.G. Kemeny "Man and the Computer"	President, Dartmouth College
1973	8	T.H. Martin "The User Interface in Interactive Systems"	Stanford University
1976	11	P.L. Long "Computer Technology—An Update"	Phillip Long Associates, Inc.
1977	12	S.R. Bunch and P.A. Alsberg "Computer Communication Networks"	Center for Advanced Computation
1979	14	L.A. Hollaar "Unconventional Computer Architecture for Information Retrieval"	University of Illinois at Urbana

West Coast research centers such as the Rand Corporation, the System Development Corporation, and Lockheed Missiles and Space Corporation, as well as some universities, entered the mainstream of online retrieval through their research projects and by providing leadership to the national establishments such as NASA and the NLM. Two of our featured specialists come to mind: Roger K. Summit of Lockheed's DIALOG, who was instrumental in applying Lockheed's techniques to the NASA-RECON online bibliographic retrieval system; and Carlos A. Cuadra of the SDC, who administered the ORBIT II in the NLM's AIM/TWX experiment (Table 5).

The Real Beginnings of Man–Computer Symbiosis

Despite the early attempts to make the computer a symbiotic partner (Strachey, 1960; Licklider, 1960; Kemeny, 1972), the first recorded example of

TABLE 4

Human–Computer Interaction: Relevant Chapters in *ARIST* and Other Key Works, 1980–1984

Year	Volume	Author(s) and title	Affiliation
1980	15	A.E. Cawkell "Information Technology and Communications"	Institute for Scientific Information
1981	16	P.W. Williams and G. Goldsmith "Information Retrieval on Mini- and Micro-Computers"	University of Manchester Institute of Science and Technology
1983	18	H.R. Ramsey and J.D. Grimes "Human Factors in Interactive Computer Dialog"	IIT Programming Technology and Development
1984	19	C.L. Borgman "Psychological Research in Human–Computer Interaction"	UCLA
1984	19	A.D. Pratt "Microcomputers in Libraries"	University of Arizona

a man using a remote computer as a working partner occurred when Dr. George Stibitz of the Bell Telephone Laboratories, at a meeting of the American Mathematical Society in September 1940, conducted a demonstration at Dartmouth College in New Hampshire while connected to a computer at the Bell Labs in New Jersey (Stibitz and Larrivee, 1957, pp. 53–54). The date of this activity was confirmed by Dr. J. W. Mauchly during a panel discussion at a 1961 conference (Greenberger, 1965, p. 238). Ruth M. Davis reported that the Bell Telephone Lab's first time-sharing system appeared ''around 1950'' (Davis, 1966, p. 226, quoting Samuel, 1965). This information is ambiguous. We now know that the first online interaction was 1940; the first time-sharing may have been and no doubt was a different matter.

Mauchly was himself a giant in the computer world, having co-invented and built in the 1940s, with J. Presper Eckert, the famous ENIAC (Electronic Numerical Integrator and Calculator) at the Moore School of Engineering at the University of Pennsylvania in Philadelphia. The ENIAC, the first electronic computer, was dedicated in 1946, six years after the first man–computer online interaction had taken place. Mauchly also co-designed and built the UNIVAC, the first commercial electronic computer after the Eckert–Mauchly Computer Corporation was absorbed by Remington Rand in 1947–1950 (Greenberger, 1965, pp. xvii–xviii).

TABLE 5
A Selection of Early Online Systems

Year Online	System	Function	Affiliation	Reference
1940	No name known	Demonstration	Bell Telephone Labs	Mauchly (1965); Stibitz and Larrivee (1957)
1952–1957	SAGE (Semi-Automatic Ground Environment System)	Air defense	Dept. of Defense	Licklider (1965); Cuadra (1971a)
1962	SABRE	Airline reservations	American Airlines	Parker (1965)
1964	TIP (Technical Information Project)	Bibliographic online retrieval	MIT	Kessler (1965)
1965–1967	BOLD (Bibliographic Online Display)	Online communications with computer	SDC	Borko (1966)
1964–1969	NASA-RECON (-Remote Console)	Bibliographic information retrieval online	Lockheed, NASA	Wente (1971)
1970	AIM/TWX (Abridged Index Medicus/Twx)	Experimental online bibliographic retrieval	SDC, NLM	Katter and McCarn (1971)

Most of the early online retrieval experiments occurred in the late 1950s and early 1960s. Examples are SAGE, SABRE, and TIP, which are air defense, airline reservations, and bibliographic online retrieval systems, respectively. We cite three additional experiments between 1965 and 1970 (Table 5) that illustrate the beginnings of the powerful online bibliographic retrieval systems that were developed at the Lockheed and System Development Corporation centers in California. BOLD was an experiment in display techniques (Borko, 1966), and ORBIT was to lead to MEDLINE. Similarly, Lockheed's development of NASA-RECON was to lead to a national and international system of the same name (Table 5). The West Coast was now involved in research and development, and the commercially oriented vendor was about to emerge.

Online Information Retrieval
from Large Databases

An enormous new business was soon created. Equipment for remote utilization of the computer was designed, developed, and installed. Publications related to online retrieval emerged—directories, textbooks, bibliographies, and journals—and research studies of the effect of online retrieval on users were undertaken (Wanger *et al.*, 1976). The vendors collected databases from the producers, who developed their databases by organizing the documents created by researchers and other writers. The vendors then distributed portions to users upon online request.

Following the appearance of the earliest online systems, several other improvements were needed before massive retrieval of bibliographic references was possible. First, large, machine-readable databases had to be created. These were produced in increasingly large numbers in the 1970s. In 1974, for example, there were fewer than 100 such databases available (Williams, 1974), and by 1984 there were 2805 databases in 2509 separate entries according to one compilation (Williams, 1985c, Vol. 1, p. 11). Second, databases had to become available to libraries and information centers, mainly through vendors, or search services, as they came to be called. In the beginning these search services were principally from Lockheed (DIALOG) and System Development Corporation (ORBIT), with Bibliographical Retrieval Services (SEARCH) added in 1977 offering 10 databases (Reynolds, 1985, p. 118). (It is the vendors' programs for search services that are labeled DIALOG, ORBIT, and SEARCH; the latter is not often used as a name for the service.) For a considerable period these three were the principal vendors. In 1978, there were only eight commercial vendors in the United States; the new vendors were Battelle Memorial Institute, Informatics, Mead Corporation, New York Times Data Bank, and the Ohio College Library Center (Cuadra, 1978). This roster has changed many times (Neufeld and Cornog, 1986). Third, library and information center personnel had to learn how to use the vendors' services. It was a new experience; both the intermediaries in the libraries and information centers and their end users were faced with new roles.

Online Information Retrieval
Comes of Age: 1971–1979

In 1971 several major databases listed in Table 6 either were online or went online. Salton's SMART, a batch experiment since the 1960s, was finally designed to go online. The book summarizing SMART research was also published (Salton, 1971b). Brandhorst and Eckert succinctly enumerated 11 of Salton's conclusions to this point. They also listed the databases on which the research had been based and their sizes (Brandhorst and Eckert, 1972, pp. 410–411).

Three significant and unique books also appeared in 1971. The first was

TABLE 6
A Selection of Online Bibliographic Systems Operating in 1971

System	Start-up year	Affiliation
OCLC	1967	Ohio College Library Center
MEDLINE	1964	MEDLARS online
ERIC	1966	Educational Research (later Resources) Information Center
NTIS	1964	National Technical Information Service
SMART	1961–1964	Experimental Automatic Retrieval System, Harvard and Cornell universities

a proceedings of a workshop on the subject of the man–machine interface. The workshop was unique in that it was conducted for and limited to experts in the information field (Walker, 1971). An equally important work was the King and Bryant (1971) publication on the evaluation of information services, which was the first comprehensive textbook on this subject. The third work was Lancaster and Fayen's textbook "Information Retrieval On-line," published in 1973.

In addition, following a meeting of the International Federation of Documentation (FID) in September 1972 (Fry, 1973, p. i), Bernard M. Fry, editor-in-chief of the international journal, declared in an editorial that his journal, *Information Storage and Retrieval* (later to become *Information Processing and Management*), had come of age. He announced that beginning in 1973 the journal would extend its coverage into practical applications in libraries, information systems, and networks, and increase its frequency from a quarterly to a monthly publication. Brandhorst and Eckert concluded their 1972 article in *ARIST* with a comment that the community of users was now increasingly sophisticated in performing computer searches (Brandhorst and Eckert, 1972, p. 416).

Tables 7 and 8 list some of the chapters that reviewed large databases, document retrieval and services, use of machine-readable databases, experimental techniques of information retrieval, database management, online systems and techniques, and education and training for online systems. The tables are intended to present an overview of the period. Table 9 lists publications related to databases and online retrieval that have specifically involved the specialists featured in this chapter.

Specialists: Williams, Summit, Cuadra, and Hawkins

Four specialists who made significant contributions to the historical development of online retrieval services will be discussed: Martha E. Williams,

TABLE 7

Online Information Retrieval from Large Databases: Relevant Chapters in
***ARIST*, 1972–1979**

Year	Volume	Author(s) and title	Affiliation
1972	7	M. C. Gechman "Generation and Use of Machine-Readable Bibliographic Data Bases"	Information General, Inc.
1972	7	W. T. Brandhorst and P. F. Eckert "Document Retrieval and Dissemination Services"	ERIC and NASA
1974	9	M. E. Williams "Use of Machine-Readable Data Bases"	University of Illinois
1974	9	R. K. Summit and O. Firschein "Document Retrieval Systems and Techniques"	Lockheed Palo Alto Research Laboratories
1975	10	P. B. Schipma "Generation and Use of Machine-Readable Data Bases"	IIT Research Institute
1976	11	D. U. Wilde "Generation and Use of Machine-Readable Data Bases"	New England Research Applications Center, University of Connecticut
1979	14	M. J. McGill and J. Huitfeldt "Experimental Techniques of Information Retrieval"	School of Information Studies, Syracuse University
1979	14	M. A. Huffenberger and R. L. Wigington "Database Management Systems"	Chemical Abstracts Service

Roger K. Summit, Carlos A. Cuadra, and Donald T. Hawkins. They have earned
Ph.D. degrees in the fields of philosophy, management sciences, psychology,
and engineering, respectively (Table 1). Graphically they inhabit three different
states: Williams in Illinois; Cuadra and Summit in California; and Hawkins in
New Jersey. Each has been involved for several years in the relatively new
application of information science—the online search and retrieval of bibli-
ographic references from large databases. Cuadra, Williams, and Hawkins have

TABLE 8
Online Information Retrieval: Relevant Chapters in *ARIST*, 1976–1979

Year	Volume	Author(s) and title	Affiliation
1976	11	B. Marron and D. Fife "Online Systems—Techniques and Services"	Institute for Computer Science and Technology, National Bureau of Standards
1978	13	D.B. McCarn "Online Systems—Techniques and Services"	National Library of Medicine
1979	14	J. Wanger "Education and Training for Online Systems"	Cuadra Associates, Inc.

participated in major publishing projects related to online retrieval (Table 9). Their professional activities have been varied but focused.

Summit is President of DIALOG Information Services, Inc.; Cuadra is President of Cuadra Associates; Hawkins is Information Retrieval and Foreign Language Services Manager at the AT&T Bell Laboratories; and Williams is Professor of Information Science at the Coordinated Science Laboratory, University of Illinois. Williams is also Chairman of the Board of Regents of the National Library of Medicine, Chairman of the Board of Directors of Engineering Information, Inc., and Fellow of the American Association for the Advancement of Science. For a number of years she was co-author of a column in the *ASIS Bulletin* on the subject of databases; she is editor of the *Annual Review of Information Science and Technology, Online Review,* and *Information Market Indicators.* She is editor-in-chief of "Computer-Readable Databases: A Directory and Data Source Book" (1st, 2nd, 3rd, and 4th editions).

Martha E. Williams is an elected honorary Fellow of the Institute of Information Scientists of London, England, and in the United States has received the 1984 American Society for Information Science Award of Merit (Williams, 1985a). Her principal interest, aside from her obvious leadership, teaching, and research advisory roles, is assuring that the operation of the online search and retrieval activities becomes "transparent" to end users. She has summarized the history of the basic ideas leading to transparent retrieval methodology (Williams, 1986). Database monitoring has been another of her self-imposed responsibilities. A sampling of her papers reveals her numerous contributions and dedication (Williams, 1975a,b; 1977b,c,d; 1984, 1985b).

Roger K. Summit has been called the father of online retrieval (Herner, 1984). He was born in Detroit, Michigan, and migrated to California, where he earned three degrees: an A.B. in psychology in 1952; an M.B.A. in 1957; and a Ph.D. in Management Science in 1965—all from Stanford University. From 1965 to 1972 he was a research scientist in Lockheed's Information Science Lab;

TABLE 9
Emergence of Online Publications

Year	Author	Publication	Position
1966–1975	Cuadra	*Annual Review of Information Science and Technology*, Volumes 1–10	Editor
1976–present	Williams	*Annual Review of Information Science and Technology*, Volume 11–present	Editor
1976	Williams	"Computer-Readable Bibliographic Data Bases: A Directory and Data Source Book," 1st ed.	Editor-in-Chief
1977–present	Williams	*Online Review*, Volume 1–present	Editor
1977	Hawkins	"Online Information Retrieval Bibliography, 1965–1976"[a]	Compiler
1979–present	Cuadra Associates	"Directory of Online Databases" (quarterly)	President of Cuadra Associates
1979	Williams	"Computer-Readable Bibliographic Data Bases: A Directory and Data Source Book," 2nd ed.	Editor-in-Chief
1982	Williams	"Computer-Readable Data Bases: A Directory and Data Source Book," 3rd ed.	Editor-in-Chief
1985	Williams	"Computer-Readable Data Bases: A Directory and Data Source Book," 4th ed.	Editor-in-Chief

[a]Updated annually in *Online Review*.

from 1972 to 1977, Manager of Lockheed's Information Retrieval Service; from 1978 to 1981, Director of Information Systems at Lockheed's Palo Alto Research Lab; and from 1981 to the present, President of DIALOG Information Services, Inc. (Lee, 1982). By 1985 DIALOG Information Services, Inc., with Summit as president, offered more than 100 million records on many subjects from more than 200 different databases to its many customers in several countries (Camp, 1985).

There have been many changes and much growth since 1964 at the beginning of Lockheed's online retrieval system. At that time there were just two other systems that Summit, among others, considered to be precursors of it: Kessler's TIP at MIT and the experimental SMART system by Salton at Harvard (Table 5). Lockheed's second-generation design utilized "dialogue." The new system emerged slowly from a file size of 100 to 1600 to 8000 in steps called

Converse I, II, and III; in 1966 the latter was expected to switch from a tele-typewriter terminal to a CRT (Drew *et al.,* 1966). DIALOG later became the name of the retrieval program and later still the name of the company that divested from Lockheed, DIALOG Information Services, Inc., a full-fledged subsidiary. By 1967, Lockheed was well established in the area of interactive retrieval from their then few databases. In 1968 NASA contracted with Lockheed to design NASA-RECON (Table 5). Subsequent ventures made Lockheed a worldwide name in information retrieval. In 1971 Lockheed's commercial business was launched, and soon thereafter it was serving Europe as well as the United States with its first online bibliographic retrieval system.

NASA-RECON had cost from $200,000 to $300,000 plus an additional $700,000, for a total of approximately $1 million. This did not seem exorbitant at the time since IBM had developed the New York Times Information System at a cost of $3 million and ORBIT of the System Development Corporation had contracted with the National Library of Medicine to provide AIM/TWX at a cost that probably reached the $1 million mark. Subsequently the National Agricultural Library contracted for Lockheed services at a minimum of $16,000 per month. The direct system method of development for these large systems was clearly a costly way to go (Summit, 1975a). The method for developing online retrieval services would soon change. By 1974 this was manifested by the many databases held by a few vendors, with libraries and information centers acting as intermediaries. These intermediaries accepted requests from end users (Summit and Firschein, 1974).

By 1975, when Summit was officially Manager of the Systems Program Office at Lockheed Missiles and Space Corporation in Palo Alto, California, just four years after Lockheed had begun to operate the commercial services, it was obvious that this new type of organization was accepted, effective, and expanding rapidly. Many end users could now benefit from the services of one or several vendors. A completely new business had emerged. Unlike the beginnings of the earliest retrieval systems in the United States that had been government owned and operated, this new business was organized around a group of vendors that provided search services as private business establishments (Cuadra, 1978). There were three principal segments: (1) database producers who were usually also suppliers (the history of database producers is discussed later); (2) the vendors themselves, such as Lockheed and System Development Corporation, who received the citations on tapes, created standardized formats, and loaded the tapes onto random access storage devices for service (vendors could control only the acquisition and the pricing, putting them in a somewhat precarious position) (Williams, 1984); and (3) the information centers and libraries that in turn served the end users (Summit, 1975b).

In the early 1970s one of the problems that vendors encountered was how to advise their customers regarding the availability of documents. In the case of U.S. government report literature, a microfiche version could usually be acquired. The Institute for Scientific Information (ISI) offered a then unique service in their Original Article Tear Sheet (OATS) service whereby journal articles were provided (Summit, 1975b, p. 42). Of course, copyrighted books could not be supplied in this manner.

By 1979 the problem of procuring documents was solved to a large

extent at Lockheed with their newly initiated Dialorder system, which involved placing an order with one of more than 70 document suppliers worldwide. The suppliers then pick up the orders electronically and mail the documents (Camp, 1985). SDC had used a similar service somewhat earlier—their Electronic Mail-drop Service.

By 1981 when Summit became President of the recently divested DIALOG Information Services, Inc., sophisticated networking operations enhanced service to users around the world. Telecommunications engines at the front end of DIALOG routed incoming traffic from a variety of sources such as DIALNET, TELENET, TYMNET, UNINET, and In-Watts lines. These front-end devices are in the form of microcomputers that process the commands and send them out to the appropriate place for execution—to computers and to disk drives, for example (Camp, 1985). DIALOG added 93 databases between 1982 and 1984 and extended services to foreign countries. In 1985 they claimed 70,000 customers in 80 countries (Camp, 1985).

Saul Herner seems to have been correct in naming Roger K. Summit the father of online retrieval (Herner, 1984). Perhaps Summit's most notable achievement was the efficiency with which he expanded the user population from the public libraries in California (Summit et al., 1976; Summit and Firschein, 1977) to countries as diverse as Japan and Brazil (Camp, 1985). He has continued to upgrade services in the United States, including utilization of the latest technology and retrieval from full-text databases.

Carlos A. Cuadra graduated in 1953 from the University of California at Berkeley with a Ph.D. in psychology. Thereafter he was employed by the System Development Corporation whose first interactive online retrieval system, operating in 1960, was called the Photosynthex. This was a "nonrecursive, non-Boolean system with a terminal that was hard-wired to the computer" (Bourne, 1980, p. 156). It was a full-text approach to the contents of the "Golden Book Encyclopedia," the predecessor of the Online Retrieval of Bibliographic Information Timeshared System, called ORBIT, that was first applied for the U.S. Air Force at the Wright-Patterson Base in Ohio (Bourne, 1980).

In 1969–1970 a revised ORBIT program was applied to form the AIM/TWX, a 30-terminal system at the National Library of Medicine that ultimately became MEDLINE (MEDLARS online). This ORBIT II program was sold to the National Library of Medicine, who called it ELHILL (Cuadra, 1978, p. 7). Cuadra provided expert guidance in developing these systems. Incidentally, the National Library of Medicine later provided the ELHILL (ORBIT) program to the British Library for BLAISE, the British Library Automated Information Service. BLAISE is not only a retrieval system but also a cataloging system (Hawkins, 1981, p. 189).

In 1966 and while still employed by SDC, Cuadra became the first editor of the *Annual Review of Information Science and Technology*. During the previous five years he had helped develop the guidelines and procedures for the *Annual Review*. Ultimately he was selected as its first editor, with the project partially funded for its first two years by the National Science Foundation with additional funding from the SDC (Cuadra, 1966, pp. 1–14). For 10 years *ARIST* had the benefit of Cuadra's unfailing tact and editorial acumen. In 1976 with Volume 11, Martha E. Williams became the second editor of *ARIST*.